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EDITORIAL

According to the latest estimation by United Nation, the world population will amount to 9.7 billion by 2050. In that case, we have to increase food production by 0.5 times. We did it by 3 times in 50 years during 1960-2012. This was enabled by new technology, genetic engineering, use of fertilizer, development of agricultural machinery, wide spread of irrigation etc. Farmland has increased by 49 ha, but woodland has decreased by 50% in 20 years from 1997. This means 0.1 billion ha of woodland was lost. We can't expand farmland any more to increase food production. If we sacrifice woodland for farmland, it would cause depletion of water resource and climate change. Besides, it would severely affect life system including microorganisms. Currently 70% of total use of fresh water is for agriculture. A number of regions, such as a part of China, suffer a decrease of water volume in rivers. There're cases in which a river dries up during certain season.

Furthermore, we have to increase food production by more than 110% in the region of Africa to the south of the Sahara Desert and South Asia. Renewal energy is in high demand all over the world nowadays. Especially biomass energy is getting to be an essential energy source. Sugar cane and corn got to be a new renewable energy as well as wood. Limited amount of agricultural production is now sought for both energy use and food use. There could transpire the need to regulate the amount of biomass energy use in the long run. According to the latest estimation, average temperature in the world could increase by 4.5°C at the worst. As it was 2.0°C in the past, the situation is getting worse. A part of permafrost dissolved that resulted in forming a big hole in Siberia. Methane gas started to leak from this hole. It increases in speeding up the global warming. To increase food production in such situations, it is necessary to advance the genetic engineered plant tolerant to global warming, further spread of irrigation system and development of agricultural machinery which enables precision farming in volatile weather. Due to adaption of new technology, it can be presumed that robotization would rapidly advance in the field of agricultural machinery. Like smartphones are commonly used by people in the developing countries, agricultural robots must be used by farmers in the developing countries.

Yoshisuke Kishida
Chief Editor
October, 2017

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Farm Mechanization Strategy for Promotion of Animal Drawn Improved Farm Equipment in Nagaland State of India

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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 of the state. It has total cultivable are of 721,924 hectares out of which 70% is in the hilly region (up to 2,500) meters and the rest 30% is 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 of the state 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 the 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 of improved equipment for *jhum* cultivation was US$ 291.06. Under terrace farming without rice, the package cost of equipment was worked out as $ 783.70 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 adoption of improved equipment package in 5% of cultivated area were estimated as $ 6.76 million.

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

Introduction

Eleven districts of Nagaland lie between 93°20[1] to 95°15[1] E longitude and 25°60[1] to 26°40[1] 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% area of North East and 0.5% of the total land area of the country. The altitude varies from 25 m at Dimapur to 3,840 m MSL at Saramati peak (Twensang district). The average height of the hilly terrains is 900-1,200 m MSL. The slope levels of the hilly terrain vary from 40 to 60%. The annual average rainfall of the state is 2,000-3,000 mm with the highest during June to mid October and the relative humidity from 65 to 90%. 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 of 909 and population density of 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 shown in **Fig. 1** which indicate coverage of rice and other crops and four types of soils (Anon., 2013).

The Gross State Domestic Product (GSDP) of Nagaland was about Rs 120.65 billion (US$ 2.0 billion) in 2011-12. Nagaland's GSDP grew at 9.9% compounded annually for a decade, thus more than doubling the per capita income.

Livestock sector contributed 4.8-

6.6% of the total gross domestic product of India during last decade. 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 tonnes of dung annually from 3 million cattle, 0.16 million buffaloes and 16,000 horses, ponies and yaks (Census, 2011).

Farmers practice two forms of diversified traditional agriculture, viz. the *Jhum* (Shifting Cultivation) System and 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 to 83,330 hectares under TRC in 2009. There are four distinct agro climatic zones, viz. High hills, Low hills, Foot hills and 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, castor, sesamum, sunflower, rapeseed and mustard), and iv. Commercial crops (sugarcane, cotton, jute, mesta, potato, tea, tapioca and colocossia) during the Kharif and Rabi seasons. 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 grown in Kharif is higher than that in Rabi (Yojana, 2012).

During the last decade, the cropping intensity remained constant at about 110%. The maximum numbers of farmers (19,668) were found in Kohima district and maximum total land holding area was found in Phek district among all eleven districts of Nagaland.

The mechanization of agriculture has been poor because of the nature of the terrain in the state and the low purchasing power of the farmers. The consumption of fertilizers and pesticide has not been uniform and almost negligible. Farm operations like ploughing to harvesting are done with local farm tools like dao, spade etc. People are less aware of the improved implements for various farm operations. Some parts of the district like Kikruma Village use power tiller as a main implement for ploughing. Post harvest management for storage of grains and pulses are practiced traditionally in locally made bamboo mat bin with one side hollow wooden plank. Paddy is the main crop and traditionally after harvesting of paddy, it is dried and kept in a Local bamboo storage bin, one end sealed hollow wooden storage bin and gunny bags. Local Bamboo storage bins made up of bamboo mat weaved cylindrical and conical opening on the top with a separate cover are made from thick wooden trunk with a diameter of 1 to 1.30 m and a length of 1 to 1.5 m.

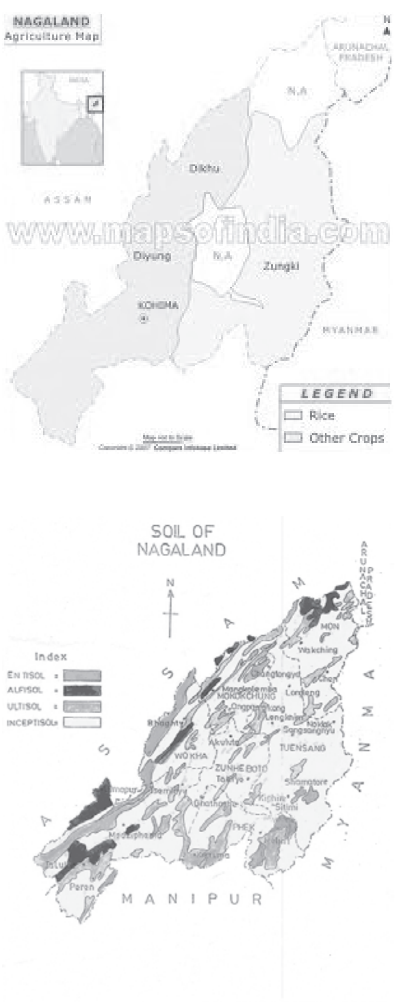

Fig. 1 Agriculture and soil map of Nagaland (Source: Deptt. of Agriculture, Govt of Sikkim-India)

Materials and Methods

The traditional form of shifting cultivation i.e. *jhum*, is the method of cultivation that is widely practiced across Nagaland. *Jhum* occupies about 90% of the area under agriculture. Terraced cultivation is confined largely to the districts of Kohima, Dimapur, Tuensang, Peren, Phek and Wokha. The single cropping system is prevalent in the state resulting in low cropping intensity.

The total farm power available in the state is 0.336 kW/ha against required power of 1.5 kW/ha. Most of the agriculture operations are performed by using animate power

Table 1 Area, Production and Yield of Cereals, Pulses, Oilseeds and Commercial crops during 2010-11 (Area in '000 hectares, Production in '000 metric tons and Yield in kg/ha)

Crop	Area	Production	Yield
Cereals	264.40	531.86	2011
Pulses	34.43	36.46	1058
Oilseeds	65.84	67.53	1025
Commercial crops	29.40	392.17	13339

Department of Agriculture, Government of Nagaland sources. The stationary farm power sources, viz 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, animal power and mechanical power is 53.1%, 45.9% and 1.0% respectively. Since most of the farm operations in Nagaland are done using animal power; hence, there is a great scope for selective mechanizing in the tribal belt where small hand tools are being used resulting in human drudgery (Singh *et al*., 1996).

About 86% of the cultivable area in Nagaland is under the traditional *Jhum* and Terrace Rice cultivation system and rest under commercial and other crops. *Jhum*, is a traditional process that involves clearing a patch of forest land by slash and burn method but retaining useful trees and plant varieties, cultivating it for two to three years and then moving on to the next patch of land. The previously cultivated land is abandoned for 10-20 years to allow the natural forest to grow back and the soil to regain its fertility. The cycle of cultivation, leaving it fallow and coming back to it for cultivation, is called the *Jhum* cycle.

The crop based data (2010-11) on area and yield of major crops were collected from Department of Agriculture, Nagaland which revealed the production of cereal, oilseeds and pulses in Nagaland state. The information on district-wise number of farmers and total area of landholdings (Census: 2006-07) in each district obtained from NABARD office located at Nagaland was instrumental to chalk out futuristic approach on package of improved equipment. The cropping pattern and problems associated with mechanization were addressed during interaction meet held at NRC on Mithun, Jharnapani (Nagaland) and strategies were finalized to mechanize different agricultural operations. For existing practices being used by farmers were seen by visiting farmers fields in Dimapur and Kohima districts. The improved equipment for rice and maize cropping pattern under rainfed farming system were introduced through frontline demonstrations at Krishi Vigyan Kendra. The unit price, output capacity, cost of cultivation and command area for improved equipment was worked out to calculate the cost of total package. The numbers of packages for mechanizing 5% of net sown area were worked out considering the actual data collected during farm test trials and frontline demonstrations of some improved equipment in the north eastern region in terrace farming for major crops.

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 of 5% of the cultivated area using available proven designs, 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 requires 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.

Results and Discussion

In Nagaland state, the main crops are rice, millet, maize, and pulses. Cash crops, like sugarcane and potato, are also grown in some parts. Plantation crops such as premium coffee, cardamom, and tea are grown in hilly areas in small quantities, but a large growth potential. Most people cultivate rice as the main staple diet of the people. About 80% of the cropped area is dedicated to rice. Oilseeds are another, higher income crop gaining ground in Nagaland. The farm productivity for all crops is low, compared to other Indian states, suggesting significant opportunity for enhancing farmer income. Currently, the *Jhum* to Terraced cultivation ratio is 4:3; where *Jhum* is local name for cut-and-burn shift farming. *Jhum* farming is ancient, causes a lot of pollution and soil damage, yet accounts for majority of cultivated area. The state does not produce enough food, and depends on trade of food from others states of India (Annon., 2011).

The soil manipulation for land preparation and sowing is minimum. Generally, no ploughing is done to prepare the field for sowing of the next crop either manually or by any mechanical means. In upland *jhum* paddy areas, the tillage operations are adopted in the form of highly reduced, energy saving form of zero tillage. Field preparation and other soil manipulation operations for creation of suitable tilth are not in practice. Land clearing is done by burning of crop residues and other woody and herbaceous plants. The only tillage operation which is being done is during sowing of the crop. In sowing operation, tilling is not done by any plough but by a very indigenous implement known as *alluppi* or Naga *khuraphi*. By *alluppi*, a small shallow pit is dug at irregular space to make the area for sowing of the seed of upland paddy (Annon., 2013).

The most prevalent method of sowing under upland *jhum* cultivation is the direct sowing of pre-soaked seed or after some sort of seed priming. As the germination under direct sowing is not up to the desired level, it necessitates going for pre-sowing treatment. The purpose of priming is to reduce the germination time and improve stand and germination percentage. In most of the rice ecosystem of the state, the weeding is mainly done by manual means. Other than weeding generally no intercultural operation is being done in the paddy field. Irrigation management is only done in the wet terrace and *Pani Kheti* areas and generally no water management is usually done in *jhum* paddy which depends entirely on natural course of rain water. The cultivars so selected are of long duration and crop sown in June-July becomes ready for harvest in month of December -January. Harvesting is done by picking up of mature panicles and leaving straw in the field itself in *jhum* paddy and in most of the TRC/WTRC field.

As soon as paddy is harvested, deep ploughing is done in the terrace along with whatever residue weeds and straws present in the field. As the field gets a little dry, soil clods are broken and preparations are made to sow seed potato. Potato is harvested just before the time to puddle and the owner gets some cash income by selling the potatoes. Not only that, the first normal ploughing is averted and also cleaning of the risers and embankment operations are done while giving cultural operations to the potato crop. Residual moisture from paddy crop and a shower that comes in March is sufficient to have a bumper harvest of potato. Tomato seed is broadcasted in the month of September as water level in the terraces begins to recede. Paddy stalks are utilized as mulch, as well as support to tomato stems. As the farmer carry out the first ploughing operation in the month of February, tomato is harvested. The cost of cultivation for maize, pea, wheat and mustard were US$ 146.153/ha, $ 161.153/ha, $ 156.923/ha and $ 115.384/ha respectively under traditional system.

The package of animal based farming system of improved equipment consisted of 18 equipment of proven designs suitable for terrace cultivation in Nagaland (**Table 2**). The command areas of manually operated and animal drawn improved equipment were considered as 1 and 1.5 ha, respectively. The command area for motorized wire-loop paddy thresher and multi-crop thresher was taken as 1.5 ha. The effective field capacity of improved equipment for seedbed prepara-

Table 2 Package of improved equipment for animal based farming system under terrace cultivation in Nagaland

Improved equipment	Unit price, US$	Effective field capacity, ha/h	Cost of operation, $/ha	Command area, ha/season
Animal drawn wing plough (size: 200 mm)	15.384	0.02	28.923	1.5
Animal drawn improved clod crusher-leveler-planker-puddler (size: 700 mm)	76.923	0.06	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: 950 mm)	38.461	0.06	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	0.02	20.769	1
Manual 4 row paddy drum seeder	100	0.03	14.615	11
Multi-crop plot thresher (Single phase electric motor, 1 hp)	538.461	125 kg/h	9.23	1.5
Manual double screen cleaner	38.461	150 kg/h	7.692	1
Grubber weeder with handle	5.384	0.005	73.846	1
Naveen dibbler	10	0.028	12.307	1
Total	1,165.23			

tion ranged 0.020-0.060 ha/h. The animal drawn two row improved seed drill, manual rice transplanter and manual rice seeders will serve the purpose in sowing and planting operation and the work output of such equipment ranged 0.020-0.065 ha/h in terrace condition. The intercultural operations can be performed by manual wheel hoe and cono weeders which are capable to perform work ensuring average field capacity of 0.01 ha/h. For potato harvesting, animal drawn potato digger of 600 mm size will fulfill the need of digging tubers showing average work rate of 0.065 ha/h. 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 selective mechanization of *Jhum* cultivation will require $ 1.323 million for introducing the package which has combination of manually and animal drawn equipment for the potential crops (**Table 4**). The package of 10 improved equipment suitable for *Jhum* cultivation can reduce the hardships of tribal people in the region. The tillage operation in *Jhum* cultivation can be performed by animal drawn improved wedge plough and hand ridger which give output of 0.033 ha/h and 0.025 ha/h respectively. The manually operated two row paddy seeder (work rate of 0.02 ha/h) and cono weeder (work rate of 0.008 ha/h) are important improved equipment which can eliminate drudgery in rice cultivation under *Jhum* system. The pedal operated wire-loop thresher with work rate of 70 kg/h is the viable option to reduce requirement of labour and cost of operation without any seed loss. The shelling operation of maize requires manual hand maize sheller delivering output capacity of 20 kg/h. The suitable improved equipment for harvesting all major crops of region is improved sickle requiring 200 h/ha in the *Jhum* cultivation of Nagaland. 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 5**. The rice crop needs 4,547 packages of improved equipment costing $ 1.323 million under *Jhum* cultivation in mechanizing 5% cultivated area of rice. The package of improved equipment to mechanize 5% cultivated area of rice under terrace cultivation will need 2,778 no. of improved equipment costing $ 3.237 million.

Conclusions

The following conclusions can be drawn from the study.

i.) The package of animal drawn improved equipment can be adopted in agriculturally backward Nagaland state for mechanization of different agricultural operations for potential crops.

ii.) The cost of package for *jhum*

Table 3 Package of improved equipment for selective mechanization under jhum cultivation

Name of the equipment	Unit price, US$	Effective field capacity, ha/h	Cost of operation, $/ha	Command area, ha/season
Hand ridger	5.384	0.033	23.84	1
Naveen dibbler	10	0.028	28.46	1
Grubber weeder	10	0.005	69.23	1
Improved sickle	0.923	0.005	61.53	1
Tubular maize sheller	0.923	20 kg/h	13.84	1
Pedal operated paddy drum thresher	38.461	70 kg/h	11.53	1.5
Manual wheel hoe	5.384	0.01	39.23	1
Manual cono weeder	27.692	0.008	30.76	
Animal drawn improved wedge plough	15.384	0.025	24.61	1.5
Manual paddy drum seeder (2 row)	38.461	0.02	19.23	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, million, US$
Paddy				
Jhum system	90,940	4,547	4,547	1.323
Terrace system	83,330	4,166.50	2,778	3.237
Maize	66,420	3,321	2,214	1.735
Pulses	34,430	1,721.50	1,148	0.899
Oilseeds	65,840	3,392	2,262	1.772
Commercial crops	29,400	1,470	1,307	1.024
Total	370,360	18618	14,256	9.99

cultivation was worked out as US$ 291.06.

iii.) Under terrace farming, without rice equipment the package cost was worked out as US$ 783.70 under animal based farming in hills in Nagaland.

iv.) The cost of each package of equipment for rainfed rice cultivation in hills was estimated at US$ 1165.23.

v.) The requirement of total packages (14,256) will cost US$ 9.99 million for mechanizing 5% cultivated area in the hill state under animal based farming system through selective mechanization.

vi.) The total annual benefits from each package was estimated at US$ 781.754 and benefits from single package will be US$ 596.76/ha.

vii.) For mechanizing 5% cultivated area in Nagaland-India the estimated investment on package of improved equipment would be US$ 6.76 million.

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

Improved equipment	Annual benefits per unit, US$	Annual benefit per unit command area, US$/ha	5% of the cultivated area, ha	Total benefit considering 5% of cultivated area, million US$
Animal drawn wing plough (size: 200 mm)	34.61	23.076	18518	0.427
Animal drawn improved clod crusher-leveler-planker-puddler (size: 700 mm)	46.153	30.769	18518	0.569
Animal drawn improved wedge plough (size: 230 mm)	29.538	19.692	18518	0.364
Animal drawn two row improved seed drill (size: 700 × 950 × 740 mm)	10.769	10.769	13971	0.15
Animal drawn improved potato digger (size: 600 mm)	38.076	25.384	1470	0.037
Manual wheel hand hoe (size: 210 mm)	53.076	53.076	13971	0.741
Manual knapsack sprayer	30.769	30.769	18518	0.569
Manual cono weeder (size: 210 mm)	33.846	33.846	8713.5	0.294
Improved sickle	15.384	15.384	18518	0.284
Tubular maize sheller	17.23	17.23	3321	0.057
Animal drawn multi-crop planter	38.461	19.23	9804.5	0.188
Motorized wire-loop thresher	64.615	43.076	8713.5	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	8713.5	0.469
Multi-crop plot thresher (Single phase electric motor, 1 hp)	27.692	18.461	5042.5	0.093
Manual double screen cleaner (size 900 × 600 × 140 mm)	30.769	30.769	18518	0.569
Grubber weeder with handle (size: 1750 × 240 × 1060 mm)	27.692	27.692	9804.5	0.271
Naveen dibbler (size: 280 × 260 × 1060 mm)	12.307	12.307	8334.5	0.102
Hand ridger	55.384	18.461	9804.5	0.181
Pedal operated wire loop thresher	123.076	74.461	8713.5	0.648
Total	781.754		596.759	6.763

Available Resources for Farm Mechanization in Two Urban Areas of Enugu State of Nigeria

by

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Abstract

A study was carried out to assess available resources for mechanized farming in two urban areas of Enugu state of Nigeria. The two urban areas used for this study in Enugu state of Nigeria are Enugu and Nsukka. Investigative survey approach using questionnaire was used to carry out the study. Results obtained showed that the basic resources such as land, water and power needed for mechanized farming are grossly inadequate in the two urban areas. This resulted to near absence of mechanization in these two urban areas. Tractor services are almost nonexistent, the average farm size is less than 0.1 ha and the major source of water is rain. Governments are advised to make new and bold efforts to formulate policies and develop programmes that will improve operations in the sector.

Introduction

Ojiako (1984) reported that after the civil war, governments of Nigeria laid foundation for sustainable agricultural production and processing. These include reactivation of the abandoned farm settlements in the East, supply of 40,000 tons of fertilizer to farmers by the government of North Western state, planting of 15,417 hectares of cocoa and 12,000 hectares of oil palm in Western state, building and commissioning of Yakubu Gowon Dam at Tiga, Kano state, etc. Within two years of these efforts, the GNDP, mainly from agriculture, doubled that of projection. But oil has since changed that picture (Ogunleye, 1992). The agricultural share to Nigeria export fell to 3.7% as against oil which was 92% (Odigboh and Onwualu, 1994). This condition was caused by government neglect of the agricultural sector which in-turn increased rural to urban migration.

In the urban areas, the expected jobs are not there. Even for those who are working, the salary is poor which is either denied or delayed. In these areas also, there are abandoned buildings, open spaces, wastes, water from flowing streams, lakes, burst pipes, etc. These resources are being harnessed for farming by the residents of urban cities in Nigeria including those who migrated from the rural areas (mostly youths) to seek for jobs and to trade, retired civil servants, low salary earners, etc. (Adama and Onwualu, 2014)

Urban area is defined as a place in which majority of the people are not directly dependent in national resource base occupation and includes the entire built up non rural area and its population. It is more broadly defined as a town or city having a free standing built up area with a service core and sufficient number and variety of shops and services including perhaps a market, to make it recognizably urban in nature (Bureau of Census, 1990; D. Blife and Mufler 1990). Urban and peri-urban agriculture is perceived as agriculture practices within cities which compete for resources (land, water, energy and labour) that could also serve other purposes to satisfy the requirement of the urban population. The important sectors include horticulture, livestock, fodder and milk production, forestry, agriculture (FAO, 2004).

Agricultural mechanization is the development, introduction and utilization of mechanical assistance of all forms and at any level of mechanical sophistications in agricultural production (Onwualu *et al*., 2006). In its widest sense, it encompasses hand technology, animal drawn technology and mechanical technology (Anazodo, 1980).

Mechanizing farm operations will ensure increased food and fibre production, create gainful employment, remove drudgery associated with farm operation, restore the dignity of the farmer, protect the farming environment, etc (Anazodo, 1980; Odidgoh and Onwualu, 1994; Onwualu, *et al*., 2006). Most researchers in the field of agriculture focus attention in the rural areas believing that the rural area is the place where farmers are found. Research has shown that farming takes place in urban areas at various levels and forms (UNDP, 1997; FAO, 2004; Adama and Onwualu, 2014). The objective of this paper is to present the result of a research carried out to assess the availability of the resources for mechanizing farm operations in two urban areas of Enugu state of Nigeria.

Materials and Methods

The Project Area

Enugu State is one of the 36 states in Nigeria. The state has a population of 3,257,298 million people (2006 Census). It is located in the derived savannah zone of Nigeria. The field survey and data collection were limited to two most important urban areas of the state. The two urban areas involved in the study are Enugu and Nsukka.

Enugu urban area is the capital of Enugu state. It is a scape footed town lying on the plains close to the East facing Enugu-Awgu crest with rich formation known as the lower coal measures with crops at the foot of the escarpment (Ofomata, 1978). The dominant vegetation is the tropical Rainforest and the soils of the area range from low to medium productivity potentials. The mean annual temperature is between 24°C and 26°C (Ofomata, 1975) and the rainfall ranges between 1,520 mm and 2,030 mm (Idachaba *et al*., 1991). It consists of three local government areas namely; Enugu East, Enugu North, and Enugu South all having a population of 722,664 (FRN, 2007).

Nsukka urban area, on the other hand is the second most important town in Enugu State. It possesses a distinctive physique dominated by a cuesta land scape with a long rain season which lasts from April to October (Ofomata, 1975). The dominant vegetation is the derived Savannah (Anazodo and Onwualu, 1988). The mean annual minimum temperature is between 24°C and 27°C while the maximum temperature is between 33°C and 36°C (NIMET, 2011). From October to February, the relative humidity is between 35 to 65% and 60 to 85% during the rest of the year. Annual rainfall ranges from 980 mm to 2,088 mm. The city can grow crops all year round where there is corresponding supply of water (Inyang, 1978).

The Research Instrument

This report is a part of a two phase study which started in 2007 and ended in 2014. In phase 1, nooks and crannies of the study area as reported by Adama and Onwualu (2014) were visited on foot by the author between 2007 and 2012 to identify the agricultural enterprises being practiced and their exact locations in the cities. This was followed by the use of questionnaire to obtain necessary information and data such as ownership system for resources used in farming, background of the farmers, factors that make them to farm in the urban areas, and constraints to farming in the city.

This phase of the study which was conducted in 2008/2009, 2012 and 2014 was divided into two parts (parts I and II). Part I evaluated the extent of availability of the resources and the changes that occurred over the years (2008 to 2014). The resources assessed are power, land and water. The main instrument for this research is the questionnaire designed in a close ended format. The questions contained in the questionnaire were aimed at obtaining information on type of power system used, size of land cultivated, sources of water for farming, etc. Part II of this phase which is not part of this report tends to evaluate the need level and awareness index of the farmers in the study area.

Results and Discussion

Available Resources

Table 1 presents the yes scores in percent of the extent of availability of the resources needed for mechanized farming in Enugu and Nsukka urban areas of Enugu state. From **Table 1**, 10% of the respondents in 2008/2009 have enough land for farming in Enugu urban area but in Nsukka urban area, the score was 11%. Farmers in Enugu urban area experienced a decline of 1% on availability of land while in Nsukka an increase of 2% was experienced in 2012 but declined to 9% in 2014. The decline on availability of land in the study area may not be unconnected with urbanization with roads, residential houses, churches,

Table 1 Availability of Resources

Resource	Percent positive (yes) score					
	Enugu urban area			Nsukka urban area		
	2008/ 2009	2012	2014	2008/ 2009	2012	2014
Land	10	9	9	11	11	9
Power	70	65	59	80	70	68
Water	75	75.9	77	65	66	68
Fertilizer	65	75	80	76	87	93

Fig. 1 A vegetable garden between Otikpa roundabout and Artisan Quarters in Enugu

markets, hotels and other industrial activities to which the farming lands gave way. For instance, in 2008/2009, the empty spaces between Otikpa junction/Con oil and Artisan Quarters in Enugu urban area was used for all season vegetable production (**Fig. 1**). By 2014, the area have been cleared, fenced and large quantities of building materials were seen in the site by the time the 2014 survey exercise was conducted.

The availability of power sources for farming activities in Enugu and Nsukka urban areas decreased progressively between 2008 and 2014. In Enugu urban area, the power sources available for farming activities fell by 5% between 2008 and 2012 and further declined by 6% between 2012 and 2014. In Nsukka urban area, power sources available for farming activities declined by 10% within four years (2008 to 2012) and in 2014, the power sources available fell further by 2% (from 70% to 68%) as shown in **Table 1**. **Fig. 2** shows Vegetable and Maize Farm in Artisan Quarters in Enugu tilled and planted using hand powered system.

On water, marginal improvement was recorded. In 2008/2009, 75% of the respondents admitted having enough water for farming in Enugu urban area while in Nsukka urban area, 65% was recorded. In the 2012 survey exercise, records obtained for Enugu urban area increased by 0.9% and by 1% in Nsukka urban area. In the 2014 survey exercise, 77% of farmers in Enugu urban area have enough water for farming activities, recording an increase of 2% from the 2008/2009 survey exercise. In the Nsukka urban area an increase of 3% was recorded in 2014 when compared with the results obtained from 2008/2009 survey exercise.

Another input evaluated in this study was fertilizer. Results obtained showed that from the 2008/2009 survey exercise, 65% of the farmers have enough fertilizer for farming activities in Enugu urban area while for the same period covered in Nsukka urban area, 76% of the farmers have enough fertilizer for farming activities. The two urban areas in the 2012 survey exercise recorded an improvement in the use of fertilizer for farming with a record showing 75% and 87% for Enugu and Nsukka urban areas, respectively. In the 2014 survey exercise, more farmers in the two urban areas had access to fertilizer when compared to the results of 2008/2009 and 2012. For instance, the result of 2014 survey showed an increase of 15% from the 2008/2009 survey and 5% from the 2012 survey in Enugu and in Nsukka urban areas, the results are 87% (an increase of 11%) from the 2008/2009 survey and 93% (an increase of 6%) from 2012 survey. The impressive results recorded in availability of fertilizer in the two urban areas could be as a result of the fertilizer policy of the Federal Government of Nigeria through the Agricultural Transformation Agenda (ATA).

Analysis of Available Power by Source for Field Operation in Enugu and Nsukka, Urban Areas of Enugu State of Nigeria

The power sources available for field operation in the study area was analyzed based on their availability. The sources include manual, animal and mechanical power. Results in **Table 2** shows that in the two urban areas in the three survey exercise carried out, manual power is the most dominant with a record showing 82% and 100% for Enugu and Nsukka urban areas, respectively, during 2008/2009 survey exercise. In the survey conducted in 2012 and 2014, Enugu urban area recorded 84% and 87%, respectively while in Nsukka urban area manual power recorded 99% each in the 2012 and 2014 survey exercise showing an improvement of 1% in the use of mechanical power. The results of this survey supports the findings of Takeshima and Salau (2010) which stated that many Nigerian farmers still use manual labour and basic hand tools such as hoe, cutlass and matchet and occasionally employ labour saving tools draught animal, ploughs or tractor. Oyedemi and Olajide (2002) had earlier concluded that about 86% of the total agricultural land under cultivation in Nigeria is prepared using hand tool technology.

The decline in the number of farmers who used mechanical power for field operations in Enugu urban area could be attributed to scarcity of tractors following the auctioning of tractors owned by the Rural Development Department of the Federal Ministry of Agriculture and Rural Development. Another reason for this decline could be as a result of the relocation of the Market Garden in 2010 to Akwuke. At the

Fig. 2 Vegetable and maize farm in Artisan Quarters in Enugu tilled and planted using hand powered system

Table 2 Types of power available for field operation in Enugu and Nsukka urban area of Nigeria

Power source	Percent positive (yes) score					
	Enugu urban area			Nsukka urban area		
	2008/2009	2012	2014	2008/2009	2012	2014
Manual	82	84	87	100	99	99
Animal	0	0	0	0	0	0
Mechanical	18	16	13	0	1	1

Market Garden, which was located near the old Trade Fair ground Enugu, tractors were used to till the land for farmers. Mechanized farming in the area has given way to hotels, offices, residential buildings, etc. The improvement in the utilization of mechanical power in Nsukka urban area could be due to very few farmers who used tractor to till land around the University of Nigeria, Nsukka Experimental Farm.

No farmer made use of animal traction in the two urban areas used for this study in the three survey exercise carried out. This result is in agreement with the findings of some researchers (Onwualu and Odigboh, 1994; Nwuba, 2009) that animal draught technology is used only in Northern Nigeria where the case of trypanosomiasis caused by tse-tse fly bite is low.

Analysis of Available Land for Farming in Enugu and Nsukka Urban Areas of Enugu State of Nigeria

Analysis of land available by size for farming in Enugu and Nsukka urban areas is presented in **Table 3**. The 2008/2009 survey showed that 65% of the farmers in Enugu urban area cultivate less than 0.1 ha while for Nsukka urban area the scores obtained was 62%. In the two urban areas, only 1% of the farmers cultivate more than 1 ha. Increase in the number of farmers cultivating less than 0.1 ha was witnessed in the subsequent surveys in the two urban areas. In general, the size of land under cultivation in the areas declined over the years from 2008 through 2012 to 2014. A closer examination of the results shows that land fragmentation known as a problem of agricultural mechanization in Nigeria is worsening by day in spite of government efforts (Igbozurike, 1980 and Mabogunje, 2009). It further lends credence to the earlier findings of Anazodo (1982) which concluded that apart from low yields and slow rates of work which are typical of traditional hand powered agriculture in developing countries, small size and fragmentation of farm land is getting worse.

Analysis of Sources of Water for Farming in Enugu and Nsukka Urban Areas of Enugu State of Nigeria

The sources of water available for farming activities in the study area are rain, flowing stream, artesian well, sewage, water from Enugu State Water Corporation connected to the field using rubber hose and water at burst pipes.

Analysis of water sources available for farming activities in Enugu and Nsukka urban areas of Enugu State is shown in **Table 4**. From **Table 4**, in the three survey-exercise carried out rain water ranked highest as source of water available for farming activities in the two urban areas. In 2014 survey, rain water recorded 62% in Enugu urban area with an increment of 2% over the results obtained in the 2008/2009 survey exercise. In Nsukka urban area, 66.40% was recorded in the 2008/2009 survey exercise carried out. This value later decreased by 0.4% in 2012 and further by 1.4% in 2014. In Enugu urban area, flowing streams ranked second after rain water in the three surveys carried out with 15%, 18% and 19% recorded for 2008/2009, 2012 and 2014 survey exercise, respectively. In the Nsukka urban area of the State, sewage ranked second recording 25.60% in the 2008/2009 survey exercise and 26% in both 2012 and 2014 survey exercise. For borehole connected directly to farms through taps, 7% was recorded for both Enugu and Nsukka urban areas in the 2008/2009 survey exercise. No farmer from the Nsukka urban area used water from burst pipes. In the case of Enugu urban area, 10%, 7% and 5% were recorded for the 2008/2009, 2012 and 2014 survey exercise carried out, respectively. This source was more predominant around Ekulu Primary School areas. However, this source experienced a decrease in the subsequent surveys probably because of rehabilitation works by the government in which old water lines were replaced by modern pipes.

Table 3 Size of land under cultivation in Enugu and Nsukka urban areas of Nigeria

Size of land	Percent (yes) score					
	Enugu urban area			Nsukka urban area		
	2008/2009	2012	2014	2008/2009	2012	2014
<0.1 ha	65	67	67	62	63	65
0.1 – 0.5 ha	30	30	21	35	33	32
0.6 – 1.0 ha	4	3	2	3	4	3
>1.0 ha	1	-	-	1	-	-

Table 4 Sources of water for farming in Enugu and Nsukka urban areas of Nigeria

Source of water	Percent (yes) score					
	Enugu urban area			Nsukka urban area		
	2008/2009	2012	2014	2008/2009	2012	2014
River	0	0	0	0	0	0
Bore hole from water corporate	7	10	10	7	8	9
Water from burst pipes	10	7	5	0	0	0
Artisan well	1	0	0	0	0	0
Stream/spring	15	18	19	1	0	0
Rain	60	59	62	66.4	66	65
Sewage	7	6	4	25.6	26	26

Conclusions

There are technical and socio-political problems facing farm mechanization in the two urban areas of Enugu state. Analyses of data obtained from three survey exercise conducted between 2008 and 2014 showed that these problems include improved power sources, water for irrigation and land for expanded production. These problems have resulted to near absence of farm mechanization in the areas this study was carried out.

Government has no programme to aid farm mechanization in Enugu and Nsukka urban areas of Enugu State of Nigeria. The few resources which had been aiding the farmers to improve their farming operations had been withdrawn by a policy. Such resources include availability of land at the Market Garden, Enugu, tractor hiring programmes by the state and Federal Government. As at now, there are no tractor hiring services in the area and farm lands available are lesser than 0.1 ha. The major source of water is rain.

In view of the important roles played by urban farming, it is recommended that government of Enugu state should formulate and implement policies that will improve operations in the sector. Such policies should give access to tractor services for mechanizing farm operations, guarantee the availability of land, and develop available natural water systems (stream, springs and small rivers) for all year round cropping.

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A Cost Analysis Model for Agricultural Bush Clearing Machinery

by

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Abstract

A model was developed to predict the cost of agricultural bush clearing machinery. The cost components modelled include capital, shelter, fuel, oil, repair and maintenance, mechanical clearing effects and labour costs. The model developed was validated using data from literature, survey and field experiments. Three categories of crawler tractor bulldozers of models D6, D7 and D8 were used to conduct the field experiments. Results obtained from the developed model showed that the costs of bush clearing machinery using crawler tractor bulldozer of models D6, D7 and D8 were $330.02/ha, $296.31/ha and $271.84/ha, respectively. Results from field experiments, gave cost values of $285.28/ha, $257.74/ha and $222.94/ha for using crawler tractor bulldozer of models D6, D7 and D8, respectively.

Introduction

Management decisions on use of machinery to carry out farm operations always take into consideration the cost implications. These costs include procurement (purchase or hire) and running or operating costs. Machinery costs remain a significant portion of production cost for most food and agricultural crops (Buckmaster, 2003). Among the various inputs to crop production system, power and machinery costs represent the largest single item of expenditure constituting about 60% of the total investment (Dash and Sirohi, 2008). Machinery costs are very important because the success of any mechanized farm enterprise depends to a large extent on them (Adama and Onwualu, 2008). Many researchers have developed and tested models specifically for costing and selecting agricultural machinery. Willett *et al.* (1972) developed a model for figuring machine costs taking into consideration farm size, hours of use, type of crop, age of machine, etc. McClendon *et al.* (1987) reviewed several models for machinery selection using simulation over multiple years driven by weather data while considering both risk and net returns. Aderoba (1989) developed a generalized model using a linear programming technique to select and cost farm power and machinery for a given cropping system. Witney and Saadoun (1989) used the relationship between the purchase price (Pp) and resale values (Sn) to determine what they referred to as decremented depreciation. Schular and Frank (1991) estimated the fixed and variable costs as a percentage of remaining value as developed by the American Society of Agricultural Engineers (ASAE). Ismail (1998) combined a number of models such as Hunt (1983) and ASAE Standards (1990) to determine the costs of a set of machinery. Dash and Sirohi (2008) developed a computer - based least-cost model in C-programming language for costing and selecting optimum size of power and machinery system for paddy-wheat cropping system. Kloub bakht *et al.* (2008) presented appropriate mathematical models, based on repair and maintenance costs of MF285 tractor, for predicting tractor costs. Isik and Sabanci (1993) developed a computer model to select optimum size of farm machinery and power for mechanization planning. These models and many others focused on post bush clearing operations. They assume that field operations start from tillage and end at harvesting thereby making models for machinery selection and costing limited to those operations that neglecting bush clearing. The cost components of these models and the total cost are expressed per hour. But in some cases, the farmer is interested in knowing the cost of the machinery and hence the cost of operation per hectare. The objective of this study is to develop a model for predicting cost of agricultural bush clearing machinery.

Materials and Methods

The cost components modelled in this study are capital and variable costs. The capital cost involves the cost of depreciation plus interest while variable cost involves the cost of fuel, oil, repair and maintenance and labour. The capital cost was modelled based on the machine's purchase price, life, cost recovery factor and the effective field capacity. The shelter cost was assumed to be 2% of the purchase price. The fuel cost was determined first from the fuel consumption by taking into account the physical and operational characteristics of the machine and soil conditions such as tractive efficiency, mechanical efficiency, the soil cone index and the soil depth of cut (ASAE, 2003; ASABE, 2011; Wards, 1995). The cost of engine oil was predicted from the rated engine oil consumption. The repair and maintenance cost was modelled from the effective field capacity and repair and maintenance constants developed by ASAE (2003). The labour cost was estimated from operators' wage based on the salary of a Chief Machine Operator in government civil service while that of his assistant was based on that of a Technical Assistant in government service. Their daily feeding allowances were obtained from field survey. Costs such as insurance, taxation and lubrication, steering and hydraulic oils and timeliness costs were neglected. This is because these machines are not insured and their oils and lubricants are not changed often. The model was validated using data from literature, survey and field experiments. The field experiment was conducted on a virgin land located at Ako Nike, Enugu state in the derived Savannah zone of Nigeria. Three categories of crawler tractor bulldozers of models D6, D7 and D8 as shown in **Figs. 1** to **3** were used. The quantity of fuel used by the machines to clear the plot in each block was measured using a graduated dipping stick (**Fig. 4**) produced after calibrating the fuel tank (**Figs. 5** and **6**). The derived Savannah zone, where the experiment was carried out, lies on 5°55 and 7°08 North of Equator and 6°35 and 7°55 East of Greenwich Meridian. Ako Nike is the farm site of Demacco Integrated Farms Ltd. The farm is about 50 km from Enugu the capital of Enugu state. A questionnaire was developed and used to obtain relevant data on the machines' purchase price, prevailing interest rate and fuel pump price.

The experiment was conducted to measure the quantity of fuel consumed during bush clearing operation. The field was mapped into three blocks which served as replicates using Randomized Completely Block Design (RCBD). Each block was divided into four plots. A total of twelve plots were involved.

The Model

The cost of agricultural bush clearing machinery can be modelled as

$$C = C_{1f} + C_{1v} \quad (1)$$

Where, C = total system cost, \$/ha

C_{1f} = fixed cost, \$/ha

C_{1v} = variable costs, \$/ha

Fixed Cost (C_{1f})

The fixed cost component of the model consists of three cost items namely depreciation (DEP), interest on investment (INC) and shelter

Fig. 1 Model D6 fuel tank in preparation for field operation

Fig. 2 Model D7 in field operation pushing and felling down of vegetation

Fig. 3 Model D8 in operation pushing and felling down of vegetation

Fig. 4 The dip sticks used to measure fuel consumption

Fig. 5 Calibraion of the fuel tank using SATAM model Rz machine

Fig. 6 Calibration of the tank of one of the tractor bulldozers in progress

(SHC), while insurance cost (ISC) was neglected. This was expressed as:

$C_{1f} = DEP + INC + SHC, (\$/ha)$..(2)

Depreciation and interest costs are jointly determined as capital costs (CAC) by modifying the following models developed by Hunt (1995) which is given as:

$$CAC = \frac{(PP - SV)^{CRF} + SV \times I}{L}, (\$/h) \quad ......(3)$$

Where, CRF = capital recovery factor and expressed as:

$$CRF = \frac{I (1 + I)^{L}}{(1 + I)^{L-1} - 1} \quad ......(4)$$

where, I, PP, L and SV respectively stands for interest rate in decimal, purchase price in \$, life of the machinery in h and salvage value in \$.

Equation 3 was modified by introducing the terms K_0,/K and K_{eff} to take care of the hours devoted to bush clearing within the year and to relate the cost to the size of the farm as follows:

$$CAC = \frac{[(PP - SV)^{CRF} + SV \times I] K_0}{L \times F_{eff} \times K}, (\$/ha) \quad ......(5)$$

K_0 = number of hours devoted to mechanized bush clearing within the year, h

K = total number of hours the machinery was used for the year, h

F_{eff} = Effective field capacity, ha/h

The shelter cost cannot be neglected entirely. Although the machinery is not housed, the owner suffers the cost of increased wear and corrosion due to weather. Therefore, shelter cost is given as:

$SHC = [(0.02PP \times K_0) / (L , \times F_{eff} \times K)], (\$/ha)$ ....(6)

The constant 0.02 is the housing cost assumed to be 2% of the purchase price, (PP). This assumption was made because of the high rate of wear due to unfavourable climatic conditions in the tropics.

Variable cost (C_{1v})

The variable cost component in this model consists of fuel (FUC), repair and maintenance (RMC), oil (OC) and labour (LBC). The variable cost was calculated by modifying the model equations developed by Witney and Saadoun (1989), Ismail (1998), ASAE (2003) and ASABE (2011) as:

$C_{1v} = FUC + OC + RMC + LBC, (\$/ha)$ ....(7)

The Fuel cost FUC was given as:

$FC = 2.64F + 3.9 - 0.203\sqrt{738F + 173}$ (ASAE, 2003) ......(8)

Where,

FC = Fuel consumption, lit/kW-h

F = power utilization ratio =Maximum power required / Maximum power available

The power transmitted to the blade is always lesser than that delivered by the engine. This was due to wheel slippage, rolling resistance and frictional losses in the drive train between the engine and the dozer tracks. To account for this, the power required was determined from (Wards, 1995). This was expressed as:

$P_{req} = [\{z \times n \times b \times (d / Me) \times T_e\} + W \times CRR] V$ ....(9)

Where,

P_{req} = maximum power required (kW)

z = resistance to soil cutting, tree felling and windrowing (kN/m^2)

n = number of blades

b = width of the blade (m)

d = depth of cut (m)

Me = mechanical efficiency of the machine's transmission system from engine flywheel to the dozer tracks (%)

T_e = Tractive efficiency allowing a wheel slip of 25%

W = Weight of the machine (kN)

CRR = coefficient of rolling resistance

V = speed of operation (m/s)

The available power (P_{aver}) is estimated from the net flywheel power under the prevailing soil condition (ASABE, 2011). For bulldozers (track tractors), the power is transmitted directly to the blades except for rome ploughing operation. In the case under consideration, the soil is firm and so the available power is 76% of the flywheel power.

The total fuel consumed TFC is therefore, given as:

$TFC = FC \times P_{flyw} \times T, (L)$ ....(10)

The fuel cost, FUC is therefore given as:

$FUC = TFC \times PC, (\$)$ ....(11)

Where, PC = fuel cost per litre, (\$/L)

Therefore, the fuel cost per hectare is given as:

$FUC_h = FUC / S, (\$/ha)$ ....(12)

S = area cleared in hectares introduced in this model to estimate the fuel cost in Dollar per hectare.

The oil cost, (OC), includes the cost of engine oil, hydraulic oil and transmission oil. The hydraulic and transmission oil costs are neglected because these oils are not replaced often.

For diesel engines, the rate of engine oil consumption is given as:

$OC = 0.00059Z + 0.02169$ (ASAE, 2003) ....(13)

Where,

OC = the rate of engine oil consumed (L/h)

Z = rated engine power obtained from the machine operational manual (kW)

The total oil consumed is given as:

$SC = (0.00059Z + 0.02196)T, (L)$ ....(14)

Where, T is the time taken to accomplish the clearing operation.

Therefore the oil cost:

$OC = (SC \times T) Co / S, (\$/ha)$ .....(15)

Co = oil cost per litre, (\$/L)

Repair and maintenance cost

Due to variations in age of machinery, vegetation, experience of the operator, soil conditions, etc. the repair and maintenance cost of machinery is difficult to estimate. However, an equation was established by Rotze and Bowers (1991) for estimating repair and maintenance cost. Wittney and Saadoun (1989) and Ismail (1998) modified the equation and used it to estimate repair and maintenance cost of tractors and implements. In the same manner, repair and maintenance cost can be modified and used for bush clearing machinery as:

$RMC = (PP \times Ra\ [K_0 / K]^{Rb} / S$, (\$/ha) ....(16)

Where,

RMC = repair and maintenance cost (\$/ha)

PP = machine purchase price (\$)

Ra = repair constant

Rb = repair component and K_0,/K are the modifying factors that accounts for bush clearing

The model adopted for labour cost LBC in this study includes the annual salary of the operator and his help mate plus their daily feeding cost. This was expressed as:

$LBC = [(A + a) / y \times F_{eff}] + [(P + p) / t \times F_{eff}]$, (\$/ha) ....(17)

"A" and "a" are annual wages of the operator and his assistant, respectively, in Dollar per year; y is the number of hours the operator worked in a year; "P" and "p" are daily allowances of the operator and his assistant, respectively, in Dollar per day; and t is the number of hours they worked per day. Data on A, a, P and p were obtained from both survey and field experiment carried out while the data for y were obtained from the information revealed from the survey exercise since both operators used for the field experiment worked for one day each.

Generalized Model

The generalized model for costing agricultural bush clearing machinery is obtained by substituting C_{1f} and C_{1v} with their expressions provided in equations (2), (3) and (7) to give:

$C = CAC + SHC + FUC + RMC + LBC$, (\$/ha) ....(18)

Further substitutions of equations 5, 6, 12, 15, 16 and 17 into equation (18) gave the generalized model as:

$C = [\{(PP - SV)^{CRF} + SV \times I\}K_0] / (L \times F_{eff} \times K) + (0.2PP \times K_0) / (L \times F_{eff} \times K) + FUC / S + \{(SC \times T)\ C_0\} / S + \{PP \times Ra\ (K_0 / K)^{Rb}\} / S + (A + a) / (y \times F_{eff}) + (P + p) / (t \times F_{eff})$, (\$/ha) ....(19)

Table 1 Fixed Costs Components of the Model, \$/ha

Description	Abbreviation	Machinery Category/Model		
Tractor bulldozer		D6	D7	D8
Housing cost	SHC	0.02	0.02	0.02
Capital cost	CAC	0.01[1]	0.01[1]	0.01[1]
		0.01[2]	0.01[2]	0.01[2]

1 = Prediction from the model, 2 = Field survey

Table 2 The Variable Cost (VAC) Component of the Model, \$/ha

Description	Abbreviation	Machinery Category/Model		
Tractor bulldozer		D6	D7	D8
Fuel cost	FUC	251.61[1]	234.56[1]	230.29[1]
		211.53[2]	196.17[2]	181.68[2]
Repair and maintenance cost	RMC	10.38[1]	9.02[1]	7.35[1]
		9.99[2]	8,82[2]	7.07[2]
Oil cost	OIC	0.95[1]	0.90[1]	0.80[1]
Labour cost	LBC	67.04[2]	51.81[2]	33.36[2]

1 = Prediction from the model 2 = Experimental/survey

Table 3 Total Cost (C) of Bush Clearing, \$/ha

Description	Abbreviation	Machinery Category/ Model		
Tractor bulldozer		D6	D7	D8
Total fixed cost	C1f (FIC)	0.031	0.031	0.031
		0.032	0.032	0.022
Total variable cost	C1v (VAC)	329.991	296.281	271.811
		285.252	257.712	222.922
Grand Total	C	330.021	296.311	271.841
		285.282	257.742	222.942

Results and Discussion

Fixed Costs Component

The housing cost together with the capital cost (depreciation cost plus interest cost) for each of the machinery are presented in **Table 1**. From the Table, the housing and capital costs for the three machines were approximated to \$0.02/ha. Reports gathered from field survey gave a value of \$0.01 for the three machines.

Total Fuel Costs

The output data for the variable costs are shown in **Table 2**. The information in **Table 2**, shows that fuel costs (FUC) values of \$251.61/ha, \$234.56/ha and \$230.29/ha were obtained from the model prediction equation for models D6, D7 and D8 crawler tractor bulldozers, respectively. Fuel cost values resulting from field experiment recorded \$211.53/ha, \$196.17/ha and \$181.68/ha for models D6, D7 and D8 crawler tractor bulldozers, respectively. The costs were determined based on official pump price (PC) of \$0.85/litre.

Repair and Maintenance Costs

The repair and maintenance costs (RMC) used were determined for both model and field survey. In **Table 2**, the repair and maintenance costs for the three machines based on model prediction gave repair and maintenance cost values of \$10.38/ha, \$9.02/ha and \$7.35/ha for models D6, D7, and D8 crawler tractor bulldozers, respectively. From field survey data, results obtained were \$9.99/ha, \$8.82/ha and \$7.07/ha for models D6, D7 and D8 crawler tractor bulldozers, respectively.

Total Costs of Oil Consumed

The costs of engine oil as predicted from the model equation are shown in **Table 2**. Based on pump price of $2.47/litre, the oil costs (OC) values obtained were $0.95/ha, $0.90/ha and $0.80/ha for models D6, D7 and D8 crawler tractor bulldozers, respectively. It was difficult obtaining oil consumption data from the field experiment because users of these machines did not keep record of oil consumption used.

Labour Cost

The labour cost (LBC) was validated using data from both survey and field experiment. The results obtained were presented in **Table 2** which gave labour cost values of $67.04/ha, $51.81/ha and $33.36/ha for models D6, D7 and D8 crawler tractor bulldozers, respectively.

Total Cost (C) of Bush Clearing

The total cost of agricultural bush clearing machinery for both model prediction and field experiment is presented in **Table 3**. For crawler tractor bulldozer of model D6, the total cost values obtained were $330.02/ha and $285.28/ha for model prediction and field experiment, respectively. For crawler tractor bulldozer of model D7, the total cost values obtained were $296.31/ha and $257.74/ha for model prediction and field experiment, respectively. The results for the crawler tractor bulldozer of model D8 gave total cost values of $271.84/ha and $222.94 for model prediction and field experiment, respectively.

The total cost decreases as size of machinery increases. But with respect to hourly cost, (not provided in the tables presented) cost increases with respect to the size of the machinery. The decrease in cost per hectare as the size of the machinery increases could be due to higher effective field capacity of the bigger machinery size (Adama, 2013). However, this cannot be the only basis on which the machinery will be selected as the effect of the machine on the soil is also very important. In all the cases presented, model results were higher than the field (experimental) results. The deviation values ranged from 13.02% for D7 crawler tractor bulldozer model to 17.99% for D8 crawler tractor bulldozer model with D6 crawler tractor bulldozer accounting for a deviation value of 13.56%. The deviation could be attributed to uncertainties and uncontrollable factors usually associated with field experiments. The plots of the total cost against machinery size for both model prediction and field experiment are shown in **Fig. 7**. From the Figure, the total cost decreases as machinery size increases up to a point where the total cost starts to increase as the machinery size increases. The equation is of the form

$$y_1 = 7.521x^2 - 2275x + 23688 \quad (19)$$

for the model, and

$$y_2 = 6.661x^2 - 2003x + 20886 \quad (20)$$

for the field experiment

Where, y_1 and y_2 are total cost in $/ha and x is machinery size.

The machinery size at its minimal cost is the optimum power for maximizing benefit which is calculated as 147.63 kW using model equation (19) and 150.35 kW using field experiment expression shown in equation (20).

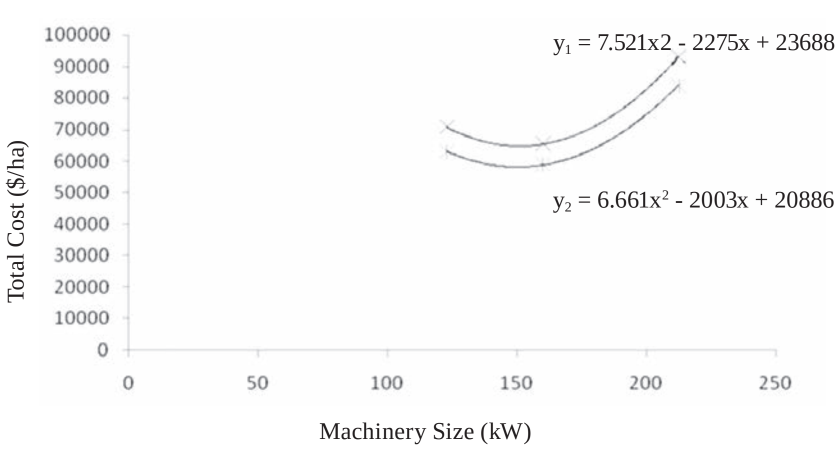

Fig. 7 Relationship between Total Cost and Machinery Size

Conclusions

The costs of agricultural bush clearing machinery have been modelled. The cost of agricultural bush clearing per hectare decreases as the size of the machinery increases from models D6 to D8 up to a point and then increases continuously to infinity. The optimum machinery (crawler tractor) size for mechanized agricultural bush clearing is between 147.63 kW and 150.35 kW.

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(Continued from page 17)

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Effect of Moisture Content on Physical Properties of Finger (Eleusine coracana) Millet

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Abstract

Design of harvesting, grading, cleaning, processing, grain handling equipment, grain storage structures and transport machineries requires the physical, mechanical, aerodynamic properties of grains. Linear dimensions like length, width, thickness, geometric mean diameter sphericity are necessary for selection of sieve separator and calculation of grinding power for size reduction whereas surface area and volume are for modelling of grain drying, aeration, heating and cooling. Bulk density determines the capacity of storage and transport system, whether true density used for separation equipment and porosity determines the resistance to air flow during aeration and drying of seeds. Terminal velocity helps in designing the cleaning system and frictional coefficient is necessary for design of agricultural product handling equipment. Effect of moisture content on physical properties of finger millet were studied in the range of 0.065 to 0.265 kg kg^{-1} dry matter and result was found that length, width, thickness, geometric mean diameter, surface area, volume and sphericity increased from 1.61 to 1.81 mm, 1.58 to 1.84 mm, 1.41 to 1.61 mm and 1.53 to 1.75 mm, 7.05 to 9.35 mm^2, 1.75 to 2.69 mm^3 and 0.95 to 0.96, respectively. True density obtained by proximate composition method was found lower than the true density obtained by toluene displacement method. Interstice was observed decreased with increase of moisture content from 0.26 to 0.01 m^3. Coefficient of friction and terminal velocity increased from 0.536 to 0.774 and 1.22 to 2.02 ms^{-1} with increase of moisture content.

Keywords: Finger millet, physical properties

Introduction

Finger millet (*Eleusine coracana*), also known as ragi, red millet, caracan millet, koracan, is widely cultivated in African and Asian countries. It is very adaptable to higher elevations, humid areas and dry areas. Finger millet is grown in above MSL Africa including Uganda, Kenya, Tanzania, Malawi, Sudan, Zaire, Zambia, Zimbabwe, Ethiopia and in India south to eastern and western Himalaya up to 2500 m height. In India it is cultivated in Karnataka, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Rajasthan, Bihar and Odisha states among which Karnataka tops with 58% share.

Finger millet having an annual grass with erect culms, laterally flattened, 60-120 cm tall, profusely tillering, fibrous root system and remarkably strong, the inflorescence is in a whorl of 2-8, digitate, straight or slightly curved spikes 12.5-15 cm long and about 1.3 cm broad, spikelets (about 70) arranged alternately on rachis, each spikelet containing 4-7 seeds, seed diameter varying from 1-2 mm, caryopsis globose to flattened, smooth or tugose, reddish brown to nearly white or black in colour. It is generally grown in the month of June-July and harvested in October-November. Normally intercropped with legumes like peanuts, cowpeas, pigeon peas, it can be stored for long time without any damage by pests and insects.

Finger millet is very nutritious minor millet which contains methionine and amino acid. Its nutritional value is: 100 g finger millet contains carbohydrate 88 g, protein 7.6 g, fibre 3 g, fat 1.5 g, calcium 370 mg, vitamin A 0.48 mg, Thiamine (B1) 0.33 mg, Riboflavin (B2) 0.11 mg, Niacin (B3) 1.2 mg. In India it is a staple food of the tribal people of Odisha and western hilly regions. It can be consumed as cooked cake, puddings, mudde, porridge, idly, dosa, roti, flat breads. It is made into fermented drink in Nepal and other African countries and also consumed as flavoured drink in festivals. Finger millet straw is used as fodder for animals.

Design of harvesting, grading, cleaning, processing, grain handling equipment, grain storage structures and transport machineries requires the physical, mechanical, aerodynamic properties of grains. Linear dimensions like length, width, thickness, geometric mean diameter sphericity plays vital role in selection of sieve separator and calculation of grinding power for size reduction. Surface area and volume important for modelling of grain drying, aeration, heating and cooling (Tavakoli *et al*., 2009). Bulk density determines the capacity of storage and transport system and used for calculating the structural loads on the storage structure, whether true density used for separation equipments and porosity determines the resistance to air flow during aeration and drying of seeds (Gharib-Zavedi *et al*., 2010). Terminal velocity plays an important role for designing the cleaning system where as frictional coefficient is necessary for design of agricultural product handling equipment (Isik & Unal, 2007). Many studies were done on physical, mechanical and aerodynamic properties by many researchers like Singh *et al*., 2010; Balasubhramanian & Viswanathan, 2010; Swami & Swami, 2010; Ojediran *et al*., 2010; Tavakoli *et al*., 2009; Tunde-Akintunde & Akintunde, 2007; Gharib-Zahedi *et al*., 2010; Seifi *et al*., 2010; Shafiee *et al*., 2009; Altuntas & Yildiz, 2005; Bhise *et al*., 2014 for the food grains like barnyard millet, minor millets, finger millet, pearl millet, barley grains, beniseed, black cumin, corn, dragon's head seeds, faba bean, wheat. The current study was done on the effect of moisture content on physical, mechanical and aerodynamic properties of finger millet within the moisture content range of 0.065 to 0.265 kg kg^{-1} dry matter.

Nomenclature	
Q	Mass of water added, kg
W_i	Initial mass of sample, kg
M_i	initial moisture content of sample, kg kg^{-1} dry matter
M_f	Final moisture content of sample, kg kg^{-1} dry matter
D_g	Geometric diameter, mm
L	Length of grain, mm
W	Width of grain, mm
T	Thickness of grain, mm
S	surface area, mm^2
V	Volume, mm^3
S_p	Sphericity
δ_{bd}	Bulk density, kg m^{-3}
T	Temperature, ºC
I	Interstice, %
δ_{td}	True density (kg m^{-3}) assessed by toluene displacement
δ_{pc}	True density (kg m^{-3}) assessed by proximate composition method
ε	Porosity, %
μ_i	Coefficient of internal friction
F_e	Load on pan required to slide the empty cylinder
F_g	The incremental load applied on the loading pan to slide the top cylinder
N	Mass of the grain or kernel sample contained in the top cylinder

Materials and Methods

Finger millet grain (Variety: *VL Mandua* 149; colour: copper colour; Plant hight: 850-900 mm; Maturity period: 105-110 days; yield potential: 2500-300 kg/ha) was taken from ICAR-Vivekananda Institute of Hill Agriculture, Almora, Uttarakhand, India. As per ASAE standard (ASAE, 1993) method moisture content was determined by keeping the grain for 12-14 hours in hot oven at 105±1°C. (Ojediran *et al*., 2010; Suthar & Das, 1996; Altuntas & Yildiz, 2007; Tabatabaeefar, 2003; Seifi *et al*., 2010; Sezer *et al*., 2011). Five levels of moisture content were taken (0.065, 0.112, 0.163, 0.22 & 0.265 kg kg^{-1} dry matter) for analysis of the properties of grain. Grain samples of desired moisture content were prepared by addition of required amount of distilled water to the sample and thoroughly mixed. After that samples were kept in polyethylene bags and sealed properly to reduce the reduction of moisture. The bags were kept in refrigerator for a week at 5°C temperature to allow the moisture to be distributed uniformly throughout the samples. Before each experiment required amount of samples were taken out and allowed to warm up to the room temperature (30±2°C) for 2 h (Balasubramanian & Viswanathan, 2010; Sing & Goswami, 1996; Yalcin & Ozarslan, 2004; Coskun *et al*., 2006, Nimkar & Chattopadhyay, 2001; Garnayak *et al*., 2008; Singh *et al*., 2010).

The required amount of water for addition to obtain the desired moisture content was calculated by the following equation (Sacilink, 2002; Karababa, 2006; Altuntas & Yildiz, 2007; Singh *et al*., 2010; Balasubramanian & Viswanathan, 2010).

$Q = (Wi\ (Mf - Mi)) / (100 - Mf)$ ....(1)

The physical, mechanical and aerodynamic properties were obtained at all the five levels of moisture contents with five replications of each.

100 grains were selected randomly and length, width and thickness were determined using Vernier calliper with 0.001 mm least count. The geometrical mean diameter of grain was calculated by the formula given below (Mohsenin, 1970; Singh *et al*., 2010; Shafiee *et al*., 2009; Sezer *et al*., 2011; Seifi *et al*., 2011).

$Dg = (LWT)^{1/3}$ ....(2)

The surface area of the grain was calculated by using the following formula (Sacilik *et al*., 2003; Tunde-Akintunde & Akintunde, 2004; Altuntas *et al*. 2005; Singh *et al*., 2010; McCabe *et al*., 1986; Dursun and Dursun, 2005; Baryeh, 2002; Al-Mahasneh & Rababah, 2007; Deshpande *et al*., 1993; Sessiz *et al*., 2007).

$S = \pi Dg^2$ ....(3)

The volume of grain was obtained using formula given below (Jain & Bal, 1997; Gharib-Zahedi *et al*., 2010).

$V = 0.25[(\pi/6)\ L\ (W + T)^2]$ ....(4)

The sphericity is defined as the ratio of the surface area of the sphere having the same volume as that of grain to the surface area of the grain. It was determined by using the relationship proposed by Mohsenin, 1978.

$S_p = (LWT)^{1/3} / L$ ....(5)

Thousand grain weight were determined by the help of electronic balance with an accuracy of 0.001 g by selecting 1,000 grain randomly.

Bulk density is the ratio of mass and volume of the grain. To determine the bulk density, a cylindrical container of 500 ml was used. It was obtained by taking a container of 500 ml filled with the grain. Then the weight of 500 ml grain was measured with the help of electronic balance with an accuracy of 0.001g and calculated by using the following formula.

$\delta_{bd} = W / 500 \times 10^6$ ....(6)

The true density is defined as the ratio of the mass of the sample to the solid volume occupied by the sample. It was reviewed that absorbing capacity of toluene (C_7H_8) is less than the absorbing capacity of water by the grain. Therefore toluene displacement method was used for determination of true density (Mohsenin, 1986; Dursun and Dursun, 2005). The actual volume will be taken as the volume toluene displaced (Singh and Goswami, 1996; Ogut, 1998; Konak *et al*., 2002).

True density can also be determined by using the proximate composition of the grain. Choi & Okas, 1986 and Singh *et al*., 2010 used the following formula for determination of the true density.

$\delta_T = 1 / \{(C_{fat} / \delta_{fat}) + (C_{carb} / \delta_{carb}) + (C_{fib} / \delta_{fib}) + (C_{protein} / \delta_{protein}) + (C_{ash} / \delta_{ash}) + (C_{water} / \delta_{water})\}$ ..... (7)

Where,

$\delta_{fat} = 9.26 \times 10^2 - 4.18 \times 10^{-1}T$, $\delta_{carc} = 1.60 \times 10^3 - 3.10 \times 10^{-1}T$, $\delta_{fib} = 1.31 \times 103 - 3.66 \times 10^{-1}T$, $\delta_{protein} = 1.33 \times 103 - 5.8 \times 10^{-1}T$, $\delta_{ash} = 2.42 \times 103 - 2.81 \times 10^{-1}T$, $\delta_{water} = 9.97 \times 102 + 3.14 \times 10^{-3}T - 3.38 \times 10^{-3}T^2$

C_{fat}, C_{carb}, C_{fib}, $C_{protein}$, C_{ash}, C_{water} are the fraction of fat, carbohydrate, fibre, protein, ash and water in the grain of finger millet at all the level of moisture content within the experimental range.

Interstices are the intermolecular space present between the molecules of protein, fat, carbohydrate, fibre, ash and water. It was calculated by the formula given below (Singh *et al*., 2010).

$I = (1000\ grain\ mass / 1000) \times (\delta_{pc} - \delta_{td} / \delta_{pc \times \delta_{td}})$ ....(8)

The porosity was calculated using of bulk density and true density with the help of the following formula (Mohsenin, 1986; Balasubramanian & Viswanathan, 2010; Sigh *et al*., 2010)

$\varepsilon = (1 - \delta_{bd} / \delta_{td}) \times 100$ ....(9)

Subramanian & Viswanathan, 2007 developed a set up for measurement of internal coefficient of friction. In this setup two identical hollow plastic cylinders of 50 mm diameter and 55 mm height were used. Lower cylinder was fixed on the horizontal surface and the top cylinder was kept free. Pulley rope arrangement with loading pan was used to make the top cylinder slide over the stationary cylinder when weight on the loading pan was increased. The coefficient of internal friction was obtained by the following equation.

$\mu_i = (F_g - F_e) / N$ ....(10)

Aerodynamic property like terminal velocity of finger millet grain were measured experimentally by the set up where, a transparent cylindrical hollow plastic cylinder was used. For each analysis 100 g of samples were taken and put into the cylinder. Then the vibrator was used for dropping into the air stream from the top of the vertical column and air flow rate was increased to suspend the grain in the air for 30 sec. The velocity was measured by the vane anemometer and recorded.

Error bar diagram was used for the statistical analysis which represents the precision of the measurements and difference from the accurate value.

Results and Discussion

Physical, mechanical and aerodynamic properties of finger millet were measured at all the moisture content level within experimental range of 0.065 to 0.265 kg kg^{-1} dry matter.

Length

Length of finger millet observed within the experimental range of moisture content was increased linearly as the moisture content increased. Length was increased from 1.61 to 1.81 mm with increase of moisture content from 0.065 to 0.265 kg kg^{-1} dry matter. This was represented in the **Fig. 1**. The relationship between the moisture content and length may be expressed by the equation 11. Ojediran *et al*., 2010 also found similar increasing trend for pearl millet. Similarly Tunde-Akintunde & Akintunde, 2007 for beniseed, Gharib-Zahedi *et al*., 2010 for black cumin, Seifi *et al*., 2010 for corn also found increased length with increase of moisture content.

$$Y = 0.5416x^2 + 0.8047x + 1.561,\ R^2 = 0.9981 \quad (11)$$

Width

Width of finger millet grain was measured at all the moisture content level and as a result it was found that width was increased slowly up to 0.163 kg kg^{-1} dry matter moisture content but increased rapidly thereafter. It was increased in the range of 1.58 to 1.84 mm as the moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter moisture content. It was represented in the **Fig. 2**. Relationship between moisture content and width was found as equation 12. Ojediran *et al*., 2010 for pearl millet, Tunde-Akintunde & Akintunde, 2007 for beniseed, Gharib-Zahedi *et al*., 2010 for black cumin, Seifi *et al*., 2010 for corn also found similar trend of increased width with increase of moisture content.

$$Y = 6.3824x^2 - 0.8225x + 1.6103,\ R^2 = 0.9997 \quad (12)$$

Thickness

Finger millet grain thickness was observed to have increased as the moisture content increased within the experimental range. When the moisture content of the grain was increased from 0.065 to 0.265 kg kg^{-1} dry matter moisture content thickness of the grain was increased from 1.41 to 1.61 mm. It can be observed from the **Fig. 3**. Thickness and moisture content relationship of finger millet grain may be expressed by the equation 13. Ojediran *et al*., 2010 for pearl millet, Sezer *et al*., 2011 for dent corn seeds, Gharib-Zahedi *et al*., 2010 for black cumin, Seifi *et al*., 2010 for corn also found similar trend of increased thickness with increase of moisture content.

$Y = -2.4357x^2 + 1.8232x + 1.3034,$

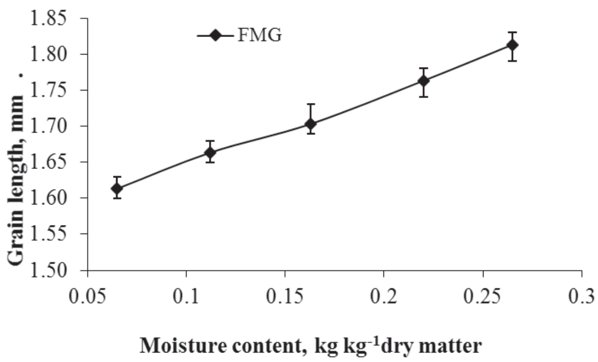

Fig. 1 Effect of moisture content on length of grain

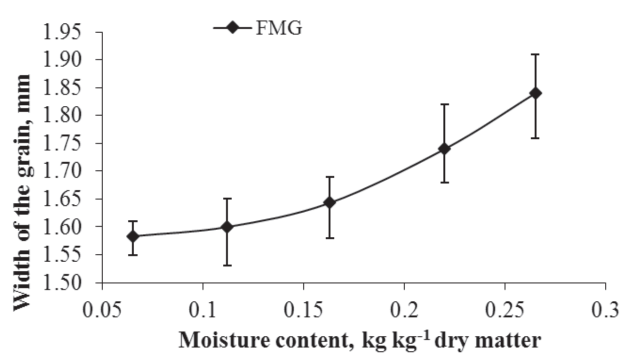

Fig. 2 Effect of moisture content on width of grain

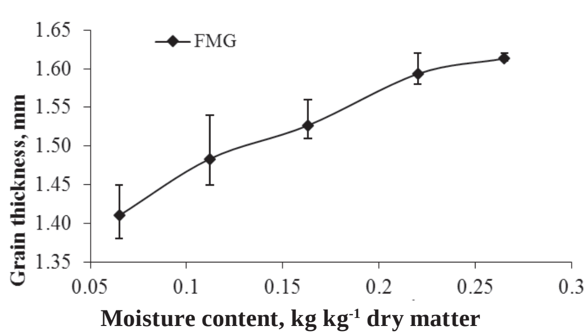

Fig. 3 Effect of moisture content on thickness of grain

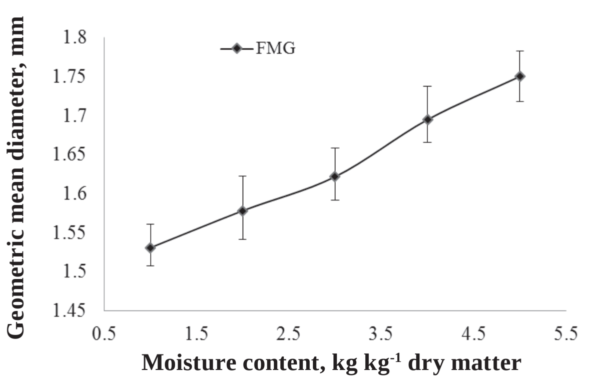

Fig. 4 Effect of moisture content on geometric mean diameter of grain

$R^2 = 0.9936$ ....(13)

Geometric Mean Diameter

Geometric mean diameter of the grain was calculated by the formula no. 2 by using the linear dimensions of the grain at all the moisture content levels and the result was observed that increase of moisture content within the experimedntal range increased the geometric mean diameter linearly. When the moisture content increased from 0.065 to 0.265 kg kg^{-1} geometric mean diameter of the finger millet grain was increased from 1.53 to 1.75 mm, which can be observed from the **Fig. 4**. The relationship built between moisture content and geometric mean diameter of the grain can be expressed by the equation 14. Singh *et al.*, 2010 for barnyard millet, Ojediran *et al.*, 2009 for pearl millet, Shafiee *et al.*, 2009 for dragon's head seeds also found increasing trend of geometric mean diameter with increase of moisture content.

$Y = 0.003x^2 + 0.036x + 1.491$, $R^2 = 0.996$ ....(14)

Surface Area

Surface area of finger millet grain was calculated by the formula suggested by Mohsennin and the result was obtained that surface area was increased linearly with increase of moisture content within the experimental range. When the moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter surface area was increased from 7.05 to 9.35 mm^2 as presented in the **Fig. 5**. Relation between moisture content and surface area can be expressed by the equation 15. Similar result were also found for barnyard millet by Singh *et al.*, 2010, for pearl millet by Ojediran *et al.*, 2010, for dent corn seeds by Sezer *et al.*, 2011 for soyabean grains by Tavakoli, 2009 and for dragon's head seeds by Shafiee *et al.*, 2010.

$Y = 21.453x^2 + 4.4307x + 6.6804$, $R^2 = 0.998$ ....(15)

Volume

Finger millet grain volume was observed increasing linearly as the moisture content was increased within the experimental range. When moisture content was increased from 0.065 to 0.265 kg kg^{-1} dry matter volume of the grain was increased from 1.75 to 2.69 mm^3. It can be observed from the **Fig. 6**. The relationship between moisture content and volume of grain can be expressed by the regression equation and coefficient of correlation presented in the equation 16. Sezer *et al.*, 2011 for dent corn and Gharib-Zahedi *et al.*, 2010 for black cumin also found similar increasing trend as increase of moisture content.

$Y = 10.344x^2 + 1.2375x + 1.6358$, $R^2 = 0.998$ ....(16)

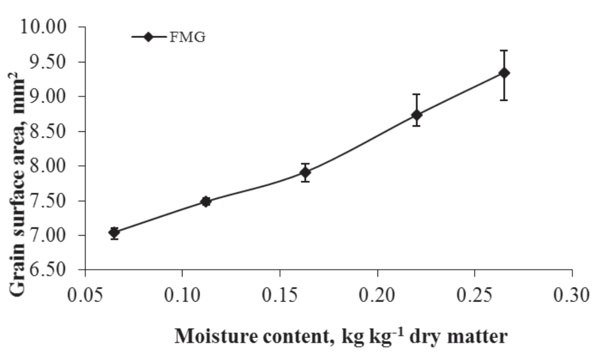

Fig. 5 Effect of moisture content on grain surface area

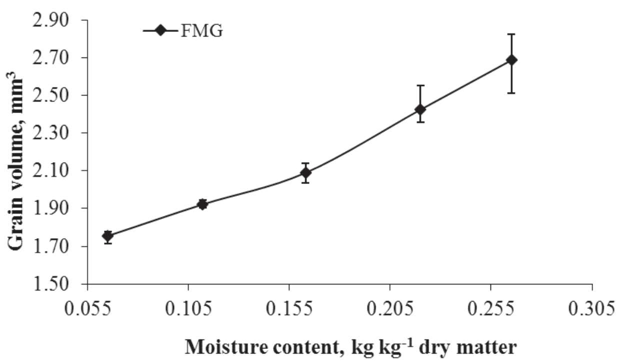

Fig. 6 Effect of moisture content on grain volume

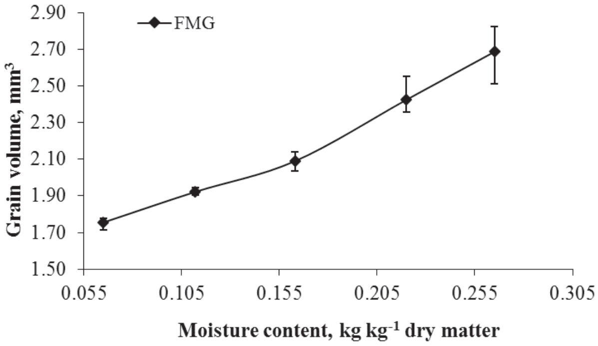

Fig. 7 Effect of moisture content on sphericity of grain

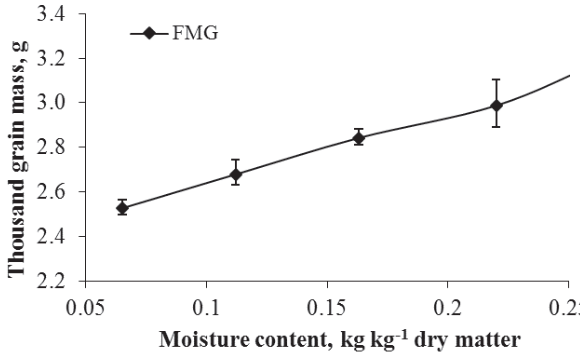

Fig. 8 effect of moisture content on thousand grain mass of grain

Sphericity

Sphericity of finger millet grain was observed slowly increasing initially up to 0.165 kg kg^{-1} dry matter moisture content but increased rapidly thereafter. It was increased from 0.95 to 0.96 with increasing moisture content of 0.065 to 0.265 kg kg^{-1} dry matter. It can be observed from the **Fig. 7**. It can be represented by the regression equation and coefficient of correlation as presented in equation 15. Gharib-Jahedi *et al*., 2010 for black cumin, Singh *et al*., 2010 for barnyard millet, Shafiee *et al*., 2009 for dragon's head found sphericity increased as a result of increased moisture content.

$Y = 0.4594x^2 - 0.0621x + 0.9517, R^2 = 0.9672$ ....(17)

Thousand Grain Mass

Thousand grain mass of finger millet was determined for all the moisture content level within the moisture content level and represented in the **Fig. 8**. It can be observed from this figure that thousand grain mass of finger millet was increased uniformly with increase of moisture content. When the moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter the thousand grains mass was increased from 2.527 to 2.987 g. Moisture content and thousand grains mass relationship was found linear and presented in the equation 18. Shafiee *et al*., 2009 for dragon's head, Balasubramanian and Viswanathan, 2009 for minor millets, Altuntas and Yildiz, 2005 for faba bean grains and Isik and Unal for red kidney bean grains found similar linearly increasing trend as a result of increasing moisture content.

$Y = 3.2192x + 2.3143, R^2 = 0.9929$ ......(18)

Bulk Density

A linear decreasing trend of bulk density was found with increase of moisture content as presented in the **Fig. 9**. When the moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter bulk density of finger millet grain was decreased from 788.1 to 627.6 kgm^{-3}. Relation between moisture content and bulk density can be expressed by the regression equation and coefficient of correlation as in equation 19. Similar decreasing trend was found by Balasubramanian & Viswanathan, 2009 for minor millets, Isik & Unal, 2007 for red kidney bean grains,

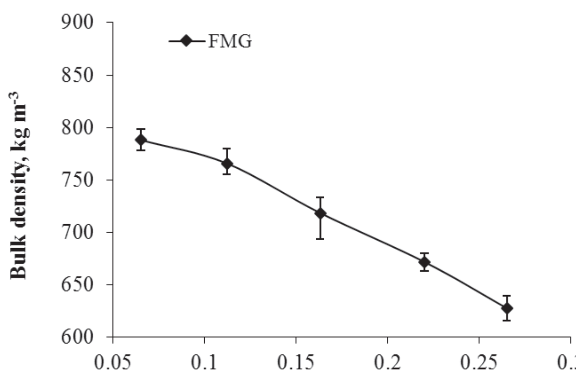

Fig. 9 Effect of moisture content on bulk density of grain

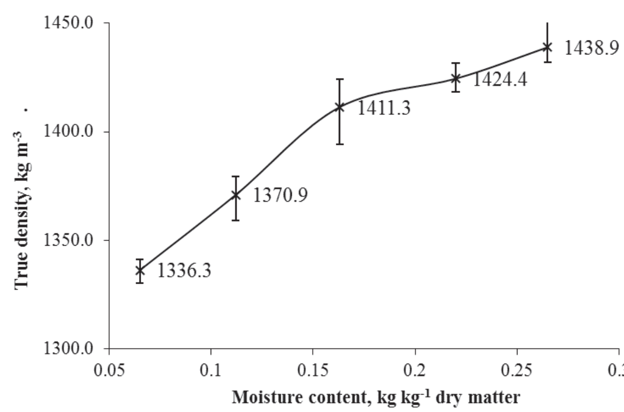

Fig. 10 Effect of moisture content on true density of finger millet determined by toluene displacement method

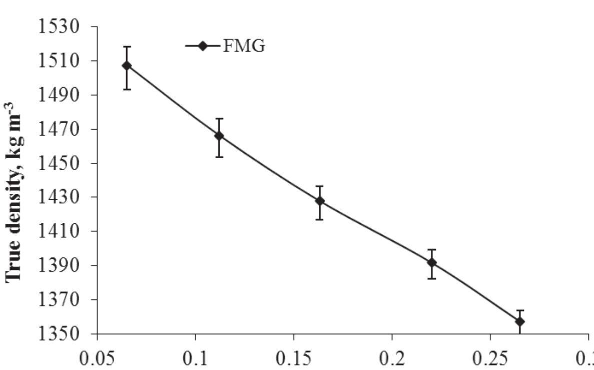

Fig. 11 Effect of moisture content on true density of grain determined by proximate composition method

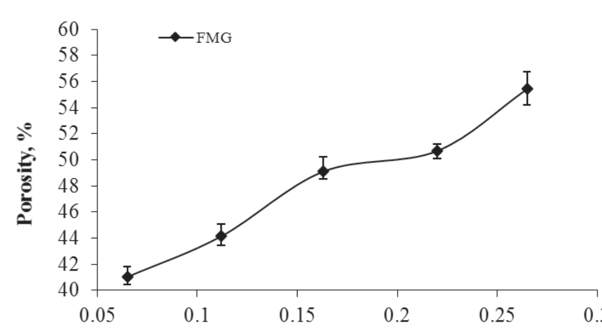

Fig. 12 Effect of moisture content on porosity of grain

Singh *et al.*, 2010 for barnyard millet and Altuntas & Yildiz, 2007 for faba bean.

$Y = -817.71x + 849.26,\ R^2 = 0.9905$ ......(19)

True Density (Toluene Displacement Method)

True density of finger millet grain was found following an increasing trend with increase of moisture content. It was observed increasing from 1336.3 to 1438.9 kg m^{-3} as moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter. It can be observed from **Fig. 10**. The relation between moisture content and bulk density can be expressed by the equation 20. Singh *et al.*, 2010 for barnyard millet, Shafiee *et al.*, 2009 for dragon head seed, Seifi *et al.*, 2010 for corn and Tabatabaeefar, 2003 for wheat also found similar increasing trend with increase of moisture content.

$Y = -2116.3x + 961.18x + 1288,\ R^2 = 0.5179$ ....(20)

True Density (Proximate Composition Method)

True density of finger millet was obtained by taking all the proximate composition of grain at all the moisture content and the result was obtained that increase of moisture content decreased the true density of the grain (**Fig. 11**). When the moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter true density was observed decreased from 1507.55 to 1357.13 kgm^{-3}. The relation between moisture content and true density can be expressed by the equation 21. Singh *et al.*, 2010 found similar decreasing trend with increase of moisture content in case of barnyard millet.

$Y = -738.19x + 1551.9,\ R^2 = 0.9971$ ......(21)

Interstice

Interstices, the intermolecular space of grain was found following a decreased trend with increase of moisture content. Interstice of grain was increased from 0.26 to 0.01 with increasing of moisture content from 0.065 to 0.265 kg kg^{-1} dry matter. Moisture content and interstice relationship can be expressed by the equation 22. Similar result was also found for barnyard millet by Singh *et al.*, 2010.

$Y = 3.4324x^2 - 2.3287x + 0.396,\ R^2 = 0.972$ ....(22)

Porosity

Porosity of finger millet grain was obtained at all the moisture content level within the experimental range and found following a increased trend. It can be observed from the **Fig. 12**. When the moisture content was increased from 0.065 to 0.265 kg kg^{-1} dry matter porosity was found increased from 41.02 to 55.43%. The relationship between porosity and moisture content can be expressed by the regression equation and coefficient of correlation as presented by the equation 23. Seifi *et al.*, 2010 for corn, Gharib-Zahedi *et al.*, 2010 for black cumin, Singh *et al.*, 2010 for barnyard millet, Sezer *et al.*, 2011 for dent corn, Tavakoli *et al.*, 2009 for soyabean grains, Shafiee *et al.*, 2009 for dragon head seeds, Bhise *et al.*, 2014 and Karimi *et al.*, 2009 for wheat also found similar increasing trend of result.

$Y = -16.162x^2 + 74.674x + 36.279,\ R^2 = 0.9761$ ....(23)

Coefficient of Internal Friction

Coefficient of internal friction of finger millet grain was obtained at all the moisture content level within the experimental range and as a result it was observed from the **Fig. 13** that it follows an increasing trend with increase of moisture content. When the moisture content of grain increased from 0.065 to 0.265 kg kg^{-1} dry matter coefficient of internal friction was observed increased from 0.536 to 0.774. The relation between moisture content and coefficient of friction can be expressed by the equation 24. Similar result was also found by Singh *et al.*, 2010 for barnyard millet and Subramanian and Viswanathan for millet grains and flours.

$Y = -1.7422x^2 + 0.5398x + 0.501,\ R^2 = 0.9835$ ....(24)

Terminal Velocity

Terminal velocity of finger millet grain was observed increasing as the moisture content increased within the experimental range. Terminal velocity was increased from 1.22 to 2.02 ms^{-1} with increasing

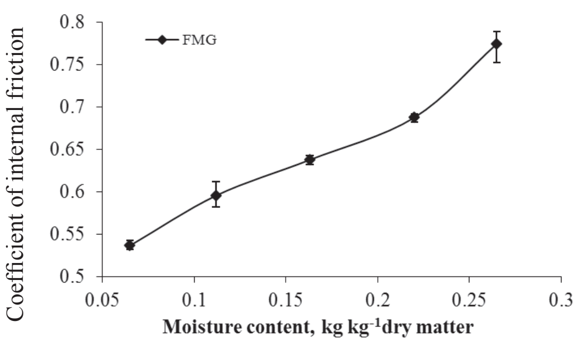

Fig. 13 Effect of moisture content on coefficient of internal friction of grain

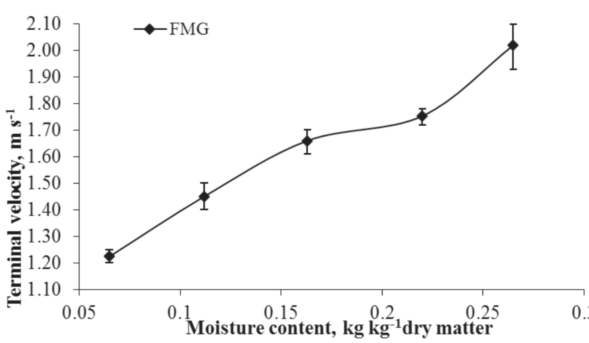

Fig. 14 Effect of moisture content on terminal velocity of grain

of moisture content from 0.065 to 0.265 kg kg^{-1} dry matter (**Fig. 14**). Relationship between the moisture content and terminal velocity of grain can be expressed by the equation 25. Gharib-Zahedi *et al*., 2010 for black cumin, Singh *et al*., 2010 for barnyard millet, Isik & Unal, 2007 for red kidney bean grain also found similar increasing trend of result.

$$Y = -1.6775x^2 + 4.2675x + 0.9715, R^2 = 0.9748 \quad (25)$$

Conclusions

All the physical properties and effect of moisture content on them was studied and some conclusion was drawn that moisture content affects the physical properties of finger millet as the moisture content increased from 0.065 to 0.265 kg kg^{-1} dry matter. Linear dimensions increased with increase of moisture content. Average length, width, thickness, geometric mean diameter were increased from 1.61 to 1.81 mm, 1.58 to 1.84 mm, 1.41 to 1.61 mm and 1.53 to 1.75 mm, respectively. Surface area and volume of grain was found increasing following a linear trend with increasing of moisture content. True density of finger millet was found higher than the bulk density in case of all the moisture content within the moisture content. True density found by proximate composition method was found lower than the true density found by toluene displacement method. Interstice was observed increased with increase of moisture content. Coefficient of friction and terminal velocity increased from 0.536 to 0.774 and 1.22 to 2.02 ms^{-1} as function of moisture content.

Acknowledgement

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An Innovative Versatile Multi-crop Planter for Crop Establishment Using Two-wheel Tractors

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Abstract

A Versatile Multi-crop Planter (VMP) was designed and built for seed and fertilizer application in lines when driven by 2-wheel tractors (2WT) for: single-pass shallow-tillage; strip tillage (ST); zero tillage; bed planting, and conventional tillage (CT). Field performance and operational costs were recorded and analysed in Bangladesh. Field capacity of VMP was 0.07 ha/h for ST which was 34% lower than for CT. Land preparation cost by VMP was decreased by up to 75% for single pass compared to CT. VMP was capable of sowing many crops from small jute seed (2 g/1000 seeds) up to maize (160 g/1000 seeds). The VMP weighs 152 kg and ex-factory price is US$ 1,000. Acceptance of this multipurpose planter by smallholder farmers who prefer two wheel tractors is expected to be high.

Introduction

Small farm sizes restrict the purchase and utility of 4-wheel tractors in many parts of Asia and Africa. The wide range of options for 4-wheel tractor in mechanised planting is not available for 2WT that are a major form of mechanised tillage in S. Asia (Baker *et al*., 2007). In Bangladesh, the 2WT accounted for tillage on 75% of fields in 2001 (Meisner 2001). Mostly these have been used in fully rotary tillage mode to prepare land or puddle wet soils for transplanted rice (*Oryza sativa* L.). The large numbers of 2WT operating in South Asia are evidence of considerable interest amongst small farmers in mechanised tillage. However, repeated full rotary tillage of soil, often practiced more than six times per year, is not favourable to maintenance of soil organic matter (SOM) and soil structure. The rapid developments in minimum tillage planting for CA using 4-wheel tractors have largely by-passed the 2WT (Baker *et al*., 2007). In principle, the same components, tool bars, furrow openers, seed meters, seed box, fertiliser box, etc. can be used on planters for 2WT as for 4-wheel tractors but on a smaller scale with fewer and smaller tool bars, fewer tines and attention to light weight construction. However, the challenge remains to design such planters and demonstrate their effectiveness, reliability, and durability at a price that allows ready adoption in the target market.

The developments in 2WT-operated minimum tillage planters are reported in Haque *et al.* (2013). Despite these promising developments, none of the present planters for 2WT are capable of planting in all modes of tillage. In diverse, intensive cropping systems such as in the Eastern Gangetic Plain, two or more planters are presently needed to carry out the range of minimum tillage and conventional tillage operations. Hence service providers are reluctant to purchase a planter that can only be used for a narrow selection of crops at a particular time of the year. The challenge is to design a multi-function planter capable of handling many crops and planting methods etc. In the present paper we describe the design, construction and operation of such a planter, called the VMP. The VMP meets the above criteria and has successfully established a diverse range of crops in Bangladesh (Haque *et al.*, 2010).

Materials and Methods

The VMP was powered by a Dongfeng or Saifeng 12 - 16 horsepower 2WT but could be used with any 2WT with similar power rating. The Dongfeng or Saifeng 2WT have different but suitable hitching points to attach with the VMP. The appropriate planter hitching needs to be used with the particular type of 2WT. The VMP was designed with capability for seeding and fertilizing with fluted roller or vertical plate meters in lines for: 1) Single-pass shallow-tillage (SPST); 2) strip tillage (ST); 3) zero tillage (ZT); 4) bed planting (BP) (for single-pass new bed-making or re-shaping of permanent beds and simultaneous planting and fertilizer application); and 5) conventional tillage (CT) using full rotary tillage following broadcast seeding and fertiliser spreading.

The rotary shaft is operated by the 2WT at 250 or 375 rpm through a chain and gear mechanism. The power transmission chain box is located on the right side of the planter with 14 teeth on the upper sprocket attached to the drive shaft and 13 teeth on the lower sprocket attached to the rotary shaft. Rotary shaft and blades are covered by a metal sheet fitted with a clearance of 240 mm

1: Seed box, 2: Fertilizer box, 3: Seed delivery tube, 4: Toolbar frame
5: Fertilizer delivery tube, 6: Depth contoroller, 7: Press roller, 8: Furrow opener

Fig. 1 Versatile Multi-crop Planter attached (marked in dash line) to 2WT in strip tillage mode

from the shaft. The net weight of VMP is 152 kg and its overall dimensions are length 990 mm, width 1220 mm, and height 840 mm (**Fig. 1**). The VMP is mounted on a 700 mm toolbar attached through side arms and connecting rods to the main handle of the 2WT. Seed and fertiliser boxes are mounted on the toolbar, as the cover of the rotary shaft. This allows for seeding and fertilizing in four adjustable lines if row spacing is 200 mm, down to a single row in case of maize sown in 600-700 mm rows. The seed box is fitted with four seed meters. Either fluted roller or vertical plate seed meters can be fitted depending on the level of precision in seed placement required. Seed rate can be adjusted by sprocket size in the case of vertical plate meters. Sprocket sizes range from 10-40 teeth giving 5 settings for seed rate and seed size. For the fluted seed meter, seed rate is varied by adjusting the length of the flutes by a handle. By fitting seed meters with 4, 8, or 16 flutes, delivery of different-sized seed can be regulated. The fertiliser box is made from the same iron sheet and has the same external dimensions as the seed box. The fertiliser box is fitted with four fluted meters with eight or four flutes.

Seed meters are attached to a shaft and fertiliser meters to a separate shaft. The power for the fertiliser meters comes from the 2WT differential shaft, through a chain driven by a 19-teeth sprocket and is relayed to the seed meter shaft through a chain and sprocket. The furrow openers are each attached on the toolbar by two U-clamps along with bolts and plate. Seed and fertiliser delivery tubes made of 27 mm diameter clear polypropylene pipe join behind the furrow opener. A pressing roller 670 mm long with 127 mm diameter (**Fig. 1**) is attached behind the furrow openers by a pair of arms 560 mm long. The photographs illustrating the VMP (**Fig. 1**) are for the 4th version. Subsequent versions involved changes to seed metering so externally the later generations have the same appearance as shown. The reasons for changes made to earlier generations are outlined below in results.

Data Collection

Seed calibration

Seed rate was calibrated over a 20 m travel distance with an 800 mm sowing width. This procedure was used to calibrate the VMP for a range of species (**Table 1**) before planting in the fields. Data on labour requirement, operational time, time loss, and field capacity were recorded during the field operation. The time losses due to turning, clogging and operators' personal needs were also recorded. Field capacity was determined using the formulae of Hunt (1973).

Field trials with lentil, chickpea, mung bean, black gram, maize, and direct seeded rice

The field trials with lentil, chickpea, mung bean, and black gram were established at the High Barind Tract, Rajshahi; and the maize and direct-seeded monsoon rice were established at the Bangladesh Sugarcane Research Institute, Gazipur, Bangladesh. The treatments were arranged in a randomized complete block (RCB) design with three replications. Treatments for the trials of lentil, chickpea, mung bean, and black gram were i) CT, ii) SPST, iii) ZT, iv) ST, and v) BP. In the case of maize trial, the treatments were i) VMP with vertical disk seed meter in SPST planting mode, ii) Earthway planter in soils that had been tilled four times, and iii) hand planted in soils that had been tilled four times. Two tillage treatments i) SPST and ii) ZT were used in the case of the direct-seeded rice trial. Data on operational capacity of the seed box and coverage per full seed box of different species; plant population/m^2; fuel consumption, field capacity, labour requirement, cost of land preparation and seeding, etc. were collected from trials of lentil, chickpea, mung bean, and black gram; and spacing between adjacent maize plants and rice hills, etc. was determined. Data were analysed statistically using one-way analysis of variance (ANOVA) with MSTAT-C. Means were compared with least significant difference (LSD) test at $P < 0.05$.

Results

The following results are based on 4th and 6th versions of VMP. After version 4, changes focussed on seed metering improvements. Version 6 replaced fluted rollers with vertical plate seed meters.

Blade Arrangement for Different Tillage Operations

By contrast with the standard rotary tiller that has blades bolted at fixed positions; the VMP has flexible blade positioning. This was achieved by replacing the round shaft with a square shaft and then designing brackets that can be flexibly re-positioned across the shaft while holding two or four blades each. The sliding of the bracket sideways without blade removal enables row spacing to be adjusted quickly in the field according the crop requirements. The previous rotary shaft had to be dissembled in a workshop if the row spacing was to be changed. Hence the square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis. For SPST planting, 32 blades are attached on eight brackets (**Fig. 1**), evenly spread across the shaft. Blades alternate between left and right twist. For ST, one bracket containing 2-4 blades is retained for each furrow opener. Blade size with either straight or twisted shape provided strip tillage to 140 mm depth and 100 mm width. Settings for bed shaping involve a decrease in the wheel-base from 740 to 600 mm (centre-to-centre) by flipping each wheel around and re-bolting to the axle. The centre line of the wheel is then aligned with both the outer blade and the outer edge of the cones used to shape beds. For newly-formed beds, blades are arranged with longer blades (230 mm) on the outer six brackets (holding 24 blades altogether) and with a twist that throws soil towards the centre of the bed. Shorter blades (155 mm) with alternate left and right twist are fitted to the two central brackets. For re-shaping of old beds, only

Table 1 The operating capacity of the seed box and coverage per full seed box of the VMP when used to sow a range of species with different seed sizes and seed rates

Species	Seed size (g/1000 seed)	Seed rates (kg/ha)	Carrying capacity of full seed box (kg)	Planted area per full seed box (ha)
Maize	160	18	21	1.17
Chickpea	138	34	20	0.67
Wheat	52	120	18	0.15
Mung bean	45	40	20	0.59
Lentil	20	34	22	0.65
Rice	18	30	15	0.67
Mustard[a] (*Brassica spp.*)	3.7	8	17	2.13
Sesame[a] (*Sesamum indicum.*)	2.7	6	14	2.27
Jute[a] (*Corchorus capsularis*)	2	5.5	17	3.05

[a] Rice husk at a 1:1 ratio was added with small seed to increase the volume for sowing using the fluted meter.

the two or three outer brackets on each side of the rotary shaft retain the long blades, while all blades on the three or four inner brackets may be retained. If there is little residue or weeds on the beds, only the longer outer blades need to be fitted to throw soil from the furrow on to the bed to re-shape it. The VMP can be operated in ZT mode with blades retained to clear some residue, but the furrow openers need to be set deep enough to ensure sufficient clearance of the blades above the soil and residue.

Seed Metering

Several types of seed metering device have been tested leading to the vertical plate device in the 6th version VMP. The vertical plate is modelled on the Earthway Garden Planter (from USA). It is made from moulded plastic in 5 different aperture sizes to accommodate seed sizes from 2 to 160 g seeds/1000 (**Table 1**). However, if continuous seed dropping is preferred, the fluted rollers are satisfactory and cheaper. Among tillage treatments, no significant difference was observed in the case of lentil and chickpea emergence after seed metering using the fluted roller; however, significant improvements were observed for emergence of mung bean and black gram compared to CT (**Table 2**).

Field Operation and Costs

Field capacities of CT, SPST, ST, ZT and BP were 0.11, 0.07, 0.07, 0.06 and 0.05 ha/h, respectively (**Table 3**). Field capacity of CT was higher (0.11 ha/h) since broadcast seeding did not require precision seed alignment like row planting. Fuel consumption was higher with CT (33.1 l/ha) and lowest in ST (5.83 l/ha) by VMP (**Table 3**). The SPST, ST, ZT and BP by VMP saved 38, 82, 50 and 13% diesel fuel over CT. The maximum cost (US$ 41.47/ha) of land preparation and seeding was incurred in case of CT system and the lowest (US$ 10.27/ha) for ST systems (**Table 3**). Compared to CT, planting by SPST, ST, ZT, and BP systems lowered costs by 52, 75, 23, and 13%, respectively (**Table 3**).

Table 2 Plant populations (plants/m^2) established using the fluted type seed meter on the VMP for lentil, chickpea, mung bean and black gram sowing in CT, SPST, ZT, ST, and BP at the High Barind Tract, Rajshahi, Bangladesh.

Crop	CT	SPST	ZT	ST	BP	CV, %	Significance
Lentil	25	100	178	171	-	59.9	NS
Chickpea	56	55	47	57	31	24.7	NS
Mung bean	27c	145ab	121b	209a	101b	20.5	**
Black gram	22b	-	99a	93a	52ab	29.6	**

Values in a row, followed by a common letter are not significantly different at P < 0.01 by Duncan's Multiple Range Test.

Table 3 Effect of tillage mode by the Versatile Multi-crop Planter on fuel consumption, field capacity, labour requirement and cost of land preparation and seeding of lentil, chickpea, mung bean and black gram in clay soil at High Barind Tract, Rajshahi, Bangladesh, 2010-11.

Tillage type	Field capacity (ha/h)	Fuel consumption (l/ha)	Labour requirement, (person-h/ha)	Cost of land preparation and seeding[a], (US$/ha)
Conventional tillage	0.11a	33.1a	48.1a	41.5a
Single pass shallow tillage	0.07b	20.6c (38)	15.4c (68)	19.8d (52)
Strip tillage	0.07b	5.83e (82)	15.3c (68)	10.3d (75)
Zero tillage	0.06b	16.6d (50)	17.3c (64)	18.1c (23)
Bed planting	0.05b	28.9b (13)	23.9b (51)	28.8b (13)
CV, %	31.9	30.8	45.4	26
Significance	**	**	**	**

Values in the parenthesis indicate the percent saving over CT.
Values in a column, followed by a common letter are not significantly different at P < 0.01 by Duncan's Multiple Range Test.
[a]Considering variable costs for labour (land preparation @Taka 30 and seeding @ Taka 20/ha); diesel fuel (@Taka 45/l). 1 US$ = 68 Taka

Planting Options, Methods, Species, and Seed Rate

Seeding has been tested for the different crops, in order of increasing seed size: jute, sesame, mustard, lentil, mung bean, rice, wheat, black gram, chickpea and maize. The vertical plate seed meter with VMP was evaluated when planting by ZT and SPST systems to sow direct-seeded monsoon rice. In the case of SPST by VMP about 78% of rice plants were spaced between 160 and 250 mm apart (mean 187; SE ± 7.6 mm) in a single-pass operation. The establishment of plants by ZT planting with the VMP achieved 70% at 160-250 mm apart (mean 170; SE ± 8.7 mm). With vertical plate seed meter in VMP, about 96% of maize plants were placed 180 to 260 mm apart (mean 205 mm; SE ± 3.9 mm) with a single-pass operation. The spacing between plants was less even (mean 231 mm; SE ± 6.7 mm) in the case of maize planted by hand in well-prepared land after four tillage operations. However, the maize planted by Earthway planter performed slightly better (mean 215 mm; SE ± 2.3 mm) compared to the vertical plate seed meter of VMP. The vertical plate seed meter has a tendency to drop more seed at <170 mm spacing than the Earthway Planter.

Discussion

The 6th version of VMP ex-factory price is ~US$ 1,000 per unit. Further reductions in cost are possible with increased scale of production. Moreover, if continuous seeding rather than spaced planting is acceptable, a further reduction in price to US$ 600 could be achieved by fitting only fluted rollers rather than the vertical plate seed meter. The VMP is fully fabricated in Bangladesh. Three manufacturers have begun production, commercialisation and scale-up. To date a total of more than 120 units have been sold including 40 to international buyers in India, Mexico, Uganda, Ethiopia, Tanzania, Zimbabwe and Vietnam. With the VMP, an operator can adjust row spacing using a spanner in the field. In two seasons of planting, contractors have sown 132 ha comprising nine crop species. No serious concerns about planter performance, operation or reliability have been identified. The multi-functional, multi-crop capabilities of VMP allow it to be used all year round in intensive crop rotations. In the dry season, planting of rainfed and irrigated crops has been accomplished on alluvial soil as well as the hard-setting High Barind Tract soil (Haque *et al*., 2010). In the early wet season, mung bean, black gram and direct seeded rice have been planted successfully. The VMP shaped permanent beds and is able to re-shape beds for each crop in a rotation. The flexibility of VMP and adaptability for a range of crops and planting methods means that service providers can feasibly make a year-round business from hiring a VMP for planting farmers' crops. Miah *et al*. (2010) reported that using of the 2WT-mounted Chinese planter in SPST mode was highly profitable as a business for service providers with the capacity of year-round operation. A similar business model should be applicable to the VMP.

Clear gains in fuel efficiency were obtained with the VMP, but essentially all the single-pass modes of planting were fuel-saving compared to CT. The field capacity of 0.07 ha/h for ST was comparable to rates with the SPST planter (Hossain *et al*., 2005). Hence in a single day's operation about 1 ha can be planted by the VMP in ST and SPST modes. Erenstein & Laxmi, (2008) reported the net benefit of ZT over CT averages US$ 97/ha across the Indo-Gangetic Plains with the contribution from the cost saving effect (53%) being slightly higher than the yield improvement (47%). The present study with 2WT and VMP reported that the ZT cost saving effect averages US$ 52/ha across the experiments and crops. Brief results in the present paper show similar or greater plant populations of chickpea and mung bean established using VMP in single pass planting (ST, ZT, and BP) using a fluted roller seed metering compared to CT.

China (10 million), Thailand (3 million), Bangladesh (0.45 million) and Sri Lanka (0.12 million) have the highest usage of 2WT (Anonymous, 2011). Parts of Africa have begun importing Chinese tractors and Nigeria may have close to 1,000. Southern Germany, northern and southern Italy, and many countries of central Europe also have significant numbers of 2WT (Anonymous, 2011). Hence the potential for application of minimum tillage planters with these 2WTs is extensive. Planters such as VMP could be used to develop CA practices across a wide range of cropping systems used by smallholder farmers in Asia and Africa (Johansen *et al*., 2012).

Conclusion

The VMP is a unique multi-functional and multi-crop planter powered by 12-16 hp 2WT with capability for seed and fertilizer application in variable row spacing using SPST, ST, ZT, BP, and CT. The square shaft and brackets designed for the VMP achieve improved flexibility for multi-crop planting and capacity for rapid adjustment of row spacing on a field-by-field basis. By using the VMP, the establishment costs for various crops in different tillage systems were significantly reduced compared to CT. Planters such as VMP could be used to develop CA practices across a wide range of cropping systems used by smallholder farmers in Asia, Africa and other regions.

Acknowledgements

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(Continued on page 44)

Development of Pneumatic Assisted Electronically Controlled Automatic Custard Apple Pulper

by

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Abstract

Custard apple (*Annona squamosa* Z,.), popularly known "sitaphal" in India is a most delicious and favourite fruit of the tropics. Extraction of pulp is a major constraint in processing of custard apple fruits. An automatic custard apple pulper was developed with the capacity of 100-120 kg/h. The machine comprises of three main mechanisms viz. fruit cutting mechanism, fruit scooping mechanism and pulping mechanism. Performance evaluation of the developed custard apple pulper machine was done with different pulping shaft speeds (100, 300, 500, 600 and 800 rpm), different pulping chamber inclination (19°, 23°, 27° and 29°) with two types of beater along with 3 type of pulping sieve. The higher amount of coarse pulp recovery has been observed with inclined slotted sieve with the shaft speed of 600 rpm along with 29° pulping chamber inclination.

Fig. 1 Custard Apple Fruits

Introduction

The world is presently over-dependent on a few plant species. Through many underutilized food crops prevail throughout the world, production and consumption of most of the underutilized food crops are dominant in South East Asia and Africa. Diversification on production and consumption habits, In particular those currently identified underutilized crops, can contribute significantly to improve nutrition and health, livelihoods, house hold food security and ecological sustainability, therefore have an important role in supporting social diversity.

The International Centre for Under-utilized Crops listed some of the fruits crops as underutilized crops at global level and identified limiting factor for those crops. Some of the identified major limiting factors are limited post-harvest knowledge for harvesting, handling and transporting techniques. (Dainiel, J. N. and Dudhode, P. A. 2007) Among the identified underutilized fruit crops, Custard apple (**Fig. 1**), Aonla and Ber are gaining commercial interest due to its nutritional value, medicinal properties and the suitability for processing into a wide range of products.

Custard apple (*Annona squamosa* Z,.), popularly known "sitaphal" in India is a most delicious and favourite fruit of the tropics. Custard apple is cultivated in more than one lakh hectares in India (Chahal *et al*. 2008). In fact custard apple fruits are collected from either wild plantation or from orchards which hardly receive any care. Majority of the custard apple today is as wild plantations in tribal areas. The fruit trees not only produce protective food but also provide assured income for livelihood in the drought prone dry lands since it is drought tolerant and it grows well with low rainfall. However, lack of efficient processing techniques and non-popularity of processed products from custard apple leads to huge wastage of produced mass.

Custard apple is one of the delicious fruits relished by many for table purposes in India. Pleasant flavour, mild aroma and sweet taste have a universal acceptance. Despite being fruit of choice, due to the large number of seeds, poor shelf life and lack of processing technology, custard apple is not cultivated in large commercial orchards. Moreover it is very perishable and have a very short post-harvest life; therefore they require efficient storage techniques (Coronel, 1994). Ripe fruits can be kept at room temperature for one day only (Salunkhe and Desai, 1984), while immature fruits stored below 15°C develop chilling injury, resulting in an unpleasant appearance (Tsay and Wu, 1989). It is observed that more than 75% of fruits produced in tribal areas go waste after harvesting due to inefficient storage techniques and short shelf life of fruits (Chahal *et al.* 2008). Further, there is no organized marketing for custard apple in India. These factors lead to huge economic losses to the arid and semi-arid region tribal farmers.

Attempts to enhance the post-harvest life of these fruits must take into account ripening physiology, physical chemical aspects of fruit quality, harvest and post-harvest handling. Custard apple fruits can be stored at 15 to 20°C with low oxygen and ethylene tensions, combined with 10% $C0_2$ and 85 to 90% RH (Broughton and Tan, 1979).

Custard apple fruits can be processed and used in the preparation of nectars, drinks, sherbets, ice-cream, syrup etc. Development of enzymatic browning within an hour of pulp extraction, bitterness, unpleasant repulsive off-flavour in the pulp on heating beyond 65°C and presence of gritty cells are problems encountered during processing of fruits.

Extraction of pulp is a major constraint in processing of custard apple fruits. Manual pulp extraction has been tried which leads to browning in short time. Pulpers are available in the market suitable for extraction of juice/pulp from citrus fruits, mango, guava etc. There is no pulping machine exists that can be used to safely remove the pulp specifically from the custard apple (Chahal *et al.* 2008).

Under this scenario of custard apple typically in India need to be considered for research and development particularly in handling and processing to improve the socio-economic condition of the arid and tribal farmers. With this purview the main objective of this study was to develop a custard apple pulper which would be suitable for small and medium scale processing.

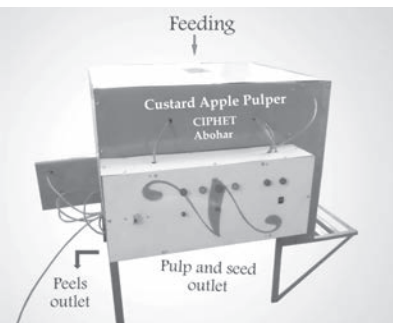


Fig. 2 Custard Apple Pulper

Material and Method

The underutilized fruits are being underutilized till today because of lack of handling and processing machineries. So-far very few researchers reported about handling machineries for underutilized fruits. Eyarkai nambi *et al.* (2012a), reported about an automatic machine for removing the seeds continuously from the aonla fruits. In literatures, the reports about the handling and processing machines for custard apple are merely nil.

Based on the previous empirical knowledge and preliminary laboratory trails, a prototype machine (**Fig. 2**) was developed at Central Institute of Post Harvest Engineering and Technology (CIPHET), Abohar. In order to completely mechanize the handling and processing of custard apple fruits, the whole process were divided into three main unit operations viz. Cutting the fruit, peel separation and pulp & seed separations. Then each operations were addressed to develop a mechanism and the machine parameters were optimized. Some of the machine parameters like pulping chamber inclination, speed of the pulping shaft and the type of the beater were affected the pulping efficiency of custard apple pulping machine (Eyarkai nambi *et al.* 2012b).

Based on the selected unit operation, the whole machine were divided into 3 main parts, these are fruit cutting mechanism, fruit scooping mechanism and pulping mechanism. Fruit cutting and scooping mechanism were made with pneumatic actuators and electronic controls. This invention is fully automatic machine, assisted with pneumatic power and electronic controllers. The detail dimensions were not given with this paper, since this machine has been filed for grant of patent under Indian IPR.

Fruit Cutting Mechanism

This part contains two opposite rotating rollers with fruit holding cups (**Fig. 3**). The fruit holding cups are arranged in a way that the fruit is held and guided without any damage while cutting and falling over the guide plate, which is provided below the cutting mechanism. The cutting knife is attached with pneumatic actuator (25 mm diameter and 100 mm displacement) along with

24V DC solenoid valve with electronic controller which provide cyclic ON/OFF commands to the valve thus lead to reciprocal motion of knife continuously. The guide plate helps the two halves of fruit to fall downwardly (cut face at bottom).

Fruit Scooping Mechanism

Fruit Scooping Mechanism has three parts viz. peel holding sieve, pressing mechanism and scooping mechanism. The peel holding sieve was fabricated with SS rod. In order to optimize the clearance between the rods three clearance were tested. The front side of the sieve platform were made in such a way for easy removal of peels. The whole sieve is fixed in a movable frame which contains fruit pushing hand. The whole frame is operated by a pneumatic actuator (25 mm diameter and 300 mm displacement) with 24V DC solenoid valve. Pressing plate (SS) is provided vertically and it presses the two halves of fruits over the sieve from the top with the help of pneumatic actuator (25 mm diameter and 150 mm displacement) along with 24V DC solenoid valve. Scooping part contains a SS scooping blade and a pneumatic actuator (25 mm diameter and 300 mm displacement) along with 24V DC solenoid valve. The scooping blade was made in such a way that the knife was well fitted with sieve in order to maximize the pulp separation from the peels. The schematic diagram of fruit cutting and scooping mechanism is given in **Fig. 3**.

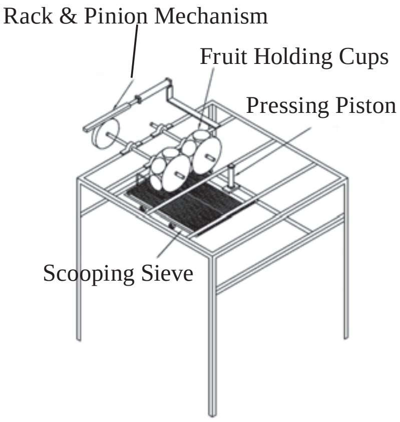


Fig. 3 Schematic diagram of Fruit cutting and scooping mechanism

Pulping Mechanism

The pulping mechanism (**Fig. 4**) has feed hopper, pulping chamber with pulping sieve and pulping beater, pulp separator, seed outlet and electric motor. All these parts have been made as detachable with food grade stainless steel. The frame of the machine has been designed and fabricated with height adjustment to increase or decrease the slope of the pulping chamber. A motor with variable speed control has been used to test the machine with variable speed. Three types of pulping sieves (**Fig. 5**) have been made with different perforations. Two types of beater (**Fig. 6**) with variable dimensions were made.

Electronic Control Unit

An electronic control unit was developed to control and operate the cutting and scooping mechanism in a synchronized manner. All the sequence of operations are controlled through solenoid valves with the help of integrated circuits and timer relay circuits.

Experimental Design

The machine has been tested for its performance with various machine parameters. The pulping mechanism were evaluated with three types of sieve at different pulping shaft speed, in different pulping chamber inclination with two types of beater and with three type of pulping sieve. Each run in pulping mechanism has been tested with three kg of scooped pulp. The pulping time were kept as constant (2 min.) The parameters like amount of pulp along with the peel, amount of peel in pulp, quantity of coarse pulp recovery and amount of fine pulp from the pulp outlet and pulp wastage from seed outlet were recorded. The collected data were analyzed for its significance using ANOVA with full factorial design. The statistical analysis and graphi-

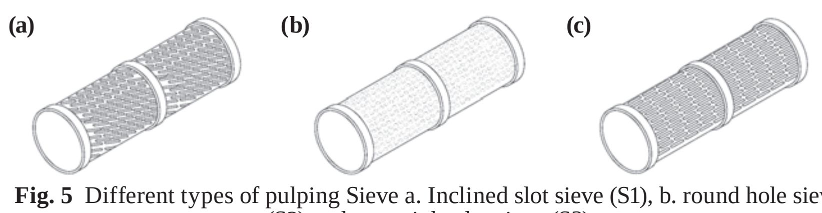


Fig. 5 Different types of pulping Sieve a. Inclined slot sieve (S1), b. round hole sieve (S2) and c. straight slot sieve (S3)

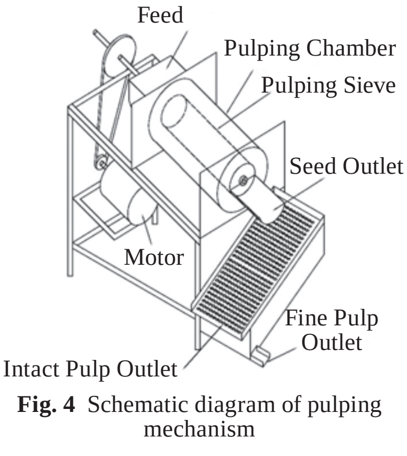


Fig. 4 Schematic diagram of pulping mechanism

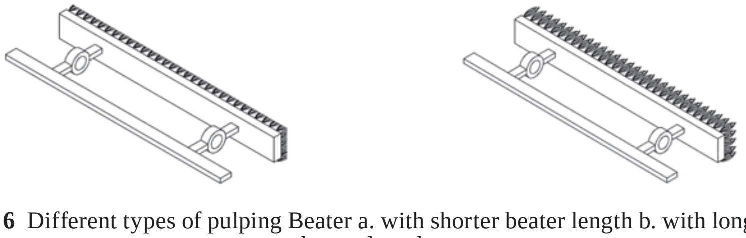


Fig. 6 Different types of pulping Beater a. with shorter beater length b. with longer beater length

cal representations were done using JMP software package.

Results and Discussion

The machine has been taken to Maharana Pratap Agricultural University, Udaipur for testing. Based on the experimental full factorial design, the machine was evaluated.

Performance Evaluation of Cutting and Scooping Mechanism

The whole fruits were fed directly on the feed hopper. The cutting mechanism had worked as desired. In order to optimize the scooping mechanism, the peel holding sieve were tested with three clearances (10 mm, 12.5 mm & 15mm). This range was fixed based on the preliminary study about the geometrical properties of the seeds and peels. The amount of peels in pulp outlet and the amount of pulp in peel outlet were measured. The observed data were plotted and given in **Fig. 7**.

Our aim was to get lower pulp wastage along with peels and to get lower the peel mixture in the pulp outlet. From the **Fig. 7**, it could be concluded that 12.5 mm clearance has given the optimum condition with low pulp wastage and peel mixture.

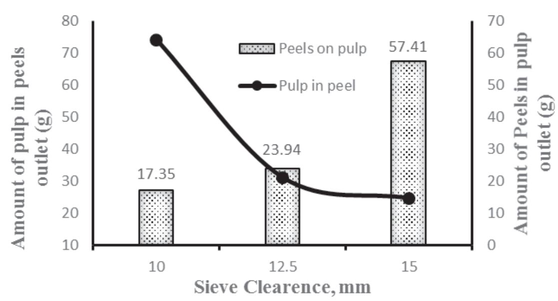


Fig. 7 Effect of sieve clearance on amount of pulp in peel and amount peel in pulp

Performance Evaluation of Pulping Mechanism

The pulping mechanisms were tested based on the full factorial design. The mechanism was evaluated with three main dependent variables viz. quantity of coarse pulp recovery, amount of fine pulp in pulp outlet and amount of pulp in seed outlet. Amount of seeds in pulp outlet was avoided as a dependent variable, because very negligible quantity were observed in preliminary trials. The seed damage was almost nil in all the cases. Due to the commercial value for the coarse pulp is higher than the fine pulp, our interest was to get higher amount of coarse pulp rather than fine pulp. The collected data were analyzed for its significance using ANOVA and the consolidated ANOVA Table with 3 level interaction is given in **Table 1**. Among the machine parameter, the type of sieve, speed of the pulping shaft and the inclination of the pulping chamber were observed as highly significant on pulping process whereas type of beater was non- significant over the pulping process (**Table 1**).

Table 1 Consolidated ANOVA table with 3 factor interaction

Source	Sig.(p-value)		
	Amount of fine pulp	Amount of coarse pulp	Amount of pulp in seed outlet
Corrected Model	0.000**	0.000**	0.000**
Intercept	0.000**	0.000**	0.000**
Sieve	0.000**	0.000**	0.000**
Beater	0.155	0.042*	0.022*
Speed	0.000**	0.000**	0.000**
Inclination	0.000**	0.000**	0.000**
Beater × Inclination	0.101	0.003**	0.178
Sieve × Beater	0.338	0.062	0.097
Beater × Speed	0.217	0.17	0.309
Sieve × Inclination	0.051	0.000**	0.183
Speed × Inclination	0.000**	0.016*	0.000**
Sieve × Speed	0.002**	0.002**	0.013*
Sieve × Beater × Inclination	0.739	0.005**	0.247
Beater × Speed × Inclination	0.021*	0.731	0.291
Sieve × Beater × Speed	0.342	0.335	0.212
Sieve × Speed × Inclination	0.591	0.015*	0.134

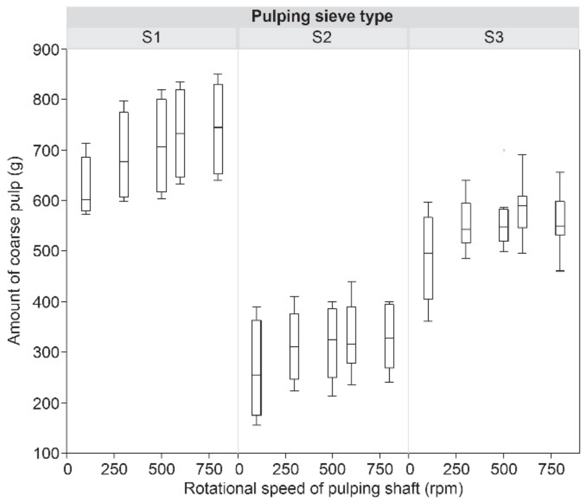
**significant at 99%
* significant at 95%

Effect of Machine Parameters on Pulping

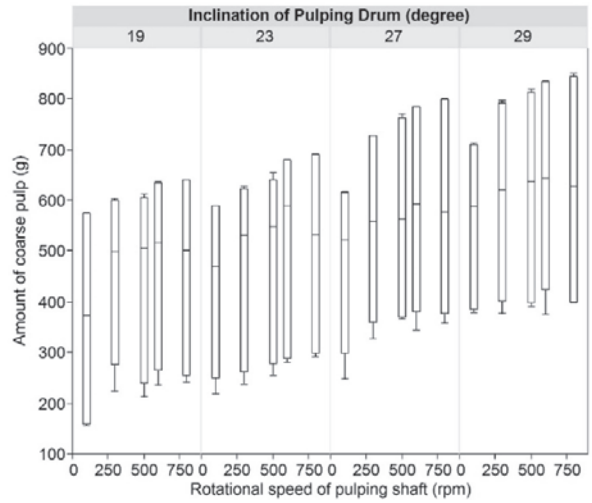
The speed of the pulping shaft has been fixed in 5 limits of 100, 300, 500, 600 and 800 rpm and tested with the three different sieve types. The interaction effect between the pulping shaft speed and type of sieve on pulping process were shown as box plot in **Fig 8**. It was observed that the quantity of coarse pulp was increasing with increase in shaft speed. At the same time, the quantity of pulp in seed outlet were decreasing with increase in shaft speed. Among the different type of sieve, sieve S1 had shown higher coarse pulp recovery rather than S2 and S3. The sieve S2 had shown higher fine pulp recovery than sieve S1 and S3. From the **Fig. 8** it can be observed that there is a clear sweep of sieve S1 over sieve S2&S3 in terms of coarse pulp recovery. No significant difference was observed between the pulping shaft speed of 600 and 800 rpm in case of coarse pulp recovery.

The pulping chamber inclination has been fixed in 4 levels viz. 190, 230, 270 and 290. The interaction effect between the pulping shaft speed and pulping chamber inclination on pulping process were shown

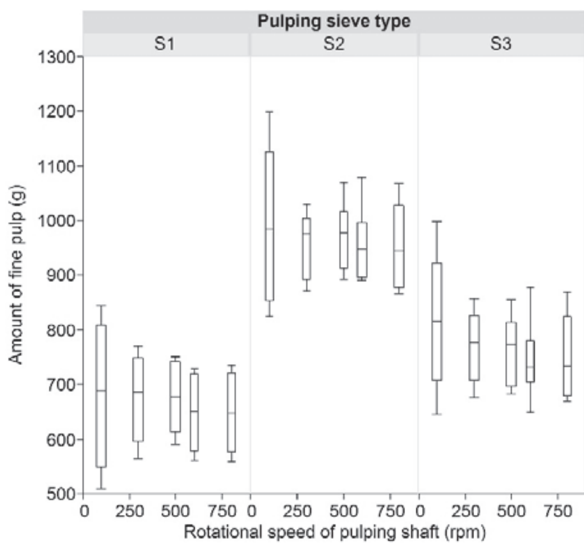
a)



a)



b)



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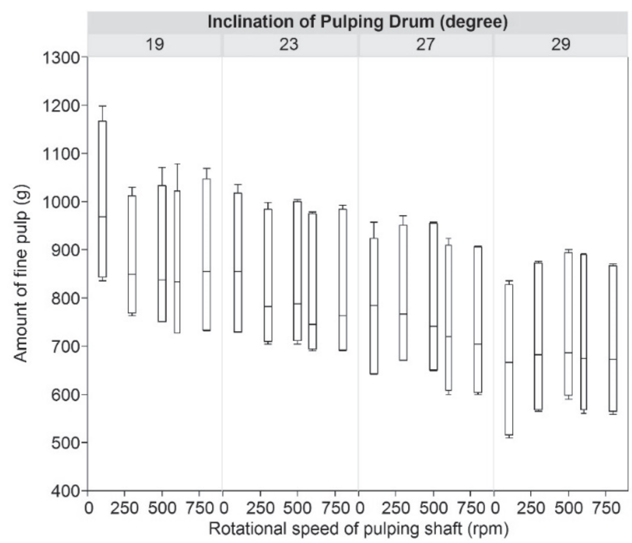

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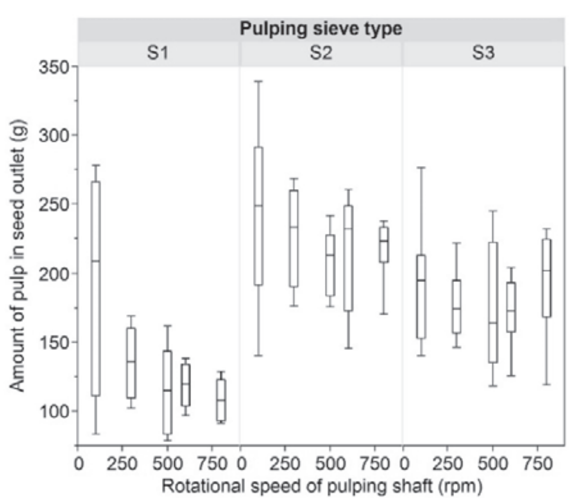


Fig. 8 Effect of pulping shaft speed and sieve type on a) amount of coarse pulp in pulp outlet, b) amount of fine pulp in pulp outlet, c) amount of pulp in seed outlet

c)

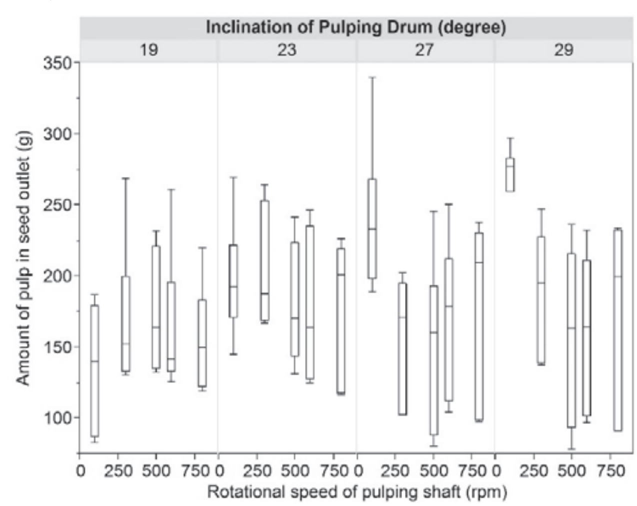
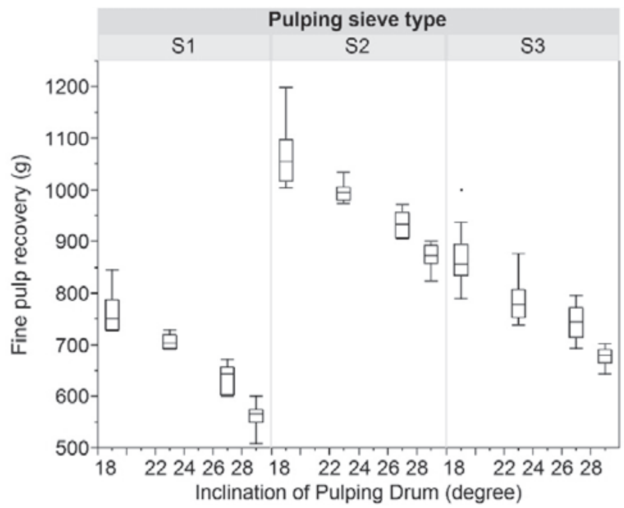


Fig. 9 Effect of pulping shaft speed and pulping chamber on a) amount of coarse pulp in pulp outlet, b) amount of fine pulp in pulp outlet, c) amount of pulp in seed outlet

a)



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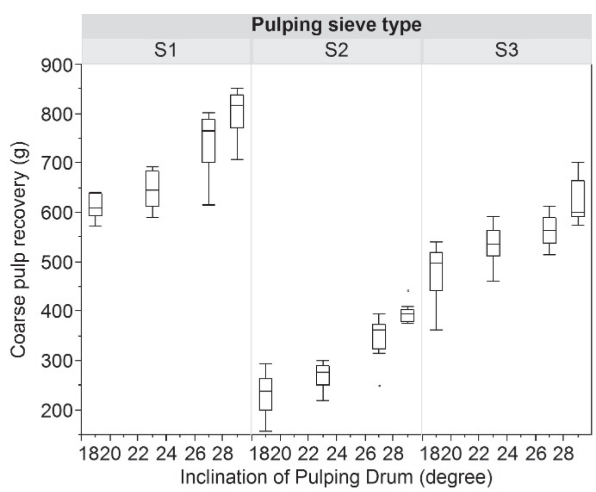

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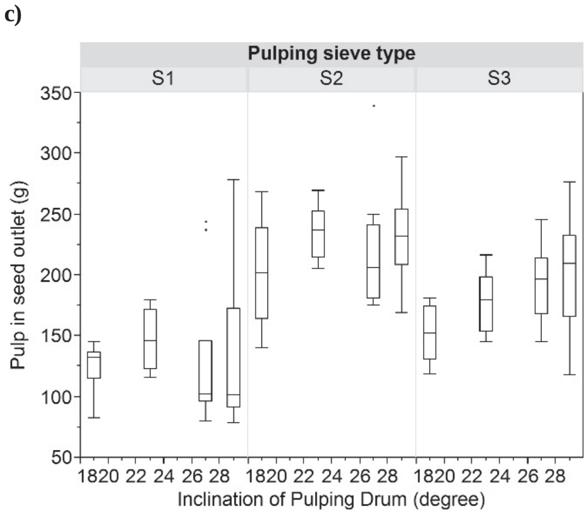

Fig. 10 Effect of sieve type and pulping chamber on a) amount of coarse pulp in pulp outlet, b) amount of fine pulp in pulp outlet, c) amount of pulp in seed outlet

as box plot in **Fig 9**. An increasing trend were observed in coarse pulp recovery with increase in chamber inclination. Higher coarse pulp recovery and lower fine pulp recover were found at 290 inclination. The amount of pulp in seed outlet was almost similar for the pulping chamber inclination 270 and 290. The interaction effect between the sieve type and pulping chamber inclination on pulping were shown as box plot in **Fig. 10**. From the **Fig. 10**, it can be concluded that the higher coarse pulp recovery with lower fine pulp and less pulp in seed outlet were found with sieve S1 along with higher pulping chamber inclination. Since the beater type had not shown the significant effect on pulping (**Table 1**), the box plot was not plotted for the beater type.

Optimization of Machine Parameters

Based on the full factorial analysis, the sieve S1(inclined slotted) with the pulping chamber inclination of 290 along with the pulping shaft speed of 600 rpm had given the best optimum results. Further increase in the inclination (more than 290) may lead to more pulp wastage in seed outlet. Same way the higher speed of the pulping shaft may not be useful in case of coarse pulp recovery. Fine pulp is needed for the preparation of processed beverages, for that sieve type S2 along with all other optimized machine parameters would be useful. Lower the perforation size may increase the yield of fine pulp. With these optimized condition, the capacity of the machine was calculated as 100-120kg/hr. The calculated intact pulp recovery was 80-82% and the rest were fine pulp.

Conclusion

An automatic custard apple pulper was developed with the capacity of 100-120kg/h. The machine comprises of three main mechanisms viz. fruit cutting mechanism, fruit scooping mechanism and pulping mechanism. Performance evaluation of the developed custard apple pulper machine was done with 5 different pulping shaft speeds, 4 different pulping chamber inclination with two types of beater along with 3 type of pulping sieve. The higher amount of coarse pulp recovery has been observed with inclined slotted sieve with the shaft speed of 600 rpm along with 290 pulping chamber inclination. The calculated intact pulp recovery was 80-82% and the rest were fine pulp.

Acknowledgement

National Agricultural Innovation Project (NAIP), Indian Council of Agricultural Research (ICAR) for funding the subproject entitled ‘‘A Value Chain on Commercial Exploitation of Underutilized Fruits of Tribal Zones of Rajasthan’’

Intellectual Property Right(IPR)

The entire machine with the process were filed for the grant of patent in Indian (3050/DEL/2011)

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Design, Development and Evaluation of Neem Depulper

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Abstract

Neem (*Azadirachtaindica A Juss*) is one of the most suitable and valuable tree species found in India. There are about 20 million neem trees in India. A neem tree starts fruiting in 3 to 5 years and can produce 30 to 50 kg fruits/year. To harness the natural resource, a hand operated axial-flow neem depulper was designed, developedand evaluated to meet demand of neem seeds and its products. Using standard mechanical design procedures, an axial-flow hand operated neem depulper was developed. The optimized parameters of this machine is 3 days soaking period of neem fruit, 20 h^{-1} water flow rate, 18 × 5mm sieve size, rotor speed of 0.32 m. s^{-1}, 5mm clearance between sieve and rubbing unit with spiral flat belt. A farm worker can easily operate the machine; however, two persons (one for its operation and another for feeding) are required for daylong work with this machine. The overall output capacity of depulper was about 22.22 kg fruits/h at 30-35 rpm. The depulping efficiency was 98% and breakage was in the range of 0.02- 0.12%.

Introduction

India is the second most populous country in the world with 121 million population, 60% of which is engaged in agriculture (Anonymous, 2012). Neem (AzadirachtaindicaA. Juss) is recognized as a natural product for solving global agricultural, environmental, public health problems and environmentally safe alternative to synthetic pesticides etc. Neem seeds as its oil occupy a significant place in Indian economy for generating employment in rural area. About 14 million farmers are engaged in production of various oil seeds and 0.5 million in processing sector (Hegde, 2005).

According to the estimates of Neem Foundation, there are about 20 million neem trees in India and as per industry estimates, neem bears 3.5 million tonnes of kernels every year, and from this, around 7 lakh tonnes of neem oil can be obtained. However, total neem oil produced in India is about 2.5 lakh tonnes, which is only 30% of the total potential, the report said, indicating the scope for optimising yield

Table 1 Methods of collection of neem fruits

Parameters	Traditional method	Improved method	Manual picking
Plucking method	Fallen near tree over a night	Branches shaken manually with a pole	Direct from tree by hand
Flooring under tree	Barren earth	200 micron thickness poly sheet	NA
Time taken, man-h	1.5	2	3
Fruit collected per tree, kg	17.62	20.9	10.5
Time taken in sorting, min/ person	33	14.5	nil
Weight of waste material, kg	5.3	4.6	nil
Effective output (neem fruits), kg/h	6	7.27	3.5
Type of waste	Moulds, stone, debris, sticks and leaves etc	Unripe fruits, leaves and sticks	nil
Start of decomposition	On 3rd day	On 4th day	On 6th day

(Anonymous, 2013).

There is immense potential of neem based products in India, which can be tapped if the medicinal plant, as part of agro-forestry and Integrated Rural Development Program (IRDP), is popularized and its value added products are rolled out through village industries.In rural areas, neem fruits are collected and processed manually in locality for domestic use and sale by marginal and landless farmers/occupants. The large size commercial machines are available which are used by chemical based industries.

Uttar Pradesh Government and the Indian Institute of Pulses Research, Kanpur had developed mechanical devices for neem processing (Sharma *et al*., 1953). The depulper, developed at the institute, consisted of hopper and agitation cylinder of horizontal wire mesh of 9 mm, in which agitator rotatedwire mesh immersed in water reservoir. Mitra (1963) developed neem fruit depulper which consisted of a cylindrical steel drum with a central revolving shaft; carrying blades are fitted on the wall of drum. Prior to use of neem fruits in machine, it has to undergo with pre-treatment process of soaking for 4-5 days. In this machine, 40 kg of fruits were fed at a time. Due to bulky size of machine, it did not find adoption at village level. Anonymous (2005) reported that 50% of collected seed goes waste without having proper depulping facility. The depulping should be done within 3-4 days and dried immediately. Depulped seeds dry faster as compared to the undepulped seeds and yield better quality oil.

The harvesting and post-harvest technology for neem specially depulping and decortication has not received due attention of researchers. This might be due to the climatic conditions at the time of its maturity and its fast perishable quality. Keeping this in view, low-cost, small size neem depulper was designed and developed to suit the need oflandless and small farmers.

Materials and Methods

Collection of Neem Fruits

The neem seeds are collected during May-July and are sun dried. Conventionally the fruits are collected by brooming under the tree or shaking tree/ branches. Traditional collection process was studied to get the time involved, waste material and output during each time and compared with improved method (collection of neem fruits on polythene sheet) and manual plucking (**Table 1**).

Physical and Mechanical Properties of Neem

Neem starts bearing fruits after 3-5 yearsand it comes to full bearing at the age of 10-12 years. Fruit yield is 10-25 kg per tree per year in the initial years. A mature tree produces 35-50 kg fruits/year. The size, shape, bulk density and true density, seed volume, porosity, angle of repose, coefficient of static friction, terminal and carrying velocity and compression and shear strength of neem fruits were determined following standard techniques (**Table 2**).

Designhypothesis

Based on the review and data, the design hypothesisisdecided which are as follows:

Requirement of user/ group: Landless and small farmers used to collect about 200 kg neem fruits per year from 4 to 6 trees. The total time span of neem fruit collection per tree is for about 20 days, of which, 80% collection is in ten to eleven days. The local farmers of Haryana collect and make heep near treeand after decomposition, it was used as manure. The farm-

Table 2 Physical and mechanical properties neem fruits

Parameters	Values
Size	
Length	17.4 mm (16.21-19.00 mm)
Diameter	13.0 mm (11.52-15.00 mm)
Angle of repose	40.12°
Bulk density	633 kg/m^3
Porosity	55.53%
Compressive force	20.8N (18.83 – 22.76N)
Shear force	19.82N (17.85 – 21.78N)
Fruit weight	1.58-2.72 g
Weight of 1000 fruits	1613±52.36 g
Weight of 1000 seeds	325.1±11.21 g
Weight of 1000 kernels	197.5±3.27 g

ers were fully aware of its other uses but farmers could not fully utilize the benefits due to lack of small processing machinery (up to 200 kg/ day) and collection centres.

Manual power: Keeping this in view, it was thought to provide such a machine which can be operated manually for removal of pulp.

Cleaning simultaneously while depulping: Machine should also have a provision to clean/ wash the seed while depulping for better and efficient output as pulp would have tendency to make paste which adversely affect the performance of machine.

Simple and energy efficient mechanism: The energy efficient mechanism, particularly for rubbing unit will help in achieving better output with a manual operated machine as human beings are having limited power for continuous operation. A simple machine would have advantage for its adoption by users because it can be fabricated bylocal artisans.

Ease in use: The collection by local farmers is from tree to tree at a distance and they are also scattered. Machine should easily be transported from one place to another.

Design of Depulper for Neem Fruits

Based on review, data and hypothesis, a manual operated neem depulperwas designed which consisted of depulping unit (cylinder, rubbing unit, outlets andwater supply system), power transmission unit, hopper, and frame.

Depulping unit

An energy efficient axial-flowdepulping unit was designed. It consistedof rubbing unit, sieve cylinder, outer cylinder cover, and water supply system.

Rubbing unit

The spiral rubbing system (**Fig. 1**) was selectedas material passed through the rubbing zone between the sieve cylinder and spiral rubbing unit. It was continuously remained in movement with the rubbing surface in a helical path, which provided longer path to the fruits as well as more retention time and helped in removal of skin and pulp easily. This system consumedless energy because it workedon two directional sheering actions.

Design considerations:

Bulk density of neem fruit = 633 kg per m^3

1000fruit weight = 1613g

For 25 kg/h capacity of machine, total volume for rubbing unit should be nearly double of its capacity so that nearly half of its volume would be utilized for feeding only to get required depulping.

Axial-flow mechanism being energy efficient, the length was kept 810 mm.

The machine was to be operated by human beings so the bigger diameter of cylinder (rubbing unit) will be helpful for getting required powerto depulp the neem fruit. Thus diameter of rubbing unit was kept 190 mm andcovered with sieve cylinder of 200 mm diameter.

Principle of screw conveyor was utilized for rubbing unit which was made in spiral shape.

Total volume ofneem fruit was0.073 m^3.

Parameters for shaft design of rubbing unit:

Modulus of elasticity of mild steel shaft (Typ) = 84 × 104 kg m^{-2}

Modulus of rigidity of the mild steel shaft (G) = 21 × 106 kg m^{-3}

Maximum angle of twist = 1° (Hall *et al.*, 1961)

Factor of safety (FS) = 2.5

Where,

L_c = length of rubbing chamber, mm

L_s = length of shaft, mm

L_r = length of rubbing unit, mm

d = diameter of shaft, mm

D_1 = diameter of cylindrical base for rubbing system, mm

D_2 = outer diameter of rubbing unit, mm

H = height of rubbing unit, mm

c = clearance between rubbing unit and rubbing surface, mm

P = pitch of screw, mm

Inner diameter (D_1) of rubbing unit = 100 mm

Outer diameter (D_2) of rubbing unit = 195 mm

Pitch, p = 41 mm

Clearance between sieve and rubbing unit = 5 mm (on the basis of minimum diameter of seed, i.e. 5.7 mm).

Length of sieve cylinder, L_c = 810 mm

Length of rubbing unit, L_r = 816 mm (spirally fitted with the help of ordinary bolt of 10 mm)

The design of shaft was based on the maximum shear theory of Spotts (1971)

$T_{max} = 0.5 \times T_{yp} / FS$ …..................(7)

$T_{yp} = [0.5 (84 \times 104)] / 2.5 = 168$ N/ m^2

Where,

T_{max} = maximum shear stress

T_{yp} = yield stress of mild steel

FS = factor of safety

Now

$\tau_{max} = 16 \{T / (\pi d^3)\}$ ….........…..........(8)

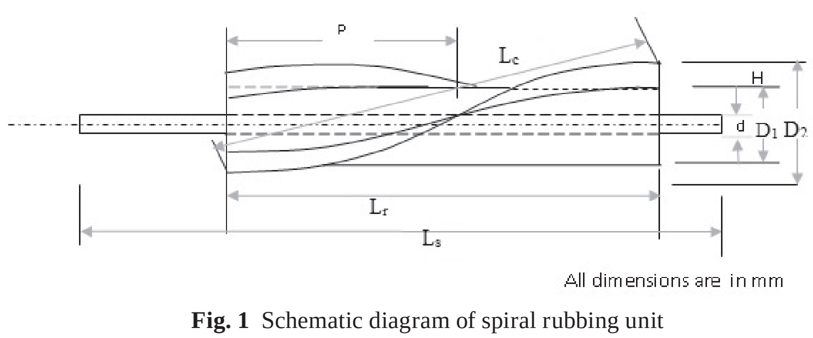


Fig. 1 Schematic diagram of spiral rubbing unit

As a design check, the equation for torsion of a solid shaft

$T/J = \tau/R = G\beta/L$ ....(9)

From which ,

$\tau = (R\ G\ \beta)/L$ …………..............…(10)

Where

τ = torque, N-m

J = polar moment of inertia = $(\pi d^4)/32$ ……………..................…..(11)

R = radius of spiral, m

β = angle of twist

L = length of screw, m

G = modulus of rigidity of material, kg/m^3

$\tau = (0.01 \times 21 \times 106 \times 1)/0.80$

$= 262.5\ N/m^2$

As the torque 168 N/m^2 is much less than 262.5 N/m^2.Therefore, the 10 mm diameter was safe for twist angle of 1° fora length of 800 mm. The shaft of 20 mm diameter can withstand a stress of 262.5 N/m^2 which is more than calculated stress of 168 N/m^2.

For applied torque

$\tau = (J\ G\ \beta)/L$ ……...............……..(12)

$= 157\ N/m^2$

Therefore, diameter of shaft (d) will be 20 mm. The shaft design is safe for stress and torque.

Cylindrical sieve

It works as a depulping cylinder consisted of holes throughout the length and dimeter for providing sufficient retention time to avoid carrying of un-depulped neem fruits. As the action is sheering the total power requirement in depulping is less.

The main determinant for sieve is size of holes, thickness of sheet, diameter and length of seed. A rectangular hole size of 18 × 5mm was used with the 4 mm gap between each hole and 8 mm gap between rows. The 18 gauge mild steel sheet was used for making of sieve cylinder. The inner diameter of cylindrical sieve is 200 mm and length including a collar of 10 mm is 820 mm (**Fig. 2**).

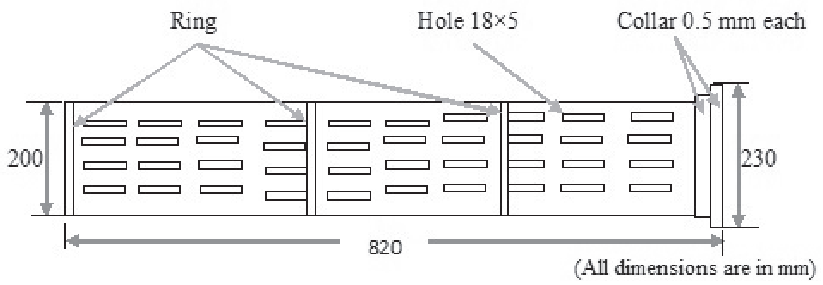


Fig. 2 Schematic diagram cylindrical sieve

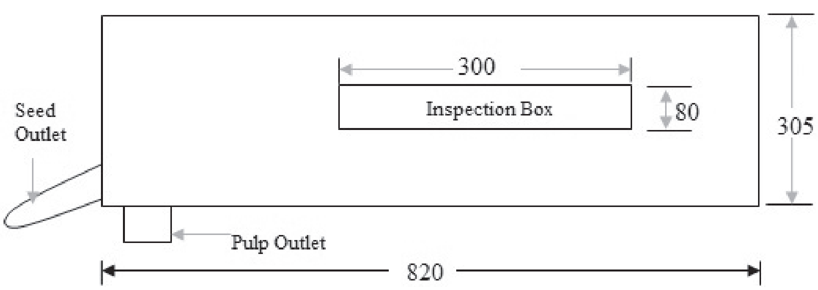


Fig. 3 Schematic diagram of main cylinder

Fig. 4 Water supply system

Outer cylinder cover

It provide cover and to hold the slurry of pulp and water with skin and pulp. The main cylinder is made of 18 gauge m.s. sheet rolled in the diameter of 305 mm and the length of 820 mm. The main cylinder (**Fig. 3**) is providing the cover to the whole unit and holds the pulp and skin mixed with water and carries this slurry to the outlet. An inspection box is provided to see inside the rubbing system. There are two separate outlets provided, one outlet was provided at the bottom of main cylinder for slurry of pulp and water while other outlet was for clean seeds at the end of sieve.

Watering system

Water supply system is important in removing pulp from Neem fruit. A galvanized iron (G.I) pipe 860 mm longand 12 mm diameter was fitted inside the outer cylinder at the top of sieve cylinder (**Fig. 4**). There is a line of 21 hole each having 3 mm diameter upto the length of 800 mm from the end point in such a way that it sprinkle water on the sieve cylinder and help in cleaning and removing of pulp and other material. A valve at the beginning is provided to control the amount of water supplied.

Hopper

Being a small machine its hopper was designed for the feeding capacity of 5 kg of neem fruits. The top is in rectangular shape with size of 180 × 205 mm up to the depth of 140 mm and bottom is tapered at 45-degree angle towards the inlet opening of machine, which directly poured the material to the rubbing unit inside sieve cylinder.

Design procedure for fruit hopper, as reported by Narvani (1991) was followed. Following expression was used for determining holding capacity of hopper,

$V = W/BD$ …………….............……(1)

Where,

V = volume of hopper, m^3

W = weight of fruit fed into hopper, kg

BD = bulk density of neem fruit, kg per m^3

For smooth and continuous flow of neem fruit from hopper to depulping chamberthe following condition must satisfy

$\theta h \geq \theta$ ……………......…..............…..(2)

Where,

θh = angle of inclination of hopper bottom with horizontal axis, 0

θ = angle of repose of neem fruit (40.32°), say, θh = 45°

Volume of hopper = [(H+ h) / 2] × L × W ....……………..(3)

Weight of fruit in hopper = 5 kg

Bulk density of fruit = 633 kg per m^3

Capacity (Q), kg per m^3 = V × BD ………...................................………(4)

Where,

V = capacity, $m^3\ h^{-1}$

BD = bulk density, kg m^{-3}

V = 0.008 m^3…..............………….. (5)

The length and width of top portion of hopper was kept 170 mm and 205 mm, respectively. Height of hopper was kept 270 and 170 mm to provide slope of 45° while feeding in to cylinder.

Frame

The main frame is fabricated by using mild steel angle of three sizes for top 35 × 3mm for legs 40 × 4mm and for support to legs 25 ×

Table 3 Dimensions of different components of neem depulper

Component	Specification
Overall dimensions	
Length	1200 mm
Width	430 mm
Height	1110 mm
Main frame	
Length	900 mm
Width	393 mm
Height	762 mm
Main cylinder	
Length	820 mm
Diameter	305 mm
Thickness	18 gauge
Cylindrical sieve	
Length	810 mm
Diameter	200 mm
Thickness	18 gauge
Hole size	18 × 5 mm
Spiral type rubbing unit	
length of angle iron base	850 mm
height of flat belt	42 mm
thickness of angle iron base	03 mm
radial height of the unit	95 mm
length of shaft extension –tail side	130 mm
–front side	210 mm
diameter of cylindrical base	100 mm
Water supply system	
length of pipe	860 mm
diameter of pipe	12.5 mm
number of holes	21
diameter of holes	3 mm
stop valve	one
Hopper	
Length	205 mm
Width	180 mm
Height	300 & 140 mm
Handle	
Length	245 mm
(Continued from the left) Grip dia. inner	20mm
outer	40mm
Height	140 mm
Weight of machine	35 kg

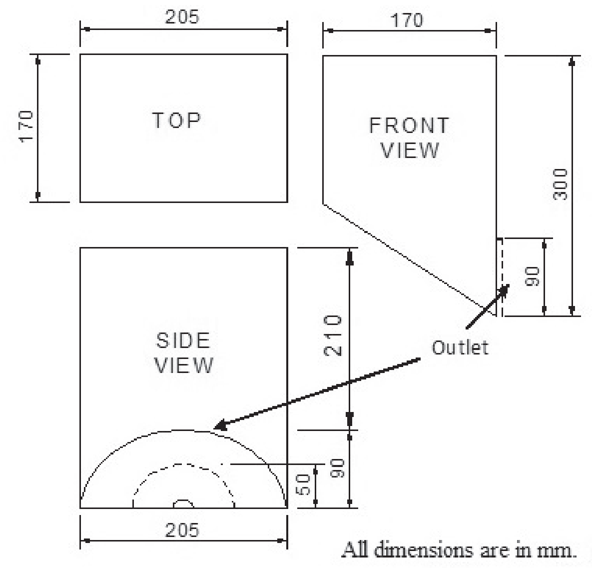


Fig. 5 Schematic diagram of hopper

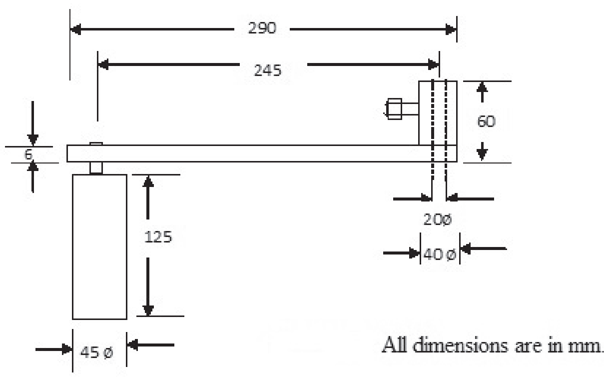


Fig. 6 Schematic diagram of handle

3 mm size. The height, width, and length of the frame are 762 mm, 393 mm and 900 mm, respectively. The adjusting system is incorporated towards the hopper side to provide slope to the main cylinder. The top of frame is joined with the legs in such a way to provide free movement while giving slope.

Handle

The handle is fabricated by using mild steel and wooden. The handle arm is made of mild steel flat of the size 40 × 6 mm and 245 mm as effective length (**Fig. 6**). It is mounted on main shaft with a hollow mild steel rod of outer and inner diameter as 40 mm and 20 mm respectively. Handle is made of round wooden with 45 mm diameter and 125 mm long and attached to connecting arm with 20 mm MS rod.

Fabrication of Neem Depulper

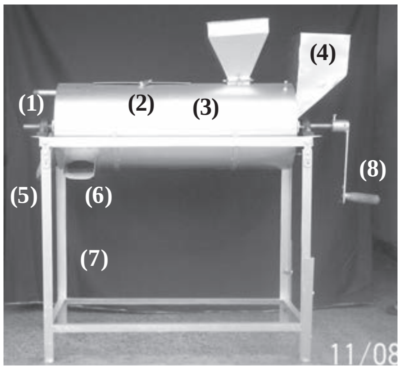
Based on the design of neem depulper, thedimensions for fabrication of prototype aregiven in **Table 3** and the fabricated prototype is shown in **Plate 1**.

Table 4 Performance data of developed neem depulper

Particulars	Mean value
Soaking period of neem fruit, days	3
Input material fed, kg	4
Number of worker	2
Hand cranking speed, rpm	32
Speed of rotor, m/s	0.32
Time taken to depulp the neem fruit, s	548
Time taken to wash seed after depulper, s	120
Water flow rate, l/h	20
Capacity of machine, kg/h	24.5
Overall capacity including washing, kg/h	22.22
Depulping efficiency, %	98
Total loss (pulp & skin), %	0.9
Energy consumption, W	67.14
Capacity of depulping with conventional method, kg/h	6.0
Cost of depulping neem fruit, Rs/kg	
With machine	3.5
With traditional method	6.25
Saving in cost, %	44.0

Performance Evaluation of Neem Depulper

After laboratory evaluation of thedepulperfor proper working of each components, the prototype was testedby feeding 3-days soaked 4 kg neem fruit to assess its performance in terms of clean seed collected at outlet, seed left in the sieve cylinder, un-depulped neem fruits in sieve cylinder and un-depulped Neem fruits collected at seed outlet. The experiment was repeated thrice to get mean value. The material received at outlet was collected and separated for un-depulped seed, clean seed, broken seed and seed/fruit left in the rubbing chamber, broken neem seed collected at pulp outlet, broken neem seed collected at sieve cylinder, water flow rate,cranking speed and time taken for depulping. Depulping efficiency, capacity of machine, percentage of clean seed, percentage of un-depulped seed, percentage of pulp loss, percentage of broken seed and cost of operation of machine were calculated as per standard formula.



1	Water line
2	Inspection box
3	Main cylinder
4	Hopper
5	Outlet for seed
6	Outlet for pulp and skin
7	Main frame
8	Handle

Plate 1 Photograph of developed neem depulper

The cost of operation of developed machine was compared with conventional method (manual) of depulping (**Table 4**).

Results and Discussion

Neem fruits collected by two persons from a tree were 17.62, 20.9 and 10.5 kgwith traditional, improved and manual picking methods, respectively (**Table 1**). The effective output per hour in terms of neem fruit was higher (7.27 kg) in improved method where plastic sheet was used and followed by 6.0 kg in traditional method and 3.5 kg with manual picking. Higher output with improved method was due to no stone and dust as compared to traditional method and low output with manual picking was due to reason of individual fruit picking.

Performance Data of Developed Axial-flow Neem Depulper

From laboratory data, optimum soaking period of neem fruit was found to 3 days (Solanki, 2012). Four kg soaked neem fruit was fed into hopper at start and machine was operated continuously for an hour to assess the performance of machine. Capacity of machine was 24.5 kg/h at hand cranking speed of 32 rpm (**Table 4**). The hand cranking speed was varied between 30 to 35 rpm which is as per the recommendation of (Grandjean, 1982). Water flow rate was 0.02 m^3/h. The produce obtained from the machine needs one washing in fresh water which took time of 2 min. Overall capacity of machine came to 22.22 kg/h. Depuling efficiency was 98% at rotor speed of 0.32 $m.\ s^{-1}$. Pulp and skin losses were 0.9%.

The output of machine was 2.7 times more as compared to conventional method of depulping the neem fruit. Fabrication cost of machine was about Rs. 10,000 (USD is 65.34 for one INR) and cost of neem fruit depulping per kg was Rs. 3.5. Operating cost was calculated on per kg seed and per hour basis which came to Rs. 1.57 andRs. 39.68, respectively.

During long run test, it was observed that a person (male worker) can easily operate the machine for about an hour at stretch and thereafter rest pause is needed. This way, the machine if operated for 6 h in a day, the capacity would be 133 kg which enables small and landless farmers having about 13 trees.

Based on the laboratory and field evaluation, the optimum values of neem fruit depulper is as follows,

1. Type of rubbing unit	Spiral flat belt
2. Clearance between sieve and rubbing unit	5 mm
3. Rotor speed	30-35 rpm
4. Sieve size	18 × 5 mm
5. Soaking period	3 days
6. Water flow rate	20 l/h
7. Slope on cylinder	horizontal

Conclusions

Hand operated neem depulper was developed using standard mechanical design procedures. It consisted of hopper, main cylinder, cylindrical sieve, spiral type rubbing unit, water supply system, handle and main frame. The optimized parameters for hand operated neem depulper is 3 days soaking period of neem fruit, 20 l/h^{-1} water flow rate, 18 × 5 mm sieve size, rotor speed of 0.32 m/s^{-1}, 5mm clearance between sieve and rubbing unit with spiral flat belt. The output of this developed machine is 24.5 kg neem fruits per h 98% depuling efficiency. The depuling of neem fruits with this developed machine is 44% economical to the traditional method. This machine can be suitable for small and landless farmers having about 13 trees.

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Development of A Hydro-Separating Cowpea Dehuller

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Abstract

The dehulling of cowpeas is a long and tedious process which involves detaching of cotyledon from the hull. Dehulling machines for soaked cowpea seeds were developed to produce clean dehulled cowpea seeds for use in food preparation. Dehulling of cowpea seeds influences the quality of the final products. An improved hydro-separating cowpea dehuller was designed, fabricated and tested. Some of the components designed for and fabricated are hopper for feeding in the material, dehulling unit where dehulling operation takes place, cleaning unit where separation of cotyledon and hull take place and the shafts for auger and agitator for transmission of power to carry out the necessary operations. The test performance carried out on the machine showed that it can effectively dehull the cowpea seeds and separate the hull from the cotyledon. The machine gave 93.61% as the highest dehulling efficiency and 73.24% as lowest dehulling efficiency. The least cleaning efficiency of dehuller was 79.96%; the average feed rate of the machine was 157.02 kg/h while output capacity of the machine was calculated to be 18.63 kg/h./batch.

Keywords: Cowpea Seed, Design, Fabrication, Dehuller/Separator, Performance

Introduction

Dehulling refers to the removal of the seed coat (hull) from the seed, resulting in the separation of the cotyledons from the hulls. In the rural sector, the dehulling process is still a part of the housewife's manual work in food preparation. Williams (1974) described the dehulling of cowpeas as a long and tedious process. Most housewives require an hour or more to dehull cowpeas depending on the quantity and the method used. Housewives generally prefer the wet method of dehulling or a combination of the dry and wet methods. The first innovation for dehulling cowpea is known as semi-mechanical method, this is achieved by firstly breaking the cowpea seeds into coarse particles consisting of hulls and seed particles using a milling machine, followed by separating the hull from the cotyledon by the process of winnowing and finally dry milling the cotyledons to produce cowpea flour. This method is popularly used by large scale processors of cowpea flour which are commonly found on food shelves in the stores. However, this method leaves the powder with black specks from the seed coat of the cowpea (Dovlop, *et al.*, 1976). Depending on the desired end products, the black specks left on the cowpea might not give the desired end product the expected quality.

Some dehulling machines have been developed by institutions like National Centre for Agricultural Mechanization, (NCAM), Ilorin and University of Ilorin, Ilorin, (Unilorin). However, the complete removal of the hull (or testa) from cowpea was achieved by the use of dehulling machines developed by Babatunde (1995) and (Kolade (2003) at the University of Ilorin and Olowonibi (1999) at National Centre for Agricultural Mechanization (NCAM), Ilorin and some Allied Institutes but most of these machines developed by institutions do not have separating chamber for the hull and cotyledon and those having separating chamber are not functioning well. This reason prompted the need to design and fabricate an improved cowpea dehuller.

This work aimed at developing a machine for detaching cowpea hull from its cotyledon so as to improve the quality of processed cowpea products. The overall objective was to design and construct an improved cowpea seeds dehulling machine.

Materials and Methods

Equipment Description

The machine comprises of a hopper, a dehulling unit, and a separating/cleaning unit; the hopper is frustum pyramid in shape made from 2 mm thick galvanized sheet situated at the top of left end of the dehulling unit housing. The dehulling unit consists of a 25 mm diameter shaft that passes through a pipe of diameter 60 mm with series of punches on the pipe. A rod of diameter 10 mm was then wind round the 60 mm diameter pipe to form a worm which serves as an auger. This auger is then enclosed inside a perforated pipe of diameter 90 mm. The whole unit is housed inside a pipe of diameter 135 mm. The cleaning/separating unit consists of two major components. A trapezoidal water trough where separation and cleaning operation take place, it is made from 2 mm thick galvanized with outlet for discharge of hull in the medium of water; at the centre top of the water trough is an agitator made of spikes of 10 mm diameter rod attached to a shaft of diameter 20 mm. Also an external rectangular water tank of 410 mm × 540 mm × 330 mm dimensions made of 2 mm galvanized sheet which constantly supplies water into the separating/cleaning chamber during operation.

Design Analysis

The major calculations and analysis carried on the design of the hydro separating cowpea dehuller were:

Hopper design

The volumetric capacity of the hopper was determined from the dimensional layout of a frustum set up in a resting position. Two kilogram of cowpea seeds is to fill the hopper. The volume to be occupied by material is calculated using equation 1 while the volumetric capacity of the hopper was calculated from equation 2 and this volume is to avoid choking of the materials when felt into the hopper.

$V\ (m^3) = M\ (kg) / \rho\ (kg / m^3)$ ....(1)

where,

V = volume of material in m^3

M = mass of the material in kg

ρ = bulky density of the material in kg/m^3

Hence, volumetric capacity of the hopper is given as

$V = 1/3\ (A_1 + A_2 + \sqrt{(A_1 + A_2)}\ h)$ ..(2)

where,

V = Volumetric capacity of the hopper (mm^3)

A_1 = Area of top of the hopper in m^2

A_2 = Area of bottom base of the hopper in m^2

h = the height of the hopper in m

The highest bulk density at 30% moisture content dry basis given by (Davies and Zibokere, 2011) to be 1,014.54 kg/m^3 since the material to be dehulled ranges between the moisture content of the bulk density. Therefore, the volume of the quantity of the cowpea seeds is determined using equation 1. Hence, volumetric capacity of the hopper is calculated to be 0.00297 m^3.

The capacity of the screw conveyor dehuller

The quantity of cowpea seeds to be dehulled and the whole component of auger (screw conveyor) are to be contained inside the dehulling unit housing. The pitch length of the auger is assumed based on the time of retention of the soaked cowpea seeds inside the dehulling chamber, this is necessary because, the dehulling operation on the soaked cowpea seeds is carried out by rubbing action of the seeds with the wall of the cover and between the seeds themselves inside the chamber. A complete removal of the teasta from the cotyledon is guarantee, if times of retention of seeds inside the chamber is longer during operation and the speed of operation is lower. That is a shorter pitch length reduces time of retention of seeds. Hence, a low speed of 318.40 rpm and 120 mm of pitch length are chosen for this design.

The output capacity of a screw conveyor in a horizontal position; C_D was calculated to be 0.0385 m^3/h using equation 3 as given by (Skilling 2001).

$C_D = \pi / 8\ (D^2_s - D^2_A)\ N \times (P - T)\ (m^3/h)$ ....(3)

where,

Ds is the screw diameter in m

DA is the axle diameter in m

T the thickness of the blade in m

P the pitch length of the auger in m

N is the speed of operation in rpm

The power/energy requirement for the dehuller' screw conveyor

The power requirement for a screw conveyor was estimated from the sum of the power required to turn the empty screw and the additional power required to move the solids as stated by (Skilling 2001). The power requirement was calculated to be 0.00023 kw using equation 4. The power required to move empty screw conveyor was estimated to be 0.00013 kw using equation 5 while the power to move material estimated to be 0.000104 kw using equation 6 based on the bulk density of soaked cowpea seeds to be dehulled as given by Yalcin (2007) and (Davies and Zibokere, 2011) to range between 979.59 kg/m^3 and 1,014.54 kg/m^3 at 30% moisture content dry basis. Therefore, 1,014.54 kg/m^3 was chosen. Thus power source higher than the required power is selected for this operation.

$P_{SC} = E_P + M_P$ ....(4)

where,

E_P is Empty Power

M_P is the Material Motion Power

and

$E_P = 2.45 \times 10^{-6} LNFDFB\ (Kw)$ ....(5)

where,

L is the Screw Length in m

N is the rotating speed in rpm

F_D is a function of the screw size, usually about 5

F_B is a factor, about 4

Also,

$M_P = 5.39 \times 10^{-6} LCWF_M F_F F_P$ ....(6)

where,

C = capacity of the Conveyor in m^3/h

W = material density in kg/m^3

F_M = a material factor usually 1.0

F_F and F_P = a flight factor and a seed factor respectively both usually 1 for both standard screws.

Auger design

The volumetric capacity of auger housing is established in the relationship of the cowpea seeds and the auger to be placed inside the housing it is calculated to be 0.0018 m^3 using equation 7 given by (Olaoye, 2011)

$$V = (\pi D^2 / 4) L \quad (7)$$

where,

V = volumetric capacity of the auger cover in m^3

L = length of the auger cover in m

D = Diameter of the auger Cover in m

The volumetric capacity of the auger Housing gave rise to the dimensions of the auger as Core diameter 60 mm, Screw diameter 80 mm, Pitch of the auger 120 mm, Radial clearance 3 mm, Thickness of screw or diameter of worm or rod 10 mm and average height of material on the screw surfaces 20 mm. According to Roberts (1999) Conveyor Throughput of an enclosed screw conveyor is influenced by the rotational or vortex motion of the bulk material during transportation and the degree of fill or "fullness" of the screw. As the rotational speed of the conveyor increases, the rotational or vortex motion decreases up to a limiting value, making for a more efficient conveying action. The net result is for the volumetric throughput of the screw conveyor to reach a limiting value. It was calculated to be 1.55 × 10^3 m/s using equation 8.This shows the materials will move through the length of the conveyor as fast as 0.00155 m in a second. Maximum theoretical volumetric throughput with conveyor running 100% full and the bulk material moving axially without rotation is calculated to be 1.83 × 10^3 m/s using equation 9 when the Γ value is 0.3934 m using equation 10 and angular velocity is 0.058 rev/sec from equation 11. The volumetric through put of a screw conveyor is given by (Roberts, 1999).

$$Q = Q_t \eta_v \quad (8)$$

$$Q_t = \Gamma \omega D \quad (9)$$

$$\Gamma = 1/8 [(1 + 2 C/ D) - (D_C / D)][(\rho / D) - t_S / D] \quad (10)$$

where,

Q_t = maximum theoretical volumetric throughput with conveyor running 100% full and the bulk material moving axially without rotation.

η_v = volumetric efficiency

D = screw diameter (m)

D_C = core diameter (m)

p = pitch (m)

ω = angular velocity of screw (r/s)

C = radial clearance (m)

t_S = thickness of screw blade (m)

The screw conveyors of large diameter attain their maximum output at lower speeds than conveyors of smaller diameter. The angular velocity,

$$\omega = gND / R_0 1789 \quad (11)$$

where,

R_0 = outer radius

g = gravitational acceleration

N = the speed of the auger in revolution per second;

D is as defined above

Also, the volumetric efficiency of a screw conveyor is the product of two components is indicated to be 84.91% from equation 12. When fullness efficiency of 8.3% is calculated using equation 13

$$\eta_v = \eta_{VR} . \eta_F \quad (12)$$

where,

η_{VR} = conveying or vortex efficiency accounting for the rotational or vortex motion

$$\eta_F = \text{'Fullness' Efficiency} = h_{av} / \rho \quad (13)$$

where,

h_{av} = average height of material on the screw surface = 10 mm

ρ is as defined above.

The conveying efficiency is given to be 10.23% using equation 14 and for it to be determined, it is necessary to first determine the variation of the path helix angle λ as a function of the radius and rotational speed of the conveyor and the effective helix angle of the screw flight = 80.95° from equation 16 while effective helix angle of the path extracted from AUTOCAD drawing is given as λ_e = 35.6°. With the knowledge that $V_T \approx$ constant and does not vary with the radius, the analysis of the screw conveyor may be simplified by lumping the rotational mass and resultant forces at the effective radius Re defined by

$$\eta_{VR} = V_{Le} / V_{Lt} = \tan \lambda_e / (\tan a_e + \tan \lambda_e) \quad (14)$$

The helix angle of the screw flight corresponding to Re is

$$a_e = \tan^{-1} [(p / nD) (R_0 / R_e)] \quad (15)$$

$$R_e = 2 / 3 [R_0 - R_1 / R_0 - R_1] \quad (16)$$

where,

R_0 = outside radius of screw flight in m

R_1 = inner radius of radius of shaft in m

ρ as defined above

D = 2 R_0 = screw flight diameter in m

Pulley design

There were two operating shafts namely; screw conveyor (auger) shaft and agitator shaft and they are to use different pulley diameter. The design and selection of appropriate power requirement for rotation of screw conveyor and the agitator was selected based on the speed of the driving motor, speed reduction ratio and centre to centre distance between the shafts at the conditions under which the dehulling and separation/cleaning action must take place. An ac motor with 1410 rev/min was used with pulley diameter of 70 mm. The dehulling operation speed of 318.4 rev/min was desired. A low speed of auger shaft rotation is expected during dehulling operation because according to (Reichert, *et al.*, 1979) dehulling of cowpea seeds at lower speed is more efficient than dehulling at higher speed. The diameters of pulley of the shafts were calculated using equation for the peripheral speed of belt as shown in equation 17 given by (Khurmi and Gupta, 2005) as:

$$\pi N_1 D_1 = \pi N_2 D_2 \quad (17)$$

where,

N_1 = Speed of the driving motor in rev/min,

N_2 = Speed of the shaft in rev/min

D_1 = Diameter of driving pulley in m,

D_2 = Diameter of driven pulley in m.

The operating speeds of the agitator is expected to be in ratio 1:4 of the speed of screw conveyor, since, it is expected to agitate the water without splashing. The pulley diameters of the agitator and screw conveyor were calculated to be 250 mm and 300 mm using equation 17. The shaft to shaft centre for the electric motor and auger shaft was chosen to be 240 mm while that of the agitator and auger was chosen to be 195 mm. The choices are based on the calculation from equation 19. The minimum obtainable distance between the central axis of the electric motor shaft and the radius of the outer cylindrical auger housing for dehulling operation as well as the distance between auger shaft and the agitator shaft influenced the choice of this parameters and it was calculated using equation 18. A v-belt of 1.14 m was recommended to drive the screw conveyor while a v-belt of 0.88 m was recommended to drive the agitator.

$$L = \{\pi / 2 \ (D_1 + D_2)\} + 2_C + \{(D_1 - D_2)^2 / 4_C\} \quad ....(18)$$

where,

L = Total length of belt in m,

D_1 = Diameter of driving pulley in m

D_2 = Diameter of driven pulley in m

C = the shaft to shaft centre, it is expressed as;

$$C = D_1 \ ; D_2 / 2 + 0.05 \quad ....(19)$$

The Power/Energy Requirement for the Dehuller's Agitator

BEE (2004) stated that the fan operate under a predictable set of laws concerning speed, power and pressure. A change in speed revolution per minute (rpm) of any fan in operation will predictably change the pressure rise and power necessary to operate it at the new rpm. This law can be applied to agricultural equipment that uses blade to carry out its operation.

One of the equations of these laws is given as;

$$K_{W1} / K_{W2} = [N_1 / N_2]^3 \quad ....(20)$$

where,

K_{W1} = power from the screw conveyor

K_{W2} = power required by the agitator

N_1 = speed of the agitator shaft

N_2 = speed of the screw conveyor shaft

This Law is applicable because speed from the screw conveyor is being transferred to the agitator during the dehulling operation. Therefore, the power required by the agitator shaft was calculated to be 3.6×10^{-6} kW using equation 20.

Torque transmitted by the shafts

The torque transmitted by the screw conveyor shafts was 0.0069 Nm while that of agitator shaft was 0.00043Nm calculated from equation 21 given by (Khurmi and Gupta, 2005).

$$T = Px60 / 2\pi N \quad ....(21)$$

where,

P = the calculated power (W)

N = the operating speed of the shaft (rpm)

Shafts design

In the design of the dehuller, two major shafts were designed for; the main shaft of the screw conveyor (auger) and the shaft of the agitator. The design of the shafts is based on strength and will be controlled by maximum shear theory. The design for the Shafts of the Screw Conveyor (Auger) and agitator is subjected to combined twisting moment and bending moment, so the shafts were designed based on two simultaneous moments on them. The shaft diameter selected for screw conveyor was 25 mm based on its maximum bending moment of 37.23 Nm while the shaft diameter selected for the agitator was 20 mm based on its maximum bending moment of 4.82 Nm using equation 22 given by (Khurmi and Gupta, 2005).

$$T_e = (M^2 + T^2)^{0.5} = (\pi \times S_S \times d^3) / 16 \quad ......(22)$$

where,

T_e = equivalent twisting moment in Nm

M = maximum bending moment in Nm

T = Torque transmitted by the shaft in Nm

S_S = Allowable shear stress with keyway = 40 N/mm^2 (Pa?)

d = diameter of the shaft in mm

Fabrication Techniques

The construction processes were carried out in the fabrication workshop, Department and Biosystems Engineering, University of Ilorin, Ilorin, Nigeria. The basic manufacturing processes which include cutting, bending, primary shaping and joining processes were undertaken.

Hopper

The hopper is a frustum of pyramid (a pyramid with a portion of the head cut off parallel to the base) this is a medium through which the grains are introduced to the dehulling units and retained prior to their introduction into the machine.

It is constructed of mild sheet of 1.5 mm thickness. The dimensions are 257 mm × 232 mm at the top and 100.2 mm × 80.2 mm at the bottom with slant of length 205.5 mm and height 214.7 mm. The fabrication was done by marking out the measurements on the plate, cutting it into shapes, welding and giving it a finishing touch by grinding.

Auger housing

The auger housing consists of two halves of 90 mm diameter pipe, (perfect circular shape) which is perforated to ease dehulling and cleaning of the unit. The upper half has an inlet of dimension 100mm × 80 mm for the base of hopper, while the discharge outlet in the bottom half situated at the opposite end of the inlet end is 67.5 mm × 40 mm opening. The auger housing has a total length of 502 mm. It was fabricated by marking out the 90 mm diameter pipe into a desire length and required shape. The finishing of the housing was done by grinding..

Screw conveyor unit (auger)

The screw conveyor unit has an over length of 815 mm with a pitch length of 120 mm and helix angle of 35.60. It is made of a pipe of diameter 60 mm with a 10 mm diameter rod worm around it, then 25 mm diameter rods of length 120 mm each were attached at the extreme ends of the worm shaft. The unit was constructed by cutting the 60 mm diameter pipe into a length of 495 mm and a 10mm rod of length 420 mm was wind round the pipe by welding to form an auger. Then the 25 mm rod was cut into two (2) shafts of 120 mm length each, the shafts were welded to end edges of the auger.

Cleaning unit

The separating unit comprises of separating trough, agitator, and chaff/water separator. The separating trough which is trapezoidal in shape has an over dimension 425 mm length, 250 mm width, the maximum height of 345 mm and minimum height of 230 mm. it has two openings; the first opening for removing the chaff while the second opening is for draining water from the cleaned cowpea cotyledons. It is constructed from 2.0 mm mild steel plate; the plate was marked and cut out into required lengths and shapes, then welded together to form trapezoidal shape.

The agitator is made of blades from 1.5 mm thickness galvanized sheet attached to a shaft which is situated at the top centre runs across the width of the separating trough and made to sit at the top of the trough. It is designed to keep the hulls in suspension after creating turbulence in the surface of the water. This is constructed from mild steel rod of 20 mm diameter shaft, 2 plates of 1.5 mm and dimension 380 mm × 50 mm were bend to 45° and fitted along the length of the shaft using bolt and nut. The fabrication of the agitator was done by cutting the 20 mm diameter rod into the required length of 450 mm and the plate into marked out shape. The blade was bending to the specified angle of 45° and fit to the shaft using bolt and nut.

The chaff/water separator is cylindrical in shape with diameter of 204 mm and height of 202 mm, it has a sieve of perforation 4 mm diameter and 31,416 mm^2 area inside the cylinder for holding the chaff and a valve tap for discharge of water. It is fabricated from 2 mm galvanized by marking and cutting out of the plate into the length and folded cylindrical shape. The mild steel plate was also mark out and cut into two circular plates. One of the plates was welded to form the base of the cylinder while the other one was perforated using drilling machine to form a sieve which is placed inside the cylinder.

Water tank and bearing housing

The water tank which is cuboid in shape has an overall dimension of 410 mm × 334 mm × 545 mm and it is constructed from 1.5 mm galvanized sheet. It is fabricated by marking and cutting the sheet into the required lengths and shapes, and then welded to form cuboid shape.

The bearing is fitted between the inner races and the shaft in interference, fitted to prevent relative rotation and wears between the race and the shaft. This is rigidly attached to the frame and cover with metal sheet serving as housing. The housing is constructed using construction instruments such as vice and anvil to fold the metal into a semicircle covering the bearing on a flat flange which was shaped out. The flange has two holes drilled on both ends of a 4 mm diameter, thickness of 18 mm. the enclosing circle depends on the external diameter of the bearing house.

Frame

The frame is cuboid in shape and gives a rigid support to the whole system. It has an over dimension of 610 mm × 460 mm × 655 mm. It is constructed of 50 mm × 50 mm × 50 mm angle and 2 mm thickness plate of dimension 610 mm × 460 mm to cover the top of the frame. The fabrication procedure was done by marking and cutting out the angle iron into different lengths of 655 mm, 610 mm, 460 mm, etc. using power hacksaw and mild steel sheet into rectangular shape then welded together to form the frame.

Pulley

Three pulleys were used in the construction of this machine. The auger has two main pulleys the major pulley has a diameter of 310 mm; the minor pulley has a diameter of 60 mm, while the third pulley which is the pulley of the agitator has 240 mm diameter.

Operation of the Modified Cowpea Dehulling Machine

The machine is operated by a 2 hp electric motor and has the following features such as hopper, dehulling unit and cleaning unit. The hopper is where the soaked beans is fed into, the dehulling unit consist of an

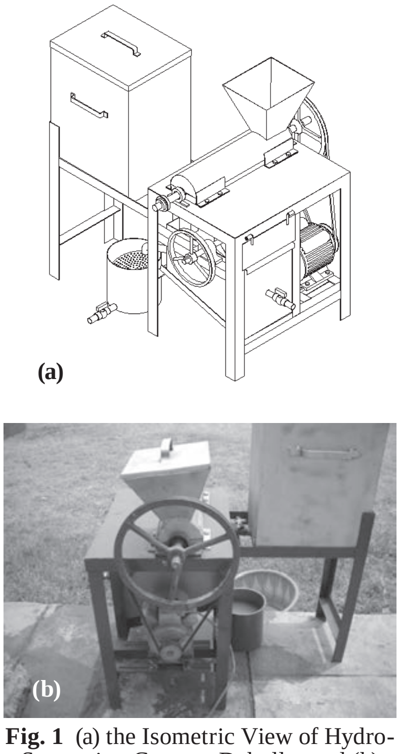

Fig. 1 (a) the Isometric View of Hydro-Separating Cowpea Dehuller and (b) the Pictorial View of Hydro-Separating Cowpea Dehuller

auger that convey the soaked cowpea that gets dehulled by rubbing action principle as it moves along the length of the screw conveyor. The auger discharges dehulled cowpea seeds into the separating trough.

The cleaning chamber which is to separate the hull from the cotyledon consist of an agitator made of blades attached to a shaft and fixed at the top of a separating trough where the cleaning takes place. The agitator stirs the water inside separating trough as the clusters of hull and cotyledon dropped inside the trough for separation. The lighter hull floats and flows out through its outlet as the water from the water tank continually fills the separating chamber during operation. The water that filled chamber allow the mechanical agitator to easily and constantly stirs the dehulled seeds and hull for easy separation of the materials, hence, allow the heavier cotyledons to settle to the bottom of the separating chamber while the lighter hulls float and flow out with the flowing water.

The hulls are collected by a chaff/water collector through a pipe while the cotyledons sink down and settle at the bottom of the separating trough. After the dehulling operation, the separating trough is pulled out from its seat, the water is then drained and the cleaned cotyledons are packed for further operation.

The electric motor simultaneously powers the screw conveyor shaft in the dehulling chamber where the soaked cowpea seeds are being dehulled and the agitator shaft that agitates the water inside separating/cleaning chamber.

Performance Test

A preliminary test was carried out on the hydro-separating cowpea dehuller using 2hp electric motor as the source of power at operating auger speed of 150, 200, 250, 300 and 350 rpm using driven pulley of diameter 493.50 mm with a corresponding agitator speed of 43.5 rpm. Four commonly available cowpea varieties namely; Yarihausa, IAR48, Oloyin, and IAR 60/62 were used as

Legend of **Fig**. 3

1	Hopper
2	Dehulling unit housing (upper part)
3	Auger pulley
4	Auger shaft
5	Screw convey or unit
6	Auger cover (lower part)
7	Dehulling unit housing (lower part)
8	Top covering seat
9	A-Belt
10	Main frame
11	Electric motor
12	Separating trough
13	Separating trough tap
14	Water guard
15	Separating trough seat
16	Water agitator
17	Agitator shaft
18	Agitator pulley
19	Water collector tap
20	Water collector
21	Filtering plage
22	Discharge chute
23	Chaff/Water outlet
24	Agitator driving pulley
25	Water tank frame
26	Water tank
27	Wtaer tank cover
28	Water tank tap
29	Auger cover (upper part)

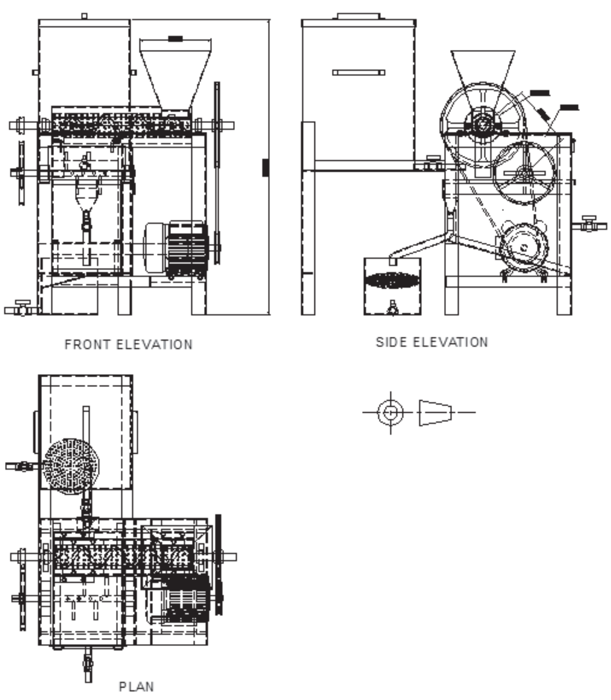

Fig. 2 Orthographic Projections of Hydro-Separating Cowpea Dehuller

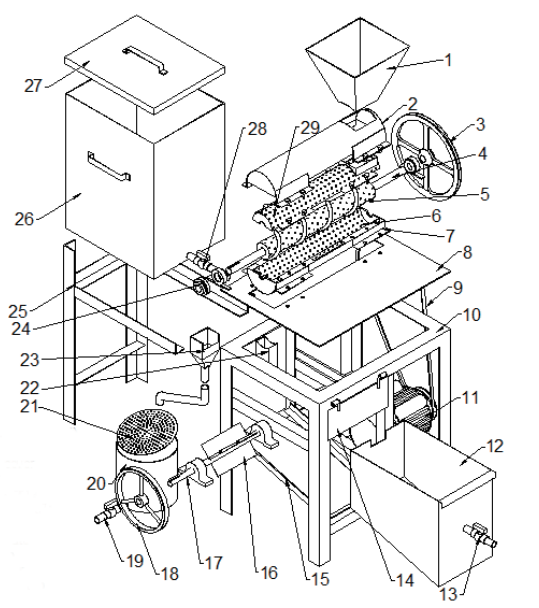

Fig. 3 Exploded View of Hydro-Separating Cowpea Dehuller

a testing material at 2, 4, 6, 8, and 10 minutes soaking time.

The performance indices used for this experiment are the equations 23-26 as expressed below following the format of Standard test code for groundnut sheller, (NIS, 1997) and Babatunde, (1995).

$D_E = (W_3 / W_2) \times 100(\%)$ ....(23)

where,

W_2 (kg) = $W_3 + W_4$

W_3 (kg)= Weight of dehulled cowpea seeds.

W_4 (kg) = Weight of undehulled cowpea seeds

$C_E = W_6 / W_5 \times 100(\%)$ ....(24)

where,

$W_5 = W_6 + W_7$

W_6 (Kg) = Weight of chaff inside chaff collector

W_7 (Kg) = Weight of chaff remaining inside the cleaning chamber after operation

$F_R = W_1 / T_1$ (kg/h) ....(25)

where,

W_1 (kg) = Total weight of soaked seeds fed into the machine

T_1 (h) = Time of feeding

$O_C = W_1 / T_2$ (kg/batch/h) ....(26)

where,

T_2 (h) = Time of operation

Analysis of the New Duncan Multiple Range Test was carried out to determine the effect of the speed of operation and soaking time on the dehulling efficiency and cleaning efficiency on the hydro separating dehulling machine using for four varieties of Cowpea seeds.

Results and Discussion

The hydro-separating cowpea dehuller was designed and fabricated. The isometric and pictorial views, orthographic projection and exploded views of the dehulling machine were as shown in **Figs. 1**, **2** and **3** respectively. The machine is operated by a 2 hp electric motor to power all the accompanied features. The dehulling unit consists of an auger that convey the soaked cowpea that get dehulled by rubbing action principle as it moves along the length of the screw conveyor. The auger discharges dehulled cowpea seeds into the separating trough.

The cleaning chamber which separates the hull from the cotyledon consists of an agitator made of blades attached to a shaft and fixed at the top of a separating trough where the cleaning takes place. The hull is collected by chaff cum water separator through a pipe while the cotyledons sink down and settle at the bottom of the separating trough. After the dehulling operation, the separating trough is pulled out from its seat, the water is then drained and the cleaned cotyledon is packed for further operation. The operation of 2 hp electric motor simultaneously dehulls the soaked cowpea seeds and agitates the water inside separating/cleaning chamber. The basic unit operations in dehulling process were handled in an operation as an improvement over Babatunde (1995), Kolade (2003) and Olowonibi (1999).

Performance Test of the Hydro-Separating Cowpea Dehuller

Table 1 shows the summary of performance test of the dehuller. The highest dehulling efficiency was 95.06% and 73.24% as lowest dehulling efficiency of the machine when four varieties, yari hausa, IAR60/62, IAR48 and oloyin, were compared. The cleaning efficiency of the dehuller ranged from 79.96% to 81.85%. The feed rate of the machine ranged from 156.18 kg/h and 157.02 kg/h while output capacity of the machine was calculated to be between 17.76 kg/h/batch and 18.63 kg/h/batch (**Table 1**). These results showed that the dehuller was capable of effectively dehulling the cowpea seeds and separating the hull from the cotyledon compared to the results indicated by Babatude (1995) and Olowonibi (1999). The hydro separating component was a unique feature of the dehuller unit. This feature made the separation of the dehulled seeds and cotyledon feasible.

Effect of Speed of Operation on the Dehulling Efficiency of the Dehuller

Table 2 showed that there was gradual decrease in the dehulling efficiency of the machine as the speed increases for all the four varieties of cowpea seeds used with excep-

Table 1 Summary of the Performance test of the Hydro-Separating Cowpea Dehuller

Variety	Operating Speed (rpm)	Soaking Time (min)	Dehulling Efficiency (%)	Cleaning Efficiency (%)	Feed rate (kg/h)	Output Capacity (kg/h/batch)
Yari Hausa	200	6	73.24	81.66	157	18.63
IAR60/62	200	6	80.7	81.85	156.18	17.76
IAR48	200	6	93.61	81.42	157.02	17.81
Oloyin	200	6	81.67	79.96	156.98	18.45

*Values are means of five replications

Table 2 Effect of Speed of Operation on Dehulling Efficiency of the Dehuller using NDMRT* for Four Varieties of Cowpea Seeds

Operating Speed (rpm)	Mean Dehulling Efficiency for Cowpea Varieties (%)			
	Yari Hausa	IAR 60/62	IAR48	*Oloyin*
150	71.2273[d]	80.7460[d]	93.0940[d]	80.1980[d]
200	74.5727[e]	83.1513[e]	96.0147[e]	83.9633[e]
250	69.5467[c]	76.4827[c]	88.3267[c]	77.7567[c]
300	63.6353[b]	72.7207[b]	82.5633[b]	72.4113[b]
350	57.9300[a]	63.0967[a]	80.2907[a]	67.5460[a]

* implies New Duncan Multiple Range Test

tion to the initial increase noticed at 200 rpm. This is not in line with Babatunde (1995) which stated that dehulling efficiency of the manually operated cowpea dehuller increases with speeds although Babatunde (1995) worked at low speed levels of 60 rpm, 80 rpm and 100 rpm while this observation is in contrast to Reichert, *et al.* (1979) that reported that dehulling of cowpea seeds at lower speed is more efficient than dehulling at higher speed. The lowest dehulling efficiency mean value at speed level 350 rpm might could be as a result of low residence time of the soaked cowpea seeds inside the dehulling chamber by the high conveying speed. There is no enough time for the seeds to rub against each other and wall of the dehulling chamber. While at speed level 200 rpm and speed levels chosen by Babatunde (1995) there was enough time for the seeds to rub against each other and the wall of dehulling chamber before they were being conveyed out. The sudden rise in the dehulling efficiency between 150 and 250 rpm affirmed that beyond the mass of mixture attaining an acceptable residence time within the dehulling chamber, sufficient separating force must be attained for effective removal of cotyledon and testa from the seed (Lindley (1991).

Effect of Soaking Time on the Dehulling Efficiency of the Dehuller

Table 3 showed the effect of the soaking time on the dehulling efficiency of the dehuller for the four varieties examined. The soaking time at 6 minutes indicated the highest dehulling efficiency for all the varieties. At this soaking time it was noted that the highest values of the output capacity were recorded as shown in **Table 1**. All these soaking time levels for all the varieties were significantly different at P ≤ 0.01. This means that they did not have the similar effect on the dehulling efficiency of the dehuler. It was observed that all four varieties of cowpea seeds used behaved differently. The reason might be that cowpea seed as a biological material grouped into different varieties and each variety is known with a specific characteristic or attributes and these characteristics make them different from each other. Henshaw (2008) stated that Seeds varied in all horticultural properties and characteristics which could include physical (shape, size, colour, Moisture content), mechanical (hardness) or electrical characteristics. Cowpea variety Yari hausa gave the least mean value of dehulling efficiency, this might be that the variety had a stronger adhesive force between hull and the cotyledon taking a longer time for absorbed water to weakening force between them for easy detachment from each other, while IAR48 variety with highest mean value of dehulling efficiency mighty have a weaker adhesive force between the hull and the cotyledon making it to easily detach from each other. According to Sefa-Dedeh *et al.* (1978) and Sefa-Dedeh and Stanley (1979), Cowpea seeds with smooth seed coat texture tend to absorb less water than seeds with wrinkled seed coat. Seed coat texture could be an important selection index when processing cowpea seeds into flour, especially for ease of soaking and dehulling operations.

Table 3 Effect of Soaking Time on Dehulling Efficiency of the Dehuller using NDMRT for Four Varieties of Cowpea Seeds

Soaking Time (min)	Mean Dehulling Efficiency for Cowpea Varieties (%)			
	Yari Hausa	IAR 60/62	IAR48	Oloyin
2	63.6427[a]	73.7367[b]	86.1727[b]	72.9953[a]
4	66.1060[b]	76.2427[d]	88.5933[c]	75.2840[b]
6	71.9040[d]	78.2433[e]	91.2027[d]	79.3813[e]
8	68.8447[c]	75.5387[c]	88.6727[c]	76.4880[c]
10	66.4147[b]	72.4360[a]	85.6480[a]	77.7267[d]

Mean with different letters are significantly different from each other

Table 4 Effect of Speed of Operation on Cleaning Efficiency of the Dehuller using NDMRT

Operating Speed (rpm)	Mean Cleaning Efficiency for Cowpea Varieties (%)			
	Yari Hausa	IAR 60/62	IAR48	Oloyin
150	82.1727[d]	82.3067[d]	80.6280[d]	83.4720[d]
200	89.9753[e]	90.2373[e]	89.6093[e]	86.8620[e]
250	72.3860[c]	73.5100[c]	73.8233[c]	73.1107[c]
300	66.5460[b]	65.8000[b]	66.6013[b]	65.1833[b]
350	52.1233[a]	52.4053[a]	52.9220[a]	52.3660[a]

Mean with different letters are significantly different from each other

Table 5 Effect of Soaking Time on Cleaning Efficiency of the Dehuller using NDMRT

Soaking Time (min)	Mean Cleaninging Efficiency for Cowpea Varieties (%)			
	Yari Hausa	IAR 60/62	IAR48	Oloyin
2	72.3287[a]	72.2780[a]	72.1107[a]	71.8413[a]
4	72.3467[a]	73.2113[b]	72.2547[a]	72.1040[a]
6	73.3440[a]	73.4640[b]	73.2373[a]	73.0640[a]
8	73.0693[a]	73.3227[b]	72.9107[a]	72.5680[a]
10	72.1147[a]	71.9833[a]	73.0707[a]	71.4167[a]

Mean with different letters are significantly different from each other

Effect of Speed of Operation on the Dehulling Efficiency of Cowpea

Tables 4 and **5** showed that the

dehulling efficiency of Cowpea seeds for the four varieties increase with respect to the speed of operation of the dehuller machine, so also their soaking time increases but a point their dehulling efficiency began to gradually decrease as their soaking time continue to increase. This observations might be that as the seed is soaked the hull gradually absorbed water and as the water is absorbed it occupy the space between then and the adhesive force between the hull and cotyledon gets weaken, hence detaches from each other under any slight application of pressure on them. The soaking time at which there was a gradual decrease in their dehulling efficiency might be that their cotyledons had started absorbing the moisture that was between it and the hull by the principle of osmosis, thus leading to turgidity of the cotyledon as a result there could be no more space between them, leading to a stronger adhesive force and hence decrease in the dehulling efficiency of the dehuller. The highest dehulling efficiency for each variety ranges between 89.61% and 90.23%.

Effect of Soaking Time of Cowpea Seeds on the Cleaning Efficiency Dehuller

The soaking time of Cowpea seeds had significant effect on the magnitude of cleaning efficiency of the machine for IAR 60/62 and IAR48 varieties of cowpea seeds tested $P \leq 0.01$. While, for yari hausa and oloyin varieties of cowpea seeds, the soaking time of cowpea seeds had no significant effect on the magnitude of cleaning efficiency of the machine tested $P \leq 0.01$ (**Table 5**). The New Duncan Multiple Range Test (NDMRT) was used to show the levels of the soaking time of cowpea seeds that led to the significant difference in the cleaning efficiency of dehuller. From **Table 5** only IAR 60/62 showed very slight significant difference while from **Tables 4** and **5** yari hausa, IAR48 and oloyin varieties of cowpea seeds showed no significant difference. **Table 5** showed that all the levels of soaking time of yari hausa were not significant from each other at $P \leq 0.01$. It means that they all have similar effect on the cleaning efficiency of the machine. The effect of soaking time for all the varieties examined on the cleaning efficiency of the machine at soaking time level 6 mins had the highest mean value of cleaning efficiency.

Conclusions

The improved hydro-separating cowpea dehuller was designed and fabricated. Some of the components designed for and fabricated are hopper for feeding in the material, dehulling unit where dehulling operation takes place, cleaning unit where the hull (seed coat) is being separated from the cotyledon; and the shafts for the auger and the agitator for transmission of power to carry out the necessary operations. A performance test was carried out on the cowpea dehulling machine using four commonly available varieties of cowpea seeds. It was discovered that the cowpea seeds were effectively dehulled and the cotyledons were separated from the hull because the performance of the dehuller gave the lowest dehulling efficiency of 73.24% for Yari Hausa and highest value of 93.61% for IAR60/62. Also, the cleaning efficiency ranges between 81.85% for IAR60/62 and 79.96% for Oloyin.

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Effect of Conservation Tillage and Crop Residue Management on Soil Physical Properties and Crop Productivity of Wheat

by

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Abstract

Field experiments were carried out on a sandy loam (Typic -Ustochrept) soil in hot dry semi-arid subtropical climate of Meerut to study the effect of tillage systems and crop residue mulching with fertilizer application doze combination on soil physical properties (aggregate size distribution, mean weight diameter (GMD) and bulk density), chemical properties (soil organic carbon (SOC) and soil microbial biomass carbon (MBC)) and its plant growth parameters and yield continuous wheat (Triticum aestivum L. emend. Fiori & Paol) system during 2008-11. Two tillage systems and four crop residue mulching with recommended doze fertilizer (RDF) combination were factorially combined in a split plot design with three replications and each plot size was 5 length and 4 m width. The tillage systems (main plots) were: no tillage (NT) and conventional tillage (CT), i.e. 4 harrowing +1 tine cultivating and one patella. The rice crop residue used as mulching and fertilizer combination treatments (sub-plots) consisted of four M_1 - No mulch + recommended dose of fertilizer (RDF), M_2 - Mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), M_3 - Mulch (0) + 125% recommended dose of fertilizer (RDF), M_4 - Mulch (6 t ha^{-1}) + 125% recommended dose of fertilizer (RDF). Results revealed that ZT had higher MWDs and lower GMDs than CT at both depths. The MWDs decreased with increase in soil depth for both tillage (T) treatments as well as rice crop residue mulching (M) treatments. The bulk density were not affected significantly ($P < 0.05$) by tillage systems and crop residue mulching × recommended dose of fertilizer (RDF) application at both 0-15 and 15-30 cm soil depth. Tillage system did not influence significantly on SOC at both depths but MBC influenced significantly ($P = 0.05$) at upper depth (0-15 cm). The SOC and MBC were affected significantly ($P = 0.01$) by crop residue mulching with combination of recommended fertilizer application rate at upper depth (0-15 cm) but 15-30 cm, SOC was significantly at $P = 0.05$ but MBC had no significant different. The SOC was significantly higher value in ZT (5.61 gkg^{-1}) than CT (4.69 g kg^{-1}) at 0-15 cm soil depth. The SOC and MBC were recorded in ordered $M_4 > M_2 > M_3 > M_1$ which had significant difference value at $P = 0.01$.

The zero tillage showed significantly ($P = 0.01$) higher infiltration

rate (1.96 cm h^{-1}) than conventional tillage. The infiltration rate (IR) was significantly (P = 0.01) higher in M_4 (2.15 cm h^{-1}) followed by M_2 (1.97 cm h^{-1}). Tillage system influenced significantly (P = 0.05) on shoot dry weight and total biomass accumulation at all three growth stages i.e. ear emergence (EE), BGF and dough stages, however, on LAI at dough stage, it significant at P = 0.01. The growth parameters (LAI, shoot dry weight, root dry weight and total biomass accumulation) were influenced significantly (P = 0.01) by residue mulching with combination of recommended dose of fertilizer (RDF) at beginning grain filling (BGF) and dough stages, however, at ear emergence stage, it was only significant (P = 0.01) on shoot dry weight and total biomass accumulation. The higher grain yield value was observed in zero tillage as compared to conventional tillage. The highest grain yield of wheat crop was observed in M_4 (5.33 t ha^{-1}) and followed by M_2 (5.21 t ha^{-1}), M_3 (5.15 t ha^{-1}) and M_1 (4.62 t ha^{-1}) but difference among the treatments was non-significant.

Key words: Mean weight diameter (MWD), Geometric mean diameter (GMD), Soil organic carbon, Microbial bio-mass carbon, Bulk density, Infiltration rate (IR)

Introduction

Rice (*Oryza sativa L.*) - wheat (*Triticum aestivum L.* emend. Fiori & Paol) is the major cropping system covering 13.5 million ha in Indo-Gangetic plain (IGP) of South Asia and feeding 20% of world population is immense importance for the food security and livelihood of region (Ladha *et al*., 2009). The widespread adoption of high yielding cereals along with improved crop management practices and availability of irrigation water and chemical inputs during the Green Revolution (GR) has led to tremendous impressive increase in system productivity. The rice-wheat productivity is plateauing and total factor productivity is declining because of a fatigued natural resource base and therefore, sustainability of this cropping system is at risk (Saharawat *et al*., 2010).

Soil tillage is one of the fundamental agro-technical operations in agriculture because of its influence on soil properties (physical, chemical and biological) which creates favourable environment for plant growth. The continuous soil tillage strongly influences the soil physical and chemical properties due to degradation of soil structure (Lal 1998, Greenland 1981). The different tillage systems and crop residue may enhance soil organic matter and microbial biomass carbon and alter C and N dynamics. Tillage promotes soil organic matter decomposition through crop residue mulching onto surface soil, physical breakdown of residues, and disruption of soil organic matter protected within aggregates (Paustain *et al*., 2000, Six *et al*., 2000). No tillage farming systems usually help to maintain soil organic matter (SOM) and aggregate stability (Rhoton 2000), conserve soil moisture, maintain constant soil temperatures (Benegas 1998) and improve water infiltration rates (Battcharyya *et al*., 2008). No tillage also results in a better soil structure and in an extensive system of macro-pores (Martino and Shaykewich 1994), which benefits root growth (Lampurlanes *et al*., 2001). Crop residues are a source of soil organic matter, which are the primary source and temporary sink of plant nutrients and an energy source for soil microorganisms (Kanazawa and Philip 1986, Cater *et al*., 1994). No tillage, residue return and cropping system may enhance soil organic matter and microbial biomass and alter C and N dynamics. Cropping systems/ intensity trends to increase SOC and microbial biomass through greatest return of crop residues (Stromberger *et al*., 2007). Crop residues have been reported to increase soil organic fertility (Shafi *et al*., 2007, Bakht *et al*., 2009) which can improve microbial activity and nutrient supply (Shah *et al*., 2003b). Previous studies have shown that microbial biomass is higher in soils under no till plot as compared to conventional tillage practices (Alvear *et al*., 2005, Bausenwein *et al*., 2008, Spedding *et al*., 2004). Adoption of better management strategies such continuous cropping, reduced tillage, improved fertilization, application of organic amendments and crop rotations including perennial forage can increase the amount of organic C and/or N stored in the soil (Liang *et al*., 2002, Malhi *et al*., 2009). By minimizing soil disturbance, reduced tillage decreases the mineralization of organic matter. The result is a large store of soil organic carbon than with conventional tillage (West and Post 2002, Al-Kaisi and Yin 2005).

The present study aimed to: (iii) examine the effect of tillage and crop residue mulching on different soil physical properties (i.e. aggregate pattern and mean weight diameter (GMD) and bulk density). (ii) effect of tillage systems and crop residue mulching on soil organic carbon and microbial biomass carbon up to 0-15 and 15-30 cm soil depth; (ii) determine the effects of tillage systems and crop residue mulching on system productivity.

Materials and Methods

Field experiments with two tillage systems and four crop residues mulching with combination of fertilizer dozes (RDF) were factorially combined in a split- plot design with three replications, size of sub plots having of 5 m length and 4 m width each. The tillage systems (main plots) were: no tillage (NT) and conventional tillage (CT), i.e. 4 harrowing +1 tine cultivating and one patella. The rice crop residue used as mulching and fertilizer doses combination treatments (sub-plots) consisted of four M_1 - No mulch + recommended dose of fertilizer (RDF), M_2 - Mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), M_3 - Mulch (0) +125% recommended dose of fertilizer (RDF), M_4 - Mulch (6 t ha^{-1}) +125% recommended dose of fertilizer (RDF). The soil (0-15 cm deep) was sandy loam soil (63.7% sand, 19.1% silt and 17.2% clay) in texture (Typic -Ustochrept), having mildly alkaline (pH 8.20), non-saline (EC 0.27 dS m^{-1}) and low in soil organic carbon (4.4 g kg^{-1}).

The sowing of wheat (PBW-343), in both conventional and zero till plot, was performed by zero-till drill at line spacing 20 cm with seed rate of 100 kg ha^{-1} and it was grown with recommended package and practices. The crop received a recommended fertilizer dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}. One third of the N and all the P and K were applied before sowing, and the remaining urea-N was top-dressed in two equal splits, 30 and 55 days after sowing (DAS). For weed control in wheat, the chemical weed control was applied using Sulfosulfuron @ 25g active ingredient ha^{-1} + Metsulfuran methyl @ 4.00 g active ingredient ha^{-1} at 30 days after sowing (DAS). This helped to maintain a weed-free condition in all treatments throughout the seasons. Wheat was grown under assured irrigated conditions as per recommendation of crop.

The experiment farm is situated at latitude of 29° 40" North and longitude 77° 40" East at an elevation of 237 m above sea level and categorized in hot dry semi-arid subtropical climate with summers and severe cold winters. The average monthly minimum and maximum temperatures in January (the coolest month) were 7.2°C and 20.1°C, respectively. The corresponding temperatures in May (the hottest month) were 24.2°C and 39.8 °C, respectively. The 10-year average annual rainfall is 823 mm, and over 75% of this is received through north-west monsoon during July-September. During experimental period the average rainfall in kharif season (June-October) during 2007, 2008, 2009 and 2010 was 480, 210, 457 and 597 mm, respectively and in *rabi* (November- March) season during 2007-08, 2008-09, 2009-10 and 2010-11 was 39.4, 19 mm.

Soil samples were collected using cores (5 cm high and 3 cm diameter) for estimation of bulk density (0-15 cm and 15-30 cm soil depth) by gravimetric method and expressed in Mg m^3. Soil samples (0-15 cm and 15-30 cm soil depth) from each plot collected randomly from three spots with the help of a core sampler (10 cm internal diameter and 15 cm height) after the wheat crop harvest in the year 2010 at each treatment. The samples were air-dried and each sample was divided in two parts. One part was used for chemical analysis while other part was used for determination of aggregate size distribution (Yoder, 1936), mean weight diameter and geometric mean diameter.

Mean weight diameter (GWD, mm) of aggregates was calculated as follows.

$$\mathrm{MWD} = \sum_{i=1}^{n} (Xi.Wi)$$

Where *Xi* is the mean diameter of aggregates fraction *i* and *Wi* is the mass proportion of aggregates fraction i (Kemper and Rosenau, 1986)

Geometric mean diameter (GMD, mm) was calculated as follows.

$$\mathrm{GMD} = \exp\left[\sum_{i=1}^{n} (Wi.In\ (Xi)\right]$$

Where *Wi* is the mean proportion of aggregates fraction *i* and *Xi* is the mean diameter of aggregate fraction *i* (Kremper and Chepil 1965).

Infiltration characteristics were obtained from the measured infiltration data after 4 years of rice-wheat cropping (after the 2010 wheat harvest). Infiltration was determined using a double-ring infiltrometer.

Table 1 Significance the effects of experimental factors and their interaction on MWD and GMD at various depth of sample, as resulting from analysis of variance (ANOVA)

Source of variations	Soil depth (cm)			
	MWD		GMD	
	0-15	15-30	0-15	15-30
ANOVA				
Tillage system (T)	NS	NS	NS	NS
Residue mulching + RDF (M)	0.09**	0.04**	0.04**	0.10**
Interaction (M × T)	*	NS	NS	NS
Treatment				
Tillage systems (T)				
CT	0.25	0.17	0.41	0.49
ZT	0.29	0.21	0.41	0.4
Crop residue mulching + RDF (M)				
M_1	0.18	0.13	0.5	0.52
M_2	0.33	0.2	0.4	0.46
M_3	0.21	0.17	0.44	0.45
M_4	0.36	0.24	0.33	0.35

RDF: recommended dose of fertilizer, MWD: mean weight diameter, GMD: Geometric mean diameter

ZT indicates zero tillage and CT indicates conventional tillage. M1, M2, M3 and M4 indicates no mulch + recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), mulch (0) +125% recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) +125% recommended dose of fertilizer (RDF), respectively.

NS, Not significant, *Significant at $P<0.05$, **Significant at $P<0.01$.

Soil organic carbon (SOC) and microbial biomass carbon (MBC) were determined after harvest of *rabi* crop by following standard procedures. The plant growth rate parameters (i.e. LAI, shoot dry weight, root dry weight (samples at 0-30 cm soil depth as standard procedure), total biomass accumulation) were recorded at three different stages in wheat (i.e. ear emergence -EE (55 days after sowing), beginning of grain filling-BGF (68 days after sowing) and dough stage (85 DAS)). Leaf area index (LAI) during respective growth stages was monitored by canopy analyzer (Model LICOR-3000). LAI was calculated using the relationship LAI = total leaf area (cm^2)/canopy of the plant (length x breadth). The total biomass accumulation of plant (such as shoot, leaf and root dry weight per square meter of crop was estimated at different three growth stages as ear emergence (EE), beginning of grain filling (BGF) and dough stage. The clean root, shoot and leaf samples were first sun dried and thereafter in oven dried at 60±5°C for 48 hour, weighted and root dry weight and shoot dry matter were calculated as dry weight/ square meter. An area of 1 m^2 from each plot was harvested for determining the grain yield.

Statistical analysis was carried out using the methods suggested by Gomez and Gomez (1984). All parameters were analysed as a split plot model (tillage systems as main effect and crop residue and fertilizer application rate as split plot effect). The significant different among the means of different parameters with treatments wise were separated using the LSD at P <0.05 and 0.01.

Results and Discussion

Soil Parameter

The mean weight diameter (MWD) and geometric mean diameter (GMD) of soil aggregates were not significantly (even at P<0.05) influenced by tillage at both depth 0-15 and 15-30 cm depth (**Table 1**). At both depths, ZT had higher MWDs and lower GMDs than CT. The MWDs decreased with increase in soil depth for both tillage (T) treatments as well as rice crop residue mulching (M) treatments. The higher MWD was recorded in ZT (0.29 mm) as compared to CT (0.25 mm) at 0-15 cm soil depth, however, in 15-30 cm soil depth, it was significant (P<0.05) (i.e. 0.21 mm in ZT and 0.17 mm in CT). The GMDs (in either ZT or CT case 0.41 mm) had shown at par value in 0-15 cm depth, however, 15-30 cm, higher value in CT (0.49 mm) was observed than ZT (0.40 mm) but not significant. The MWD was significantly (P = 0.01) higher in M_4 (0.36 mm) than M_1 (0.18 mm) and M_3 (0.20 mm) and at par with M_2 (0.33 mm) at 0-15 cm. At 15-30 cm, the MWD decreased with depth and similar pattern was shown as in case of upper depth.

The GMD of aggregates was significantly (P = 0.01) higher in M_1 (0.50 mm) than M_3 (0.44 mm) which was at par with M_2 (0.40 mm). Significantly (P = 0.01) lower GMD was recorded in M_4 (0.33 mm) than other treatments at 0-15 cm soil depth. At 15-30 cm, significantly at par GMD were recorded in treatments M_1 (0.52 mm), M_2 (0.46 mm) and M_3 (0.45 mm). The treatments M_4 (0.35 mm) was significantly (P = 0.01) lower than other treatments.

Table 2 Significance the effects of experimental factors and their interaction on SOC, MBC and BD at various depth of sample, as resulting from analysis of variance (ANOVA)

Source of cariations	Soil depth (cm)						
	SOC (g kg^{-1})		MB-C (μg g^{-1})		BD (Mg m^{-3})		IR (cm hr^{-1})
	0-15	15-30	0-15	15-30	0-15	15-30	
ANOVA							
Tillage system (T)	NS	NS	20.7*	NS	NS	NS	0.13**
Residue mulching + RDF - (M)	0.60**	0.22*	26.7**	NS	NS	NS	0.08**
Interaction (M X T)	NS	NS	NS	NS	NS	NS	**
Treatments							
Tillage systems (T)							
CT	4.69	3.39	312	237	1.61	1.61	1.71
ZT	5.61	3.63	345	248	1.59	1.62	1.96
Residue mulching + RDF- (M)							
M_1	4.06	3.24	304	233	1.63	1.63	1.46
M_2	5.90	3.64	347	247	1.58	1.61	1.97
M_3	4.46	3.48	307	236	1.62	1.64	1.75
M_4	6.19	3.68	354	253	1.55	1.57	2.15

SOC, soil organic carbon, MBC, microbial biomass carbon, BD: bulk density, IR: Infiltration rate
ZT indicates zero tillage and CT indicates conventional tillage. M_1, M_2, M_3 and M_4 indicates no mulch + recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), mulch (0) +125% recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) +125% recommended dose of fertilizer (RDF), respectively.
NS, Not significant, *Significant at P<0.05, **Significant at P <0.01.

The interaction of tillage systems with crop residue mulching x fertilizer application rates (RDF) combination on MWDs and GMDs were non-significant ($P = 0.05$) at both depth except MWD was observed significant at 0-15 cm soil depth. Tillage significantly decreased MWD and increased GMD at both depths, although the differences were not always significant at both depth (i.e. 0-15 cm and 15-30 cm) layers. The reduction in MWD with CT could be mainly due to mechanical disruption of macro-aggregates from frequent tillage operations and reduced aggregate stability. This reduction in aggregates stability with tillage has been reported in the literature. Zotarelli *et al*., (2005) reported that the MWD of the aggregates was on average greater under ZT compared with CT. Similar result was also reported by Chen et al. (2009). Zibilske and Bradford (2007) showed that plow tillage had significantly lower GMDs than no tillage. The bulk density were not affected significantly ($P < 0.05$) by tillage systems and crop residue mulching x recommended dose of fertilizer (RDF) application at both 0-15 and 15-30 cm soil depth (**Table 2**). However, lower bulk density was recorded in ZT (1.59 Mg m^{-3}) as compared to CT (1.61 Mg m^{-3}). Lower, bulk density was recorded in M_4 (1.55 kg m^{-3}) than M_2 (1.58 Mg m^{-3}), M_3 (1.62 Mg m^{-3}) and M_1 (1.63 Mg m^{-3}) in upper depth 0-15 cm which were at par values. At 15-30 cm, comparatively higher bulk density was recorded varied from 1.57 to 1.64 Mg m^{-3} in all treatments. All the interactions were found non-significant. The crop residue mulching and recommended dose of fertilizer as in treatments (M_4) have reported lowest bulk density due to microbial activity which changes the physical status of soil. The more micro organism may reduce the bulk density. Crop residue mulch has been reported to improve soil quality in terms of organic carbon and biotic activity (Karlen *et al*., 1994, Lal 1989), and this might be the cause for lower bulk density, particularly near the soil surface in the no-till plots of this study.

Tillage system did not influence significantly on SOC at both depth 0-15 cm and 15-30 cm, however, crop residue mulching with combination fertilizer application rate influenced significantly ($P = 0.01$) at 0-15 cm but 15-30 cm, it was significantly at $P = 0.05$ (**Table 2**). However, tillage system influenced significantly ($P = 0.05$) on the MBC but crop residue mulching with combination fertilizer application rate influenced significantly ($P = 0.01$) at 0-15 cm but at 15-30 cm, there was no significant different. The SOC was significantly higher value in ZT (5.61 gkg^{-1}) than CT (4.69 g kg^{-1}) at 0-15 cm soil depth. However, in 15-30 cm, it was observed lower value as 3.63 g kg^{-1} in ZT and 3.39 g kg^{-1} in CT. The effect of treatment of crop residue mulching and recommended dose of fertilizer combination had shown significant ($P = 0.01$) results on SOC and MBC at 0-15 cm soil depth. On average, compared to M_1 (control), soil organic carbon (SOC) was 50.5 and 40.8% higher in M_4 and M_2, respectively. The treatments M_4 (6.19 g kg^{-1}) had significantly ($P = 0.01$) higher than M_2 (5.90 g kg^{-1}) and both treatments significantly ($P = 0.01$) greater as compared to M_1 and M_3 (4.06 and 4.46 g kg^{-1}) which had significant at par value. The SOC decreased with depth from 0-15 cm to 15-30 cm in all treatments and similar tread were observed among the treatments as in upper layer. The MBC in soil tended to be lower (significant $P = 0.05$) under CT (312 µg g^{-1}) compared to NT (345 µg g^{-1}). The MBC was recorded in ordered $M_4 > M_2 > M_3 > M_1$ which had significant difference value at $P = 0.01$. On average, MBC in treatment M_4 (354 µg g^{-1} soil) was significantly higher (at $P = 0.01$) with M_2 (347 µg g^{-1} soil) which also was significantly higher as compared to M_1 (304 µg g^{-1} soil) and M_3 (307 µg g^{-1} soil) which were non-significant in 0-15 cm soil depth. The significantly higher MBC was recorded in M_4 (354 µg g^{-1} soil) than other treatments, it was due to 6 t ha^{-1} and 125% of recommended dose of fertilizer (RDF). The similar pattern were also observed in 15-30 cm soil depth but it was not significant at $P = 0.05$, however, the MBC was reduced (varied from 23 to 29%) in lower depth as compared to upper depth. The interaction of tillage systems with crop residue mulching x combination fertilizer application rate (RDF) on SOC and MBC were non-significant ($P = 0.05$) at both the soil depth.

Elimination of soil mixing under NT leads to a concentration of organic matter at soil surface. In other terms, low storage of carbon under CT was probably due to high oxidation rates, release of organic compounds to soluble form, and greater microbial activity (Marbet *et al*., 2001). The higher SOC & MBC contents under residue treatments could be attributed to the beneficial effects of residue such as nutrient cycling and soil quality enhancement. Dalal *et al*. (1991) observed that in the surface soil layers, the interactive effects of zero tillage and returning residues resulted in higher SOC contents compared with zero and conventional tillage. The crop residue was retained (6 t ha^{-1}) and 125% recommended dose of fertilizer (RDF) application resulted in higher SOC due to greater numbers of microbes thus enhanced the microbial activity, with the highest SOC in the soil in M_4. It was also revealed that higher fertilizer application (i.e. 125% RDF) influenced the microbes' population due to increasing the decomposition of biomass available in the field which ultimately increases the SOC and MBC of the soil in upper depth (0-15 cm). Earlier research has shown that quality and /or quantity of organic matter in soil can be altered by tillage, crop

Table 3 Significance the effects of experimental factors and their interaction on growth parameters (LAI, shoot dry weight, root dry weight and total biomass accumulation) sample of wheat crop, as resulting from analysis of variance (ANOVA)

Treatment	Leaf area index (LAI)			Shoot dry weight (g m^{-2})			Root biomass (g m^{-2})			Total biomass accumulation (g m^{-2})		
	Ear emergence	BGF	Dough	Ear emergence	BGF	Dough	Ear emergence	BGF	Dough	Ear emergence	BGF	Dough
ANOVA												
Tillage system (T)	NS	NS	0.46**	86*	97*	197*	NS	10*	NS	89*	107*	196*
Residue mulching + RDF (M)	NS	0.21**	0.33**	98**	170**	211**	NS	31**	28**	103**	160**	202**
Interaction (M x T)	NS	**	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
Tillage system (T)												
CT	2.46	2.51	2.51	563	954	1123	59	84	137	622	1038	1260
ZT	2.11	2.74	3.28	415	1115	1641	51	102	156	465	1217	1798
Residue mulching + RDF (M)												
M1	1.89	2.07	2.46	383	844	1104	43	65	116	425	909	1220
M2	2.47	2.7	3.04	552	1108	1309	59	112	149	611	1220	1459
M3	2.04	2.56	2.75	433	939	1236	49	79	153	483	1017	1390
M4	2.75	3.16	3.32	587	1247	1879	69	116	166	656	1363	2045

LAI: Leaf area index, BGF: before grain filling, Dough: before physiological maturity
ZT indicates zero tillage and CT indicates conventional tillage. M_1, M_2, M_3 and M_4 indicates no mulch + recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), mulch (0) +125% recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) +125 % recommended dose of fertilizer (RDF), respectively.
NS, Not significant, *Significant at P<0.05, **Significant at P<0.01.

residue management and fertilization (Havlin *et al*., 1990, Nyborg *et al*., 1995). Tillage increases oxidation of soil organic matter (Doran and Scott-Smith 1987), while NT reduces its oxidation because of less mixing with soil (Doran 1980). Therefore, one would expect a substantial increase of SOC in soil under ZT compared to CT (Halvorson *et al*., 2002). Crop residues provide a source of organic matter, so when returned to soil the residues increase the storage of organic C in soil, whereas their removal results in a substantial loss of organic carbon (Solberg *et al*., 1997, Malhi and Lemke 2007).

The tillage system and crop residue mulching with combination fertilizer application rate influenced significantly (P = 0.01) on the steady state (basic) of infiltration rate (IR). Zero tillage showed significantly (P = 0.01) higher infiltration (1.96 cm h^{-1}) than conventional tillage. Steady state conditions, the infiltration rate (**Table 2**) was significantly (P = 0.01) higher in M_4 (2.15 cm h^{-1}) than M_2 (1.97 cm h^{-1}), M_3 (1.75 cm h^{-1}) and M_1 (1.46 cm h^{-1}). There were also significant differences each other at P = 0.01. The interaction of tillage systems with crop residue mulching x combination fertilizer application rate (RDF) on basic infiltration rate significant (P = 0.01).

More soil organic carbon and microbial biomass carbon in the zero tillage was arguably caused by less oxidation of the organic matter (crop & weed residues, root bio mass etc) due to less disturbance of soil by tillage. This might have possibly influenced the infiltration characteristics of the soil where initial water uptake was improve but not the final (steady) infiltration rate. In the absence of so called long-term effect, the macro-channels produced after decay of roots or due to earthworm activity under zero tillage (where the soil is left less disturbed unlike the conventional tillage) are likely to have extended to surface, producing continuity in pores and water movement. The steady state infiltration rate is mostly controlled by the soil profile and less by soil surface, rate of infiltration is higher under zero tillage (Saha *et al*., 2010).

Crop Growth Parameters (I.E. Leaf Area Index (Lai), Shoot & Root Dry Weight and Total Biomass Mass Accumulation)

The leaf area index (LAI), shoot dry weight, root dry weight and total biomass accumulation (**Table 3**) were influenced significantly (P = 0.01) by residue mulching with combination of recommended dose of fertilizer (RDF) - M at beginning grain filling (BGF) and dough stages, however, at ear emergence stage, it was only significant (P = 0.01) on

Table 4 Significance effects of experimental factors and their interaction of wheat crop on crop growth, yield attributes parameters and yield, as resulting from analysis of variance (ANOVA)

Treatment	Plant height (cm)	Number of tillers (Nos. / m^2)	Spikes length (cm)	Number of spikelet (Nos./ ear)	Number of grains (Nos./ ear)	Test weight (g)	Grain yield (t ha^{-1})
ANOVA							
Tillage system (T)	NS	NS	NS	NS	NS	NS	NS
Residue mulching + RDF (M)	NS	NS	NS	1.72**	9**	NS	NS
Interaction (M x T)	NS	NS	NS	NS	NS	NS	NS
Treatments							
Tillage system (T)							
CT	99.42	129.44	10.54	19.25	58.25	35.26	5.15
ZT	103.08	139.72	11.08	20.25	66.75	36.08	5.16
Residue mulching + RDF (M)							
M_1	99.33	120.33	10.25	17.5	58.33	34.38	4.92
M_2	101.33	140.22	11.07	20.83	64.83	36.14	5.21
M_3	100.67	133.78	10.77	19	59.17	35.22	5.15
M_4	103.67	144	11.15	21.67	67.67	36.95	5.33

ZT indicates zero tillage and CT indicates conventional tillage. M_1, M_2, M_3 and M_4 indicates no mulch + recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), mulch (0) +125% recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) +125 % recommended dose of fertilizer (RDF), respectively.
NS, Not significant, *Significant at P<0.05, **Significant at P<0.01.

Table 5 Significance effects of experimental factors and their interaction on yield of wheat crop, as resulting from analysis of variance (ANOVA)

Source of variations	Sep-08	Oct-09	Nov-10	Dec-11	Pooled data
	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})
ANOVA					
Tillage system (T)	NS	NS	NS	NS	NS
Residue mulching + RDF (M)	0.04**	0.25**	0.19*	0.19*	**
M X T	NS	NS	NS	NS	NS
Treatment					
Tillage systems (T)					
CT	4.87	4.96	5.05	5.15	5.00
ZT	4.94	5.02	5.08	5.16	5.05
Residue mulching + RDF (M)					
M_1	4.71	4.79	4.84	4.92	4.82
M_2	4.93	5.03	5.13	5.21	5.07
M_3	4.86	4.95	5.05	5.15	5.00
M_4	5.13	5.18	5.24	5.33	5.22

ZT indicates zero tillage and CT indicates conventional tillage. M_1, M_2, M_3 and M_4 indicates no mulch + recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) + recommended dose of fertilizer (120:60:40 kg NPK) (RDF), mulch (0) +125% recommended dose of fertilizer (RDF), mulch (6 t ha^{-1}) +125% recommended dose of fertilizer (RDF), respectively.
NS, Not significant, *Significant at P<0.05, **Significant at P<0.01.

shoot dry weight and total biomass accumulation. Tillage system influenced significantly ($P = 0.05$) on shoot dry weight and total biomass accumulation at all three growth stages i.e. ear emergence (EE), BGF and dough stages, however, on LAI at dough stage, it significant at $P = 0.01$.

Zero tillage treatment has shown higher value as compared to conventional tillage but not significant in respect of all parameters. Significantly ($P = 0.01$) higher growth parameters (i.e. LAI, shoot dry weight, root dry weight and total biomass accumulation) at almost three stages were observed in treatments M_4 than M_2 , M_1 and M_3. Except at ear emergence stage of LAI and root biomass, the treatments M_4 was noticed at pat with other treatments (**Talbe 3**). The lowest all growth parameters were observed in M_1 and most of cases it was at par with M_3. The interaction of tillage system with crop residue mulching and combination of RDF was significant at $P = 0.01$ on LAI at BGF and root biomass at dough stage but other all interactions were not significant.

Yield Attributes and Grain Yield

The yield attributes of wheat (i.e. plant height, number of tillers and test weight) were not significantly ($P = 0.05$) affected by the tillage systems and crop residue mulching with combination of recommended dose of fertilizer (RDF), however, the number of spikelets/ear (**Table 4**), number of grains/ear were observed significant ($P = 0.01$) of crop residue mulching with combination of recommended dose of fertilizer (RDF). However, higher value was observed in zero tillage as compared to conventional tillage ultimately greater grain yield was also noticed in zero tillage.

Significantly higher number of spikelet and number of grains per ear was observed in M_4 which was at pat with M_2 (**Table 4**). Other parameters (i.e. plant height, number of tillers, spike length and test weight) were found not significant. The highest grain yield of wheat crop was observed in M_4 (5.33 t ha^{-1}) and followed by M_2 (5.21 t ha^{-1}), M_3 (5.15 t ha^{-1}) and M_1 (4.92 t ha^{-1}) but difference among the treatments was non-significant (**Table 5**).

Conclusions

The highest growth parameters (LAI, shoot dry, total biomass accumulation) and ultimately productivity of wheat crop was recorded in plot where 25% higher fertilizer and 6 t ha^{-1} (M_4) was applied than others treatments. It was concluded that wheat sown in zero tilled strip had significantly higher SOC and MBC contents while it was lowest in conventionally sown.

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Design and Development of Pedal Operated Ragi Thresher for Tribal Region of Odisha, India

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Abstract

Ragi is an important millet crop and a major source of energy rich food of tribal people of Odisha. It is mostly grown in hilly regions of Koraput, Ganjam, Rayagada, Gajapati, Kalahandi districts of Odisha in India. Threshing of ragi in traditional method is very time consuming, tedious and labourious activity. Also, the output capacity is very low, less economic and produces low quality product. As most of the tribal have small land holding, poor economy, insufficient power supply and poor transport facility, a pedal operated ragi thresher was developed for the tribal regions of Odisha. The maximum threshing and cleaning efficiency of the developed thresher was found to be 95.3% and 95.2%, respectively. The average threshing efficiency, cleaning efficiency, grain damage and total grain loss were obtained as 92.2%, 93%, 2.3% and 2.5%, respectively.

Keywords: Ragi, Tribal, Traditional, Threshing, Cleaning and Efficiency

Introduction

Ragi (*Eleusine Coracana*) also known as finger millet is very important small millet of Poaceae family, which is a major food of tribal people of Odisha state of India. The crop occupies 2.5 million hectare area and produces 2.6 million tonne of grain in India. It is mostly grown in hilly regions of Karnataka, Odisha, Tamil Nadu, Andhra Pradesh states and also in North-western Himalaya of India (Singh and Mishra, 2008). Odisha stands second after Karnataka in production of ragi by producing 11% of total production in India. The production was about 151.42 thousand tonne from 169.22 thousand hectare area with yield of 895 kg/ha. In Odisha, ragi is mostly cultivated by tribal people in Koraput, Ganjam, Rayagada, Gajapati and Kalahandi districts. Ragi is a good source of energy as it is rich in carbohydrates, proteins, minerals and dietary fibres. Ragi contains amino acid, methionine and lysine, which are essential for the poor people. It is consumed in form of cooked cakes, puddings or porridge. As compared to rice, it provides eight times more calcium, four times more minerals and four times more phosphorus per unit grain consumption. The 100 grams of ragi grain contains 88 g carbohydrate, 7.3 g protein, 1.3 g fat, 2.7 g minerals, 344 mg calcium, 3.6 g fibre, 0.33 mg thiamine (B1), 0.11 mg riboflavin (B2), 1.2 mg niacin (B3) and 328 kCal of energy (Barbeau and Hilu, 1993; Malleshi, 2005).

Odisha is having 62 tribes with a population of 84.51 million. The tribal people in Odisha occupy 22.1% of total area mostly located in hilly regions and not connected with road and electricity. In tribal areas, the threshing of ragi is done generally by traditional method, i.e. by manual beating with a stick on a hard surface. The traditional method of ragi threshing is very tedious, time consuming, less efficient, uneconomical process (Singh and Mishra, 2010). The output is very low and produces low quality products (Singh *et al.*, 2003; Singh and Mishra, 2010). Therefore, a pedal operated ragi thresher was designed and developed for the tribal people of Odisha.

Materials and Methods

A pedal operated ragi thresher was developed and evaluated by taking the Chilika variety of ragi as raw materials. Threshing efficiency, grain damage, cleaning efficiency and total grain loss were measured. The design considerations were as below.

Design of Feed Hopper

The hopper was designed on the basis of bulk density of crop, quantity of crop to be fed each time and angle of repose of the crop. The calculation was done by using the following equations,

$V \geq W / BD$ ....(1)

Where,

V = volume or holding capacity of the feed hopper, m^3

W = quantity of crop fed into the feed hopper during each filling, kg

BD = bulk density of the crop, kg/m^3

For ensuring smooth and continuous gravity flow of the ear heads from the hopper to the cylinder,

$\Theta_h \geq \Theta$ ....(2)

Where,

Θ_h = angle of inclination of the feed hopper to the horizontal, degrees

Θ = angle of repose of the crop, degrees

The feed hopper was designed for of 3 kg capacity of ear heads. The feed hopper was of rectangular shape, tapered with a slope of 45° towards the threshing chamber. The length, width and height of the hopper were 340, 260 and 200 mm, respectively. One shutter was provided which can be easily moved forward and backward manually to control the feed rate. The size of outlet of hopper was 180 mm × 80 mm. The hopper is supported by 25 × 25 × 3 mm mild steel angle which was welded to main frame.

Design of the Threshing Unit

Threshing drum

Threshing of ragi requires both impact and shear forces for better operation (Singh *et al.*, 2008). A combination of MS flat and canvas strips were used as threshing element which gave less broken grains than the iron face of the rasp bar type cylinder (Saiedirad and Javedi, 2011). The cylinder drum consisted of six bars at a gap of 48 mm and 60° angle.

$L = q / q_{a} \times R_b$ ....(3)

Where,

L = length of drum, m

q =feed rate of crop, kg/s

q_a = allowable feed rate, kg/s/m

R_b = no. of bars

The length of drum was found to be 260 mm. A canvas strip of size 260 × 25 × 5 mm was riveted in between two MS flats strips of size 260 × 25 × 5 mm welded on the cylinder longitudinally.

Diameter of drum was calculated by the formula,

$A_d / A_r = 3$ ....(4)

Where,

A_d =Peripheral area of threshing drum, mm^2

A_r = Total area of rasp bars, mm^2

The diameter of the threshing drum was obtained as 150 mm diameter.

Speed of threshing drum

$N = (v \times 60) / \pi D$ ....(5)

Where,

N=No. of revolutions of drum, rpm

v = peripheral velocity, m/s (2.75 m/s for threshing of ragi)

D = Diameter of cylinder, m

The drum speed was obtained as 350 rpm.

Threshing cylinder shaft

The shaft used in the thresher was a solid circular cross-section made of MS rod for transmitting power and rotational motion through chain drive arrangement. The shaft was subjected to shear stress due to rotational motion and bending stress due to weight of the elements over it such as pinion, coverings in addition to its self-weight and maximum permissible dynamic load on it. Also, the shaft should be designed to sustain adequate torsional strength to transmit torque and not to be over stressed. Therefore, the shaft is to be designed to sustain a combination of bending and torsional loads. The shaft is supported on two bearings. So the maximum bending moment produced on it was obtained from the equation given by Sarangi (2013),

$M = W / 2 \times L / 2$ ....(6)

Where,

M = Maximum bending moment, kg-m

W = Weight of the shelling unit on the shaft, kg

L = Distance between the two bearing, m

The developed torque was calculated from the equation considering, a person can develop 0.1 hp.

$HP = 2\pi NT / 4500$ ....(7)

Where,

HP = Horse power produced by the operator (better to use kW or Watts for power as all units are in SI)

N =Revolution per minute of the shaft, rpm

T = Torque developed, kg-m

For safety, maximum torque transmitted was taken.

The equivalent torque given by Guest's theory,

$Teq = \sqrt{(T^2 + M^2)}$ ....(8)

When a pure torque acts on a circular shaft the relation between applied moment and internal stress is given by the equation,

$T / J = Fs / r$ ....(9)

Where,

T = the applied torque, kg-cm

J = polar moment of inertia of shaft, cm^4

Fs = torsional shear stress, kg/cm^2

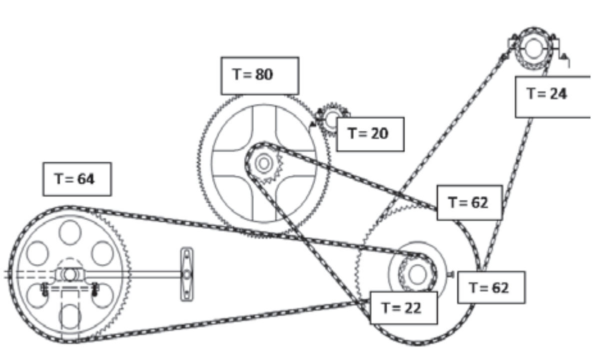

Fig. 1 Transmission system of the thresher

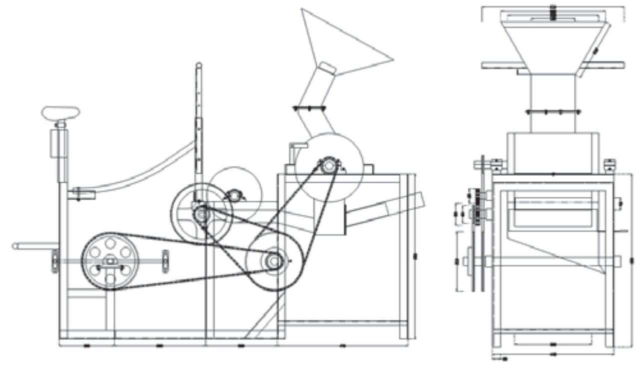

Fig. 2 Diagram of front and side view of the thresher

r = distance from neutral axis to the outer most fibre, cm

For round solid shaft, Polar moment of inertia is given by,

$J = \pi / 32 \times d^4$

So,

$Fs = 16T / (\pi d^3)$ *or* $d = (16T / \pi Fs)^{1/3}$ ......(10)

Combining equation (8) and (10), we get

$d = [(16\sqrt{(T^2 + M^2)}) / \pi fs]^{1/3}$ (11)

The size of the shaft was found to be 25 mm.

Design of Blower

The blower of ragi thresher should be designed by taking air flow rate into consideration. The air flow rate should be equal to feed rate and velocity of air should be equal to terminal velocity of bhusa.

$Z = 2.50 \times 10^{-6}Q + 0.4 \times 10^{-9}Q^2$ ......(12)

Where,

Z = amount of bhusa, kg/min

Q = air flow rate, m^3/min = d. b. v

d = diameter of the blower, m

b = width of blade, m

v = velocity of air, m/s = 4 m/s (< terminal velocity of the grain = 4.46 m/s)

The blower comprises of three blades of size 250 × 75 × 1.25mm each mounted on the cylinder shaft.

Design of Screen

The size and shape of the grain was considered for the design of the cleaning screen to be used in the thresher. A round opening screen of 2 mm size hole was used for passage of grain after threshing according to the spherical shape of the ragi grain.

Design of Transmission System

Since, the thresher is a pedal operated thresher, a chain and sprocket system can be used for power transmission to blower unit and threshing cylinder. **Fig. 1** shows the transmission system of the developed pedal operated ragi thresher. A pedalling rate of about 30-60 rpm is sufficient for the threshing operation.

Velocity of chain, $i = N_1 / N_2 = Z_2 / Z_1$ ......(13)

Where,

N_1, N_2 = Speed of rotation of the driving and driven shaft, rpm

Z_1, Z_2 = Number of teeth of the driving and driven sprocket

Main Frame

The main frame was fabricated using angle iron of size 30 × 30 × 3 mm for mounting the cylinder, blower and other parts. The components were assembled on the main frame using nuts and bolts. **Fig. 2** shows the CAD drawing of the proto-type of pedal operated ragi thresher. The specifications of developed pedal operated ragi thresher are given in **Table 1**.

The pedal operated ragi thresher

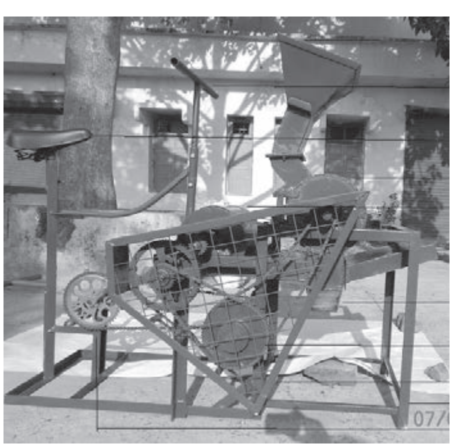

Fig. 3 The developed pedal operated ragi thresher

Table 1 Specification of developed pedal operated ragi thresher

Components	Dimensions
Weight	57 kg
Overall Length × Width × Height	1,170 × 480 × 850 mm
Hopper height	1,170 mm
Hopper size	340 × 260 × 200 mm
Threshing cylinder	260 × 150 mm
Canvas size	260 × 25 × 5 mm
Blower blades	250 × 75 mm
Transmission unit	Chain and sprocket
Seat height	850 mm
Handle height	1,160 mm
Handle width	460 mm

was designed and a prototype was developed at OUAT, Bhubaneswar, Odisha, India (**Fig. 3**). The performance evaluation of the developed pedal operated ragi thresher was conducted to determine the best suitable threshing cylinder speed, threshing element and air velocity for maximum threshing efficiency and cleaning efficiency with minimum grain damage and least grain loss. The performance of developed ragi thresher was compared with the traditional method of hand beating of the crop.

Results and Discussion

Performance Evaluation of the Thresher

The performance of the developed thresher was evaluated at different levels of cylinder speed, threshing elements and air velocity. The experiment for the evaluation was statistically designed as a three factor Randomized Block Design (RBD) with three replications. Observations like threshing efficiency, cleaning efficiency, grain damage and total grain loss were recorded.

Threshing efficiency

The mean values of threshing efficiency for all cylinder speed and threshing element are presented in the **Table 2**. The average threshing efficiency was obtained as 92.2%. The threshing efficiency with threshing element of canvas and rubber was obtained as 93.1% and 91.2%, respectively. This may be due to the reason that rubbing action of canvas is more due to the hard and rough surface than the rubber which leads to better threshing.

As cylinder speed increases, the impact load on the grain increases which leads to more detachment of the grains from the ear heads (Dhananchezhiyan *et al*., 2013; Gbabo *et al*., 2013).The interactions between cylinder speed and threshing element showed that maximum threshing efficiency was obtained in the combination of 3.5 m/s cylinder speed and canvas threshing element. ANOVA shows that the threshing efficiency was influenced significantly with cylinder speed and threshing element with all combination of levels at 1% significance level.

Grain damage

The mean values of grain damage for all cylinder speed and threshing element are presented in the **Table 3**. The average grain damage was obtained as 2.3%. The grain damage with threshing elements of canvas and rubber was obtained as 2.3% and 2.2%, respectively. It was also observed that the grain damage increased with increase in cylinder speed.

As cylinder speed increases, the impact load on the grain increases which causes the damage to the grain (Asli-Ardeh *et al*., 2009; Alizadeh and Khodabakshipour, 2010; Saiedirad and Javedi, 2011). The grain damage with canvas type threshing element was higher as compared to rubber due to the reason that hardness and surface roughness of canvas was more than that of rubber. ANOVA shows that the grain damage was influenced significantly by the cylinder speed and threshing element at all combination of levels at 1% significance level.

Cleaning efficiency

The cleaning efficiency was evaluated and the mean values for all cylinder speed and air velocity are presented in the **Table 4**. The average cleaning efficiency was obtained as 93%. The cleaning efficiency increased from 91.2 to 94.7% as the air velocity increased from 2.4 to 4.0 m/s. The minimum carrying velocity of chaff was observed as 2.3 m/s. So, as the air velocity increases the carrying amount of chaff also increases, which lead to increase in cleaning efficiency. The cleaning efficiency increased from 90.5 to 95.2% as the cylinder speed increased from 2.2 m/s to 3.5 m/s. This may be due to the reason that at increased level of cylinder speed, the chaff became finer and carried away by the air easily (Gbabo *et al*., 2013). The interactions between the cylinder speed and air velocity showed that better cleaning efficiency was obtained in the combination of 3.5 m/s cylinder speed and 4.0 m/s air velocity. ANOVA shows that the cleaning efficiency was significantly influenced by all the air velocity and cylinder speed at 1% significance level.

Total grain loss

The total grain loss includes the loss of grain through the chaff which was blown out. The observations were taken and the mean values of grain loss for all cylinder speed and air velocity were presented in the **Table 5**. The average value of grain loss was obtained as 2.5%. The total grain loss increased from 1.1 to 4.3% as the air velocity increased from 2.4 to 4 m/sand the cylinder speed increased from 2.2 - 3.5 m/s. The minimum terminal velocity of grain was observed as 4.3 m/s. So with the increase of air velocity the amount of blown away

Table 2 Threshing efficiency at different cylinder speed and threshing element (%)

Threshing element	Cylinder speed, m/s		
	2.2	2.75	3.5
Canvas	90.2	93.7	95.3
Rubber	88.7	91.6	93.3

Table 3 Grain damage at different cylinder speed and threshing element (%)

Threshing element	Cylinder speed, m/s		
	2.2	2.75	3.5
Canvas	1.02	2.16	3.86
Rubber	0.96	2.06	3.76

Table 4 Cleaning efficiency at different cylinder speed and air velocity (%)

Air velocity	Cylinder speed, m/s		
	2.2	2.75	3.5
2.4 m/s	90.5	91.3	91.7
3.0 m/s	92.7	93.3	93.6
4.0 m/s	94.2	94.8	95.2

grains might be increased. This may be due to the reason that the increased speed allowed some grain to pass off with the chaff (Sessiz and Ulger, 2003; Vejasit and Salokhe, 2004).The total grain loss between the interactions of cylinder speed and air velocity showed that grain loss was minimum at the combination of 2.2 m/s cylinder speed and air velocity of 2.4 m/s and does not depend on the type of threshing element used. ANOVA shows that the total grain loss was significantly influenced by the cylinder speed and air velocity at 1% significance level.

Conclusions

The pedal operated ragi thresher was designed and developed for the tribal region of Odisha. The performance evaluation was done and the average threshing efficiency, cleaning efficiency, grain damage and total grain loss was obtained as 92.2%, 93%, 2.3% and 2.5%, respectively. However, the highest threshing efficiency obtained was 95.3% with canvas type threshing element. The highest cleaning efficiency of 95.2% was achieved at air velocity of 4.0 m/s and cylinder speed of 3.5 m/s. The lowest grain damage of 0.96% was obtained with rubber type threshing element and the total grain loss of 1.1% at air velocity of 2.4 m/s and cylinder speed of 2.2 m/s.

Therefore, it was recommended to operate the developed pedal operated ragi thresher at 2.75 m/s cylinder speed having canvas type threshing element, as there was high threshing efficiency (93.7%) and less grain damage (2.16%).

Table 5 Total grain loss at different cylinder speed and air velocity (%)

Air velocity	Cylinder speed, m/s		
	2.2	2.75	3.5
2.4 m/s	1.1	1.2	1.3
3.0 m/s	2.1	2.3	2.4
4.0 m/s	3.9	4.1	4.3

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Performance Evaluation of Power Weeders for Paddy Cultivation in South India

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Abstract

Weed management in paddy field is a laborious and cumbersome task. In many small paddy farms of south India, currently manual weeding is being followed. The objective of this study was to evaluate the performance of commercially available power weeders (Model A, Model B and Model C) in comparison to manual weeding. The weeding efficiency and field efficiency of power weeders were in the range of 60 to 64% and 76 to 78%, respectively. Similarly, the plant damage due to power weeders was in the range of 1.2 to 2.7%. The highest field capacity was observed in Model A (0.13 ha/h) followed by Model C (0.09 ha/h) and Model B (0.07 ha/h). While adopting any power weeder, the farmer would be able to save 56 to 64% of weeding cost and 95 to 97% of time over manual weeding.

Key words: paddy, power weeder, plant damage, weeding efficiency, field capacity

Introduction

India is the second largest producer of rice (*Oryza sativa* L.) in the world (USDA, 2013). The area under rice cultivation in India has been increased from 31 million hectares in 1953-54 to 44 million hectare in 2011-12, with productivity increase from 902 kg/ha to 2,372 kg/ha during the above period (Ministry of Agriculture, 2013). The production of rice in India was about 106 MT in 2012-13, which accounted 22% of global production (473 MT) (International Grains Council, 2014).

Weed control is a major operation in agricultural production. In India, about 4.2 billion rupees (approximately 62 Indian rupees (Rs) = 1 US $) are spent every year for controlling weeds in the production of major crops. At least 40 million tons of major food grains are lost every year due to weeds alone (Singh and Sahay, 2001). The reduction in yield due to weed is predicted to be 16 to 42% depending on crops and location, and it involves one third of the cost of cultivation (Rangasamy *et al*., 1993). Delay and inattention in weeding operation affect the crop yield up to 30 to 60% (Singh, 1988). Rice and groundnut are very sensitive crops to weed, especially in the early stages and results in 50% yield reduction if failed to control (Gunasena and Arceo, 1981). Experiments revealed that competition of just one kind of weed namely Echinochloa crus-galli in paddy fields decreased around 25% of rice yield (Islam and Haq, 1991).

In general, different types of weed control such as chemical, manual, mechanical, biological and agronomical methods are followed in paddy cultivation (Mohammad, 2011). Chemical methods are more prominent than manual and mechanical methods, but it produces more adverse effects on environment. Therefore, the current trend is moving towards non-chemical weed control methods (Olaoye *et al*., 2011). The manual weeding is effective in paddy fields, however it requires 25% of the total labour requirement (900-1200 man-hours/ha) of entire crop production (Nag and Dutta, 1979). The man power requirement for manual weeding depends on weed flora, weed intensity, time of weeding, soil moisture and efficiency of worker (Goel et at., 2008).

At present, India is facing increased cost for agricultural production mainly due to the growing trend in man power shortage, higher wages and input material cost. Therefore, it is highly beneficial to mechanize (partial or complete) wherever possible in agricultural operations. Furthermore, mechanical weed control not only uproots the weed between rows, but also keeps the soil surface loose, ensuring better soil aeration and water intake capacity (Yadav and Pund, 2007; Goel *et al*., 2008). In addition, it helps to reduce drudgery involved in manual weeding where weeding is mostly done by women (Mohammad, 2011).

Kepner *et al.* (1982) and Buckingham (1976) recommended mechanical weed control methods to enhance the plant growth and quality of the crops. Hence, the objective of this study was to evaluate the field performance of commercially available three power weeders in comparison with manual weeding.

Table 1 Specification of tested power weeders

Category	Model A	Model B	Model C
	(Three row weeder)	(Two row weeder)	(Two row weeder)
Power (hp)	2	1.8	1.75
Engine displacement (cm^3)	40.2	30.8	42.7
Number of row covered	3	2	2
Row spacing adjustment	fixed	fixed	adjustable
Width of operation (cm)	18	16	18
Weight (kg)	18	10.5	18
Fuel consumption (l/h)	1.1	0.5	0.7

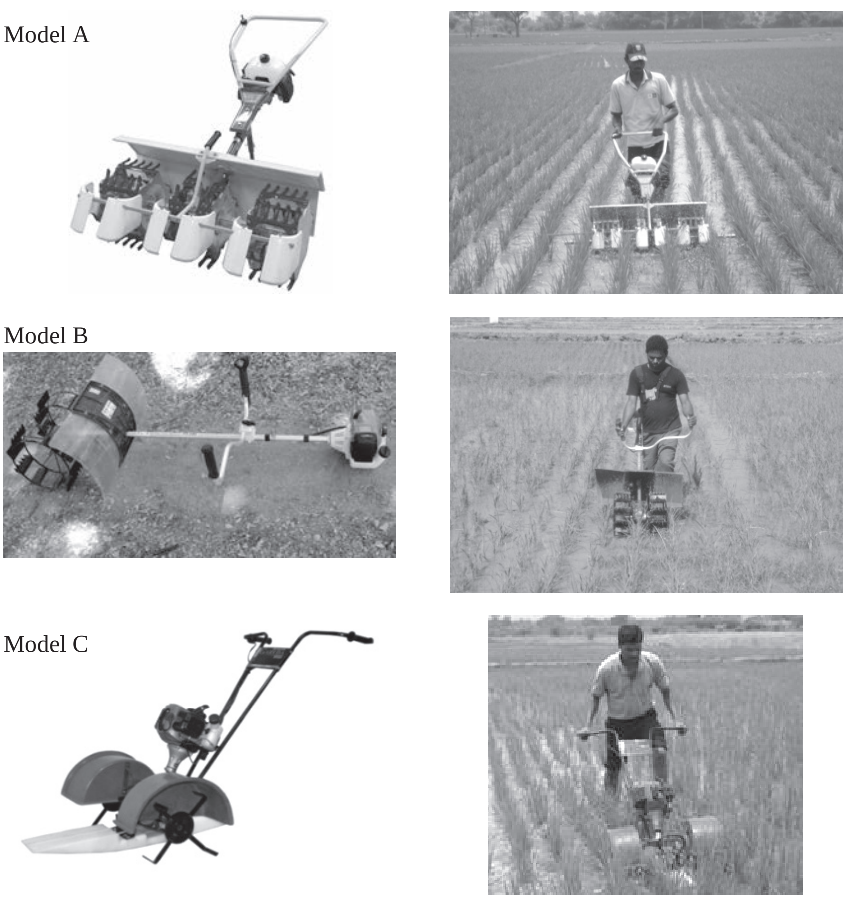

Fig. 1 Pictorial and operational views of tested power weeders

Material and Methods

Experimental Field

The experiments were conducted in row transplanted (manual or mechanical) farmer's field in Tamil Nadu, India. The study plots were cultivated with the popular paddy varieties such as ADT43, ADT45 and CO43. The height of the plant was 22 to 30 cm and depth of standing water was about 3 to 4 cm in all the tested fields. The fields were affected by common wetland weeds like Echinochloa colona (L.) Link (Jungle rice), Marsilea quadrifolia L. (Pteridophyta), Cynodon dactylon (L.) Pers and Bergia ammannioides.

Power Weeders

Three commercially available power weeders Model A, Model B and Model C were used in this study. The operational views of the tested power weeders are shown in **Fig. 1**, and the specifications of weeders are given in **Table 1**. All weeders had single cylinder, 2-stroke petrol engine. In Model A and Model B, row spacing was fixed and in model C three row spacing adjustment was provided (20 to 30 cm).

Performance Indicators

The experiments were conducted as per RNAM test code (1983) (Regional Network for Agricultural Machinery, Philippines). All weeders were tested for 20 hours in 5 different fields at 1.8 km/h operation speed. Before starting the experiments, details about the paddy plants (plant height and number of plants in 10 m row length), weeds (weed height and weed population (number of weeds per square meter)) and standing water height were recorded at ten different locations in each field. Similarly, fuel consumption, area coverage, width of operation, number of damaged plants (in 10 m row length) and weed population after operation were recorded during the field evaluation. The collected data were used to assess performance of the weeders such as weeding efficiency (%), plant damage (%), effective field capacity (ha/h), and field efficiency (%).

Weeding efficiency

The weeding efficiency is the ratio between number of weeds removed by a weeder to number of weeds present in the field before weeding in unit area. Generally it is calculated by Eqn. 1 (Anonymous, 1985):

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

Where,

W_1 = Number of weeds present before weeding in 1 m^2 area of the field

W_2 = Number of weeds present after weeding in 1 m^2 area of the field

Plant damage

The plant damage is the ratio between the numbers of damaged plants in a row after weeding to the number of plants present in that row before weeding, and calculated by Eqn. 2 (Gupta, 1981):

$$\textit{Plant damage (\%)} = Q_2 / Q_1 \times 100 \text{ ......Eqn. 2}$$

Where,

Q_1 = Number of plants in 10 m row length of field before weeding

Q_2 = Number of damaged plants in 10 m row length of field after weeding

Field capacity

a) Theoretical field capacity

Theoretical field capacity is defined as the area covered by the machine based on width of implement and speed of operation and calculated by Eqn. 3 (Kepner *et al*., 1982)

$$\textit{Theoretical field capacity (ha/h)} = (W \times S) / 10 \text{ .... Eqn. 3}$$

Where,

W = Width of the implement (m)

S = Speed of the operation (km/h)

b) Effective field capacity

Effective field capacity is actual area covered by the machine in given time.

Field efficiency

The field efficiency is the ratio of effective field capacity to theoretical field capacity and expressed in percentage (Eqn. 4) (Hunt, 1995):

$$\textit{Field efficiency (\%)} = \textit{(Effective field capacity) / (Theoretical field capacity)} \times 100 \text{ ....Eqn. 4}$$

Cost Analysis

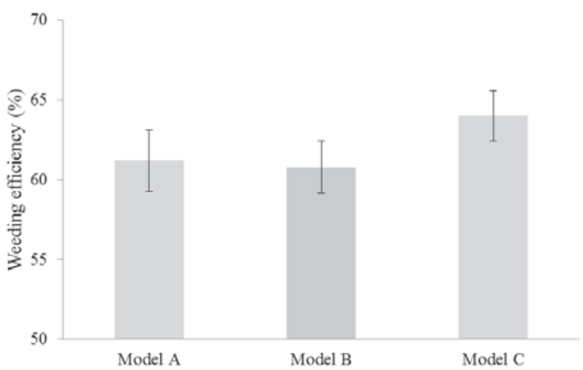

Fig. 2 Efficiency of tested power weeders

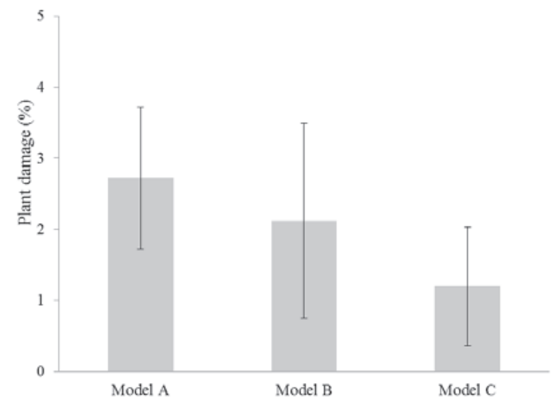

Fig. 3 Percentage of plant damage during weeding

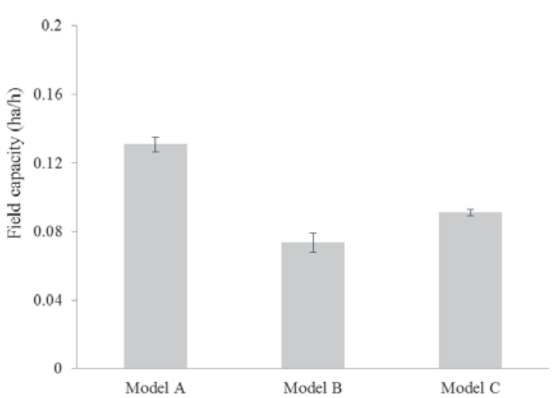

Fig. 4 Field capacity of tested power weeders

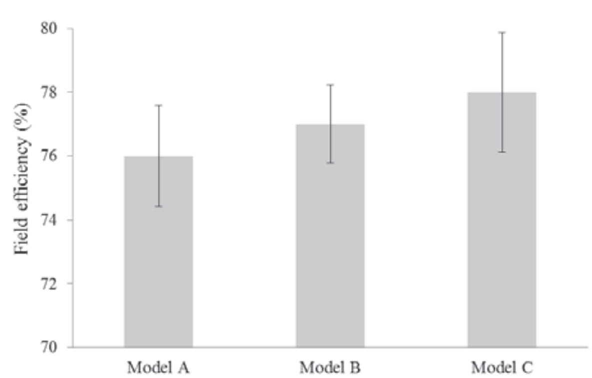

Fig. 5 Field efficiency of tested power weeders

Cost analysis was calculated using fixed and variable cost for the weeders. Straight line method to calculate annual depreciation cost as explained by Kepner *et al.* (1982) and Hunt (1995) was used. The salvage value and interest rate were assumed as 10% and 12%, respectively for the cost of the weeder per annum. The cost of insurance, taxes and shelter was considered as negligible for power weeders, and therefore not included in the calculation. Repair and maintenance cost of power weeder was assumed as 5% of capital value and lubricant cost was accounted to be 30% of fuel cost (Remesan *et al*., 2007). Weeder's actual fuel consumption was used to calculate fuel cost. Labor wage was taken as per the regional customary rate per day. Annual operation of the equipment was considered as 360 h based on maximum 15 days in each seasons (3 seasons, total 45 days, daily 8 h) of actual use in paddy weeding. The cost of operation, depreciation and interest were calculated using Eqns. 5-7 (Kepner *et al*., 1982; Hunt, 1995; and Alizadeh *et al*., 2007).

Depreciation cost

$D = (P-S) / L$ ....Eqn. 5

Where,

D = Mean annual depreciation cost (Rs)

P = Cost of the machine (Rs)

S = Salvage value (Rs)

L = Useful life of machine (number of years)

Interest

$I = \{(P + S) / 2\} \times i$ ....Eqn. 6

Where,

I = Interest (Rs)

P = Cost of the machine (Rs)

S = Salvage value (Rs)

i = Interest rate (%)

Cost of operation

$C = \text{Fixed cost} + \text{Variable cost} = (FC + RM) + (F + O + L)$ ......Eqn. 7

Where,

C = Cost of operation (Rs/h)

FC = Fixed cost (Rs/h) which included depreciation, interest on capital, insurance, taxes and shelter cost

RM = Repair and maintenance cost (Rs/h)

F = Fuel cost (Rs/h)

O = Lubricant cost (Rs/h)

L = Labor cost (Rs/h)

Results and Discussion

Performance Indicators

Weeding efficiency

The efficiency of the tested power weeders was in the range of 60.8 to 64.0% (**Fig. 2**). The weeders were able to perform in the space between rows only, and the weeds present along the row and near to plants could not be removed and resulted in lower efficiency. However in power weeding, if we employ 2-3 workers to remove weeds which were not taken by the weeders, especially near the plants, it is possible to achieve higher efficiencies. Senthilkumar *et al*. (2014) stated that the weeding efficiency of power weeders for pulse crops was from 45.4 to 74.1%. Olaoye *et al*. (2012) developed a rotary power weeder and reported that the efficiency was in the range of 53.7 to 72.4% for various engine speeds.

Plant damage

The percentage of plant damage caused by power weeders is given in **Fig. 3**. It was in the range of 1.2 to 2.7%. When the weeders move in the space between rows it encountered difficulties due to the plant spread, and caused damage. Plant damage can be minimized by providing sufficient row spacing during transplantation and operating with skilled worker. Senthilkumar *et al*. (2014) reported that the percentage of plant damage of power weeders for pulse crops was in the range of 4.2 to 9.6%.

Field capacity

The field capacity of power weeders varied from 0.074 to 0.131 ha/h (**Fig. 4**). Since, Model A was three-row weeder and hence area coverage was more compared to Model

Table 2 Cost analysis to compare tested power weeders and manual weeding

Equipment/ method	Initial cost (Rs*)	Depreciation (Rs/yr)	Annual fixed cost (Rs/yr)	Annual use (h)	Hourly fixed cost (Rs/h)	Repair and maintenance (Rs)	Fuel cost (Rs/h)	Lubrication cost (Rs/h)
Model A	80,499	14,490	23,828	360	66	4,025	77	23
Model B	47,000	8,460	13,912	360	39	2,350	35	11
Model C	36,000	6,480	10,656	360	30	1,800	49	15
Manual weeding	-	-	-	-	-	-	-	-

Equipment/ method	Labor charge (Rs/h)	Hourly variable cost (Rs/h)	Actual field capacity (ha/h)	Total cost of operation		Cost saving in power weeders over manual weeding (per ha)	
				Rs/hr	Rs/ha	(Rs)	(%)
Model A	100	200	0.131	266	2,031	3,594	64
Model B	100	146	0.074	185	2,500	3,125	56
Model C	100	164	0.091	194	2,132	3,493	62
Manual weeding	18.75**	-	0.0033	-	5,625	Base	Base

*Rs: Indian rupees (approximately 62 Rs = 1 US $)

** Rs.150/8h shift

B and Model C (two rows weeders). Also it depended on weed intensity, time of weeding and efficiency of operator. Tajuddin (2009) developed low land paddy power weeder and observed effective field capacity was around 0.075 ha/h. Shekhar *et al*. (2010) stated that field capacity was 0.067 ha/h in maize crop and power weeder was the most efficient time saving weeding tool.

Field efficiency

The field efficiency of the power weeders is shown in **Fig. 5**. It was in the range of 76 to 78%. Maximum field efficiency could be achieved by minimizing nonproductive time (shifting weeder from one pass to another pass, fuel refill time, and so on) during operation. Similar results were also reported by Olaoye *et al*. (2012) and Shekhar *et al*. (2010) that the field efficiency of power weeders was between 73% and 76%.

Cost analysis

Cost analysis of different power weeders and manual weeding is given in **Table 2**. The results revealed that the operation cost was lower in Model B (Rs.185/h) followed by Model C (Rs.194/h) and Model A (Rs.266/h). The total weeding cost was obtained in the range of Rs.2,031/ha to Rs.2,500/ha. The percentage of cost and time saving when compared to manual weeding is illustrated in **Figs. 6** and **7**. It was observed that the saving in cost and time ranged from 56 to 64% and 95 to 97%, respectively. However, the machine cost of Model A was higher than Model B, Model C and there was not much difference in saving cost and time among the weeders. Significant decrease in cost of operation and time saving in mechanical weeder over manual weeding was also reported by other researchers (Parida, 2002; Remesan *et al*., 2007; Goel *et al*., 2008; Tajuddin, 2009; Senthilkumar *et al*., 2014).

Conclusions

Three commercially available power weeders were tested for their performance in paddy fields. In general, similar effectiveness was observed in all three weeders in terms of field efficiency and weeding efficiency. However, the maximum field efficiency, weeding efficiency and minimum plant damage was found in Model C. The highest field capacity was observed in Model A (0.131 ha/h) followed by Model C (0.0912 ha/h) and Model B (0.074 ha/h). The cost of weeding in power weeders was reduced by 56-64% and time saving was 95-97% while comparing with manual weeding. It is recommended to use power weeders in paddy farms along with a few additional workers to remove the left out weeds by the weeders.

Acknowledgements

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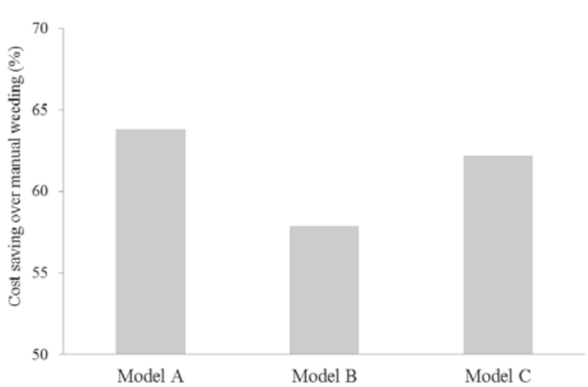

Fig. 6 Percentage of cost saving in tested power weeders when compared with manual weeding

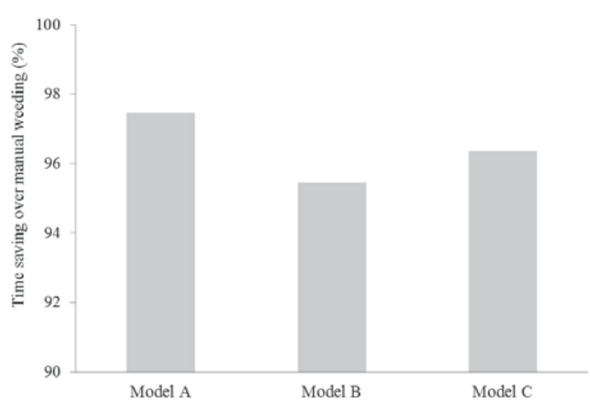

Fig. 7 Percentage of time saving in tested power weeders when compared with manual weeding

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Design and Development of A Pull Type Four Row Urea Super Granule Applicator

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Abstract

Although deep placement of urea super granule (USG) reduces the losses of urea and increases yield, it was not being practiced broadly in Bangladesh due to lack of an appropriate applicator. Therefore, a four row pull type manually operated USG applicator was designed and developed at the department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh. The width of the applicator was 1.6 m. The lowest values of missing (0.86%), overfalling (0.90%) and breaking (0.6%) of USG were found in the speed range of 2.05 to 2.21 km/h in a laboratory experiment. Therefore, the recommended operating speed of the applicator was 2 to 2.2 km/h. The effective field capacity and field efficiency of the applicator at a forward speed of 2.06 km/h were 0.26 ha/h and 78%, respectively. The average spacing between USG in a row was found to be 39.89 cm which was desired. The cost of the applicator was US$ 78 and the operating cost of the applicator was US$ 22 per hectare. The machine was easy to pull because the maximum draft and drawbar power were only 0.105 kN and 0.06 kW, respectively in puddle field. Moreover, the weight of the whole applicator was only 12 kg which made it easy to carry. The break-even point of the applicator when compared with manual application of USG justified the ownership of this machine for an area of only 0.63 ha/yr of rice land. The overall performance of the applicator was found better than that of the available USG applicators in Bangladesh. Therefore, the developed applicator might be introduced in the Bangladesh to apply USG in rice field.

Introduction

The expansion of modern agricultural practices to intensify cultivation has led to a high demand of fertilizers application in the cultivation processes. Urea is one of the main inputs which are required for increasing the crop production (NAP, 2009). Urea can be classified as prilled and granular type. Most of the farmers of Bangladesh apply prilled urea in their rice field by broadcasting method and this cause huge wastage of urea in different ways: i) a part of it converts into gaseous form and mixes with air, ii) a portion dissolves with rain or irrigation water and runoff to surrounding canal and river from the field applied, and iii) some of those go beyond the root zone of the rice plants (NAP, 2009). This wastage of urea can be minimized through deep placement of urea super granule (USG) at a depth of 7-10 cm. In this process, the effectiveness of the fertilizer could be enhanced from 40 to 70% (The Bangladesh Today, 2009) and rice yield could be increased by 20-25% (IFDC, 2005 & 2007). Most of the farmers of Bangladesh apply USG by hand which is tedious and time consuming. It takes 50 man-hrs to apply USG on one hectare of land. Manual placing of USG also creates back pain, and diseases in fingers of the

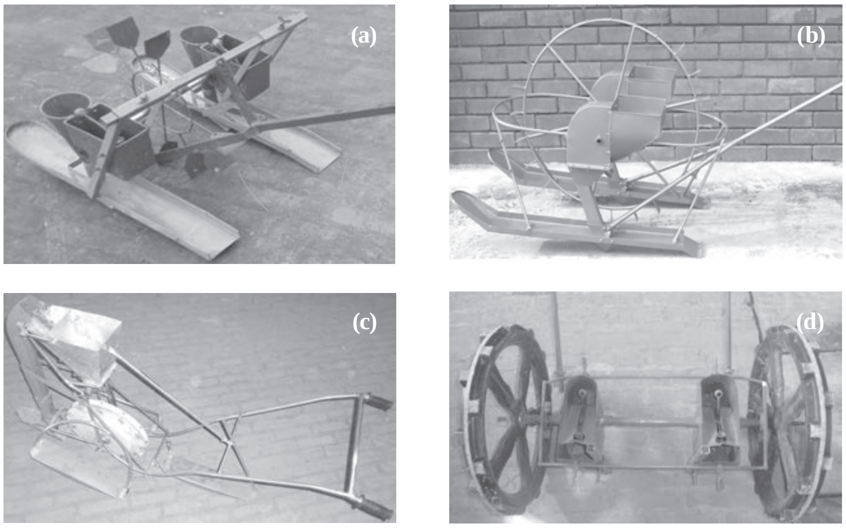

Fig. 1 Different types of USG applicators. a. BARI made USG applicator, b. BRRI made USG applicator, c. HYPA made USG applicator, and d. Alam made pull type USG applicator

farmer applying it. Moreover, it is difficult to place a USG in an accurate depth and spacing by hand. So the performance of the USG applied manually in the field is not satisfactory. With a view to overcome all these problems, a limited number of researches were conducted to develop granular urea applicator in Bangladesh. IFDC (1989) developed a device for placement of granular urea but this was not a mechanical applicator. Therefore, it did not decrease the drudgery of the farmers (Savant, 1991). Wohab et al. (2011) developed a hand driven urea super granule (USG) applicator machine at Bangladesh Rice Research Institute (BRRI). With this machine two labourers could apply USG in 33.33 decimal of rice land per hour. BARI (2009) and other institutes (BRRI, HYPA) developed 2-row push type USG applicators (**Fig. 1 a-c**) and the effective field capacity of those varied from 0.087 to 0.092 ha/h. Ahmed (2011) worked on the improvement of an existing push type USG applicator. Sultana (2011) developed a pull type single row granular urea applicator while Ajoy and Fazlu (2012), Alam et al. (2013 & 2014) designed and developed a pull type 2-row USG applicator (**Fig. 1 d**). The effective field capacity (0.11 ha/h) of the later one was found higher than those of the push type USG applicators. The effective field capacities of the existing USG applicators are still low which contributes to high cost of USG application. Still, there remains scope to increase the width of the applicator keeping the pulling force within the practical limit. Therefore, a research was conducted with a view to design and develop an improved granular urea applicator which will increase the field and economic performance compared to the available USG applicators in Bangladesh.

Materials and Method

The four row granular urea applicator was designed and developed at the engineering workshop of the department of Farm Power and Ma-

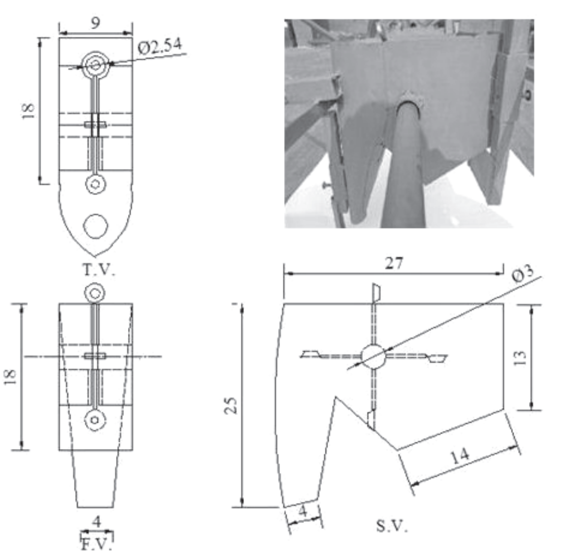

Fig. 2 Different views of hopper with metering device (All dimensions are in cm)

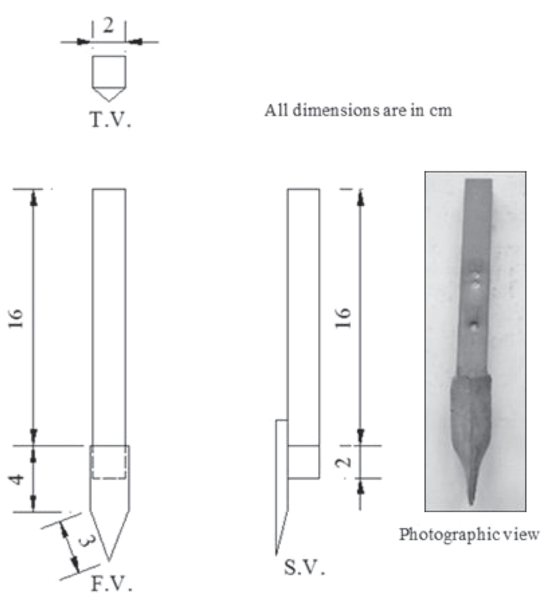

Fig. 3 Different views of the furrow opener

chinery, Bangladesh Agricultural University. The applicator was designed on the basis of the ground-wheel operated metering device. The wheels were fixed to a shaft (3.5 cm hollow MS round shaft) by nuts and bolts. Thus, the shaft and metering system rotated simultaneously with the rotation of wheels during operation. The diameter of the wheel of the applicator was selected as 50.93 cm which covered 160 cm of linear distance in each revolution. Therefore, 4 cups were set in the metering system for getting 40 cm of space between USG to USG in a row. The metering device and the hopper were made of M.S sheet. The hopper was 9 cm wide and 27 cm long having a rubber gate at the bottom of one end. Different views of hopper with metering device are shown in **Fig. 2**. The hopper was supported by an angle bar which was set on the shaft by a bearing. As a result, the rotating shaft rotated the metering device while the hopper remained stationary.

The furrow opener was made of M.S square bar of 24 cm long. It was tapered and pointed at the bottom to cut the soil to a desired depth required to place the USG. It was set with the frame of the applicator with nut and bolt. There was a provision to adjust the height of the furrow opener to obtain the desired depth. It was set to obtain a furrow depth of 8 cm. Different views of the furrow opener are shown in **Fig. 3**.

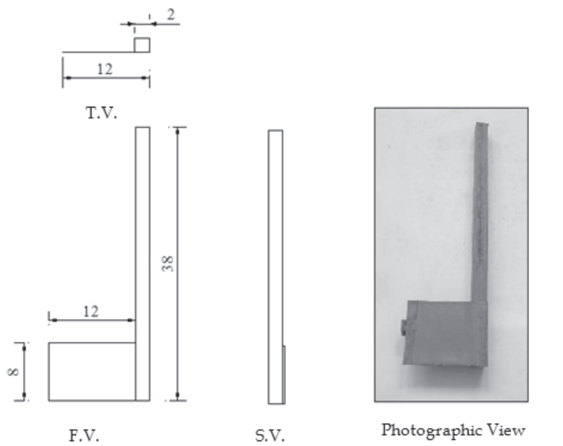

Fig. 4 Different views of the covering device (All dimensions are in cm)

The covering device was made to cover the USG dropped in the furrow by an L-shaped device. The shaft of the covering device was made of a square hollow shaft (2 cm × 2 cm), 38 cm long, fixed to the frame of the applicator by keeping a provision to set the shaft at any desired position. The size of ‘L’ arm fixed at the end of the shaft was 12 cm x 8 cm which was made of MS sheet. Different views of covering device are shown in **Fig. 4**.

The pulling handle of the machine was made of M.S flat bar (3.8 cm × 0.6 cm) and attached to the main shaft. It was 120 cm long and 72.5 cm wide. The length of the handle was adjustable to fix it according to the user’s height. Different parts and whole applicator were drawn by AutoCAD. The drawing and photographic view of the applicator are shown in **Fig. 5**.

The USG applicator worked on the principle that the forward movement of the machine caused by the operator’s pull rotated the driving wheels, the shaft and the metering device. The cups of the metering device picked up urea super granule (USG) from the hopper and dropped

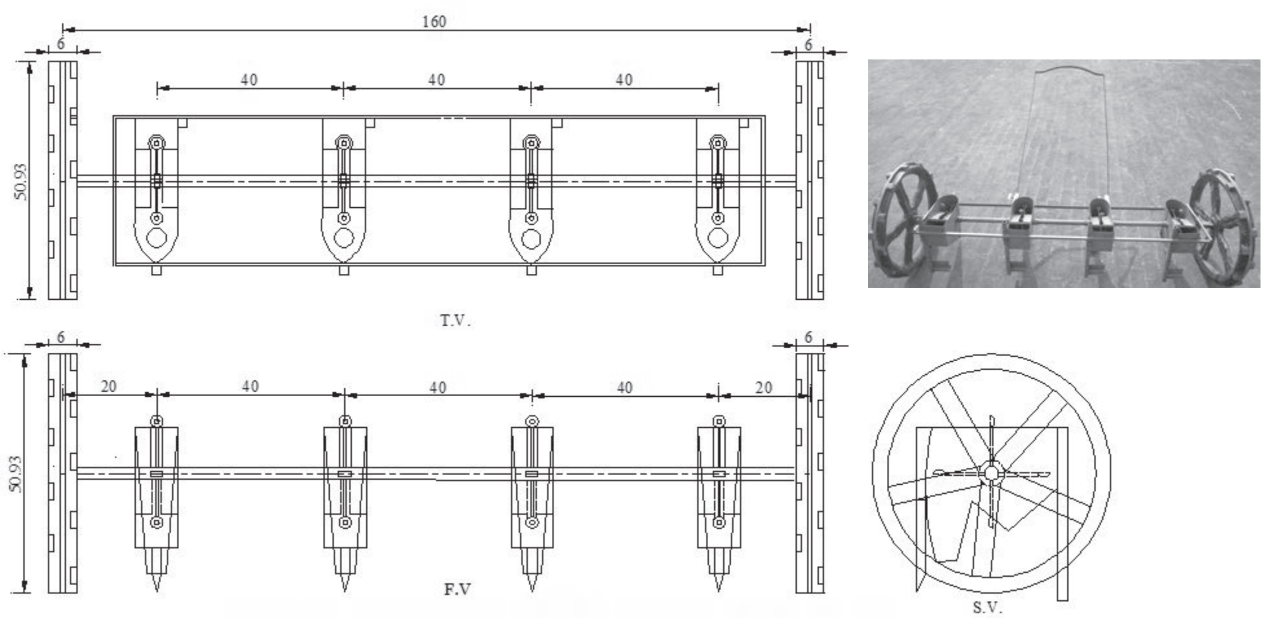

Fig. 5 Photographic view and detailed drawing of pull type 4 rows USG applicator (without handle) (All dimensions are in cm)

on to the furrow through the tube. The furrow was created by the furrow opener before dropping the USG. After that, the covering device covered the dropped USG with soil.

Lab Experiment of The Machine

Twenty four USG were weighted by a digital balance. The diameters and weights of thirty USG were measured by a slide callipers and a digital balance, respectively. The descriptive statistics of the recorded weights and sizes of the USG were determined by the Excel software. These measurements were made in order to check out the uniformity of the USG which affects the machine performance. Percentage of USG missing, over-falling, and breaking were determined in the laboratory experiment. Four plastic bags were set at the end of each tube. The metering device was rotated at different speeds (2.05 to 2.21 km/h) through turning the wheels by hand. Number of turns of the wheel was counted and the time was recorded by a stop watch. Total number of USG falling in the bag was counted and recorded. Then the missing or over-falling percentage of USG was calculated using the following equation:

$$R = [(N \times Y - NG) / (N \times Y)] \times 100$$

Where,

R = Over-falling or missing percentage of USG

N = Number of turn of wheel/metering device per minute

Y = No. of cups in the metering device

NG = Total number of granular urea fallen per minute

Negative value of R indicates over-falling of USG while its positive value indicates missing of USG. Average of missing, over-falling and breaking of USG dropped by the four metering devices were plotted in a graph as percentage.

The applicator was operated over a dry tilled field to find out the distribution pattern of USG fallen. A measuring tape was used to measure the spacing between USG to USG in each row and the average spacing was determined for all the four rows. Then descriptive statistics of the spacing was determined using Microsoft Excel software. The applicator was operated in puddled field to find out the effective field capacity, field efficiency, and required pulling force. The total time of operation was recorded with a stopwatch. The length and the width of the land were measured by a measuring tape to calculate the area. The effective field capacity of the machine was determined by dividing the total area with total time required and was expressed in ha/h. The pulling force was measured by a spring balance maximum capacity of which was 30 kg. Total cost (price, P) of the machine was determined on the basis of the material cost and fabricating cost incurred to construct the machine. The operating cost (fixed cost + variable cost) was calculated by assuming some data (i.e. expected life of the machine 10 yrs., tax, insurance & shelter 0%, repair & maintenance is 0.02% of purchase price, labour cost US$ 1/h, annual use of the machine 31 ha/yr). Break-even point was estimated by plotting the operational costs involved in applying USG by the applicator and manually against the area covered.

Results and Discussion

The average weight of the USG was 2.72 g with a standard deviation of 0.103 g and the average size of the USG was 2.16 cm having a standard deviation of only 0.07 cm. These results indicated the uniformity of the USG used by the applicator. The weight of whole USG applicator was only 12 kg. It indicated that it was not heavy to carry or transport by a person. The effect of speed on average percentage of missing, over-falling and breaking of USG dropped by all the four metering devices are shown in **Fig. 6**. The missing, over-falling and breaking percentage of USG varied from 0.5-4.5%, 0.7-5%, and 0.3-3%, respectively for varying

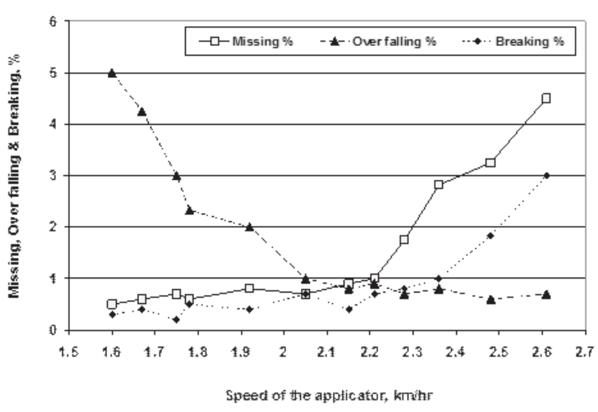

Fig. 6 Effect of speed on missing, over-falling and breaking of USG at different speeds

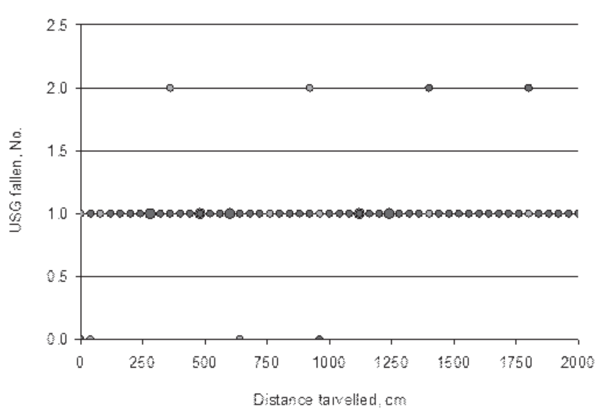

Fig. 7 Distribution of USG on dry land from all the 4 hoppers

speeds of the applicator from 1.62 to 2.61 km/h. The average data of missing, over-falling and breaking percentage of USG were calculated from 3 replications of four hoppers. It was observed that the missing, over-falling and breaking percentage of USG was less than 1% for the speed of applicator between 2.05 to 2.23 km/h in a puddled field. Therefore, the recommended operating speed of the applicator was 2 to 2.2 km/h.

The applicator was pulled over a tilled dry land at an average speed of 2.10 km/h to find out the distribution pattern of USG fallen from the metering devices. During operation the applicator dropped USG in a row with an average spacing of 39.89 cm (sd 1.74 cm and median 40 cm) between USG to USG which was very close to the desired spacing (40 cm). This result indicated the spacing between USG to USG was quit uniform. The depth of furrow at which USG was placed found to vary within 6-8 cm which was in the range of depth intended. The distribution pattern of USG fallen on dry land from 4 hoppers is shown in **Fig. 7**. Occurrence of dropping only one USG per cup of the metering unit was found to be the most (96%) while occurrence of dropping two number of USG was only 1.96% and that of missing was only 1.47%.

The width of the USG applicator was 1.6m. Thus, the theoretical field capacity of the applicator was 0.33 ha/h at a forward speed of 2.06 km/h. The effective field capacity and field efficiency of the machine was found to be 0.257 ha/h and 78%, respectively. The pulling force was measured by a spring balance. Maximum draft was found to be 105.03 N in puddled field at a pulling angle of 40°. As a result, the maximum drawbar power was 0.06 kW (0.08hp) at a forward speed of 2.10 km/h. Although the draft of the pull type single or 2-row USG applicator was less than that of the pull type 4-row USG applicator, higher field capacity of the later justified its merit. It indicated that it was very easy to operate the pull type 4-row USG applicator by a person in the field.

The total cost (material cost + fabrication cost) of the four row pull type USG applicator was US$ 78. The operating cost (fixed + variable) of the applicator was compared with that of the mannual operaion of USG appliaction and the break-even point (BEP) was determined as shown in **Fig. 8**. It was evident that a land area more than 0.63 ha in a year justified the use of the machine over the manual application of USG from the economic point of view. The costs of USG application per hectare were found to be US$ 22 and US$ 33 by the applicator and manual operation, respectively. Consequently, it could save 35% application cost compared to that of manual application of USG. The specifications of the four row USG applicator is shown in **Table 1**.

Conclusions

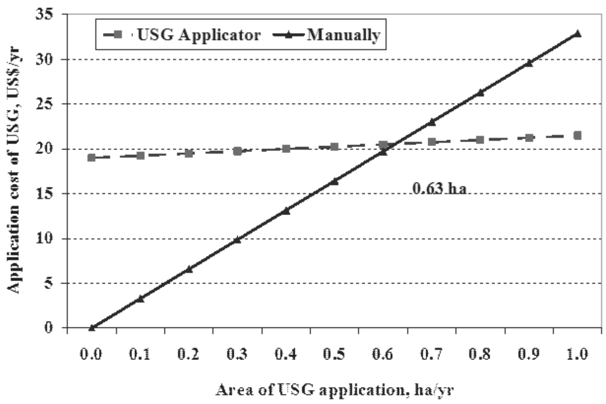

Fig. 8 Break-even point of USG application by the applicator and manual operation

Table 1 Specification of the pull type four row USG applicator

Particulars	Description
Name	Pull type four row granular urea applicator
Source of power	Manual
Source of power for driving metering mechanism	Driving wheel
(Continued on the right)	
(Continued from the left)	
Weight of the machine	12 kg
No. of operator	One
Metering system	Rotating shaft with four cups
Dropping mechanism	USG fallen due to gravitational force
Recommended travelling speed	2.06-2.14 km/h
No. of hopper	4
Dimension of the machine:Length, Width, Height	160 cm, 30 cm, 25 cm
Capacity of each hopper	1.5 kg
Diameter of ground wheel	50.93 cm
Pulling force	78.55 N
Theoretical field capacity	0.33 ha/h at 2.06 km/h forward speed
Effective field capacity	0.26 ha/h at 2.06 km/h & 78% field efficiency
Maximum draft was	105 N in puddled field at a pulling angle of 40º.
Maximum drawbar power	0.06kW(0.08hp) at forward speed of 2.10 km/h
Price	US$78
Operating cost	US$ 22/ha

The average spacing between granular urea dropped in the furrow was found to be 39.89 cm which was very close to the required spacing (40 cm). The depth of the USG placement varied from 6-8 cm which was within the desired depth of soil at which the USG should be placed. The percentage of missing, over-falling and breaking of USG did not exceed 1% for the speed range of applicator within 2.05 to 2.23 km/h in a dry tilled field. Therefore, it will not cause shortage of urea from the recommended dose in the field. The effective field capacity and field efficiency of the machine were found to be 0.257 ha/h and 78%, respectively. Although single or double row pull type USG applicators need less pulling force but their field capacities were low. The maximum draft (at an angle of 40°) and drawbar power for the machine were 105.03 N and 0.06 kW (0.08hp), respectively at a forward speed of 2.10 km/h. Hence, one person can operate it easily. The cost of the applicator was only US$ 78 which was within the buying capacity of the farmers of Bangladesh. The cost of USG application per hectare were US$ 22 and US$ 33 by the applicator and manually, respectively. Thus, it can save 35% of the application cost compared to manually application of USG. As a whole, the 4-row pull type applicator showed the best performance among all available USG applicators in Bangladesh and it can be introduced in the field.

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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.

1458

Evaluation of Tractor Rear Tyre Wear Rate During Highway Travel in Ghana: S. Y. Dorvlo, Department of Agricultural Engineering, University of Ghana, Legon, Accra, GHANA, sydorvlo@yahoo.com; **A. A. Mahama**, same; **E. A. Baryeh**, same

On most Ghanaian farms, the tractor is not only used for on-farm work but for hauling goods over long distances. Earlier studies have shown that tractor rear tyre replacement is problematic in Ghana and undergoes severe wear than other tyres. This study seeks to understand and provide information on the tractor rear tyre wear during highway travel, since for this form of transportation the farmer can get alternatives. Consequently, a 55.9 kW (75 hp) Massey Furguson 375E wheel tractor fitted with an 18.4-30 new tyres marked at four diametrically opposite sides was used for the study. From each tyre, eight lugs were each assessed at three points and the twenty-four wear measurements obtained were statistically analyzed. The average wear rate found was 10.65±1.07 × 10 - 4 mm/km. The findings of the study showed that to prevent severe wearing of the rear tyre, highway travel with the rear tyre should be done in moderation.

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1516

Study of Long Duration Utilization Effect of Denatured Aqueous Ethanol in Petrol Start Kerosene Run Type Small Constant Speed SI Engines: Manoj Kumar, Assistant Professor, Division of Agricultural Engineering, Sher-e-Kashmir, University of Agricultural Sciences and Technology-Jammu, INDIA, Dreamweaver.manoj@gmail.com; **T. K. Bhattacharya**, Dean, College of Agricultural Engineering, JNKVV, Jabalpur, Madhya Pradesh, INDIA

The study conducted for observing effect of long duration utilization effect of aqueous ethanol on fuel consumption, emission, crank case oil quality and engine cleanliness on petrol start kerosene run type small SI engine coupled with an alternator running on denatured ethanol 190° proof in place of kerosene. The result indicated no significant deposition of foreign matter on carburetor component, deterioration in the crank case oil quality and shoot formation within the recommended change period of 100 hours. The emission of CO, NO and NO_2 was found less, whereas HC found more than petrol run SI engines. The operation of engine on denatured 190° proof ethanol was found satisfactory.

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1529

Development and Evaluation of Weed Wiper for Resource Conservation in Hills of North Western Himalayas: Sukhbir Singh, Sr. Scientist (FMP), Division of Agricultural Engineering, ICAR- I.I.S.R., Lucknow-226002, INDIA, srsukhbir@rediffmail.com; **D C Sahoo**, Sr. Scientist (LWME), ICAR-CSWCRTI, Research Centre, Koraput, Odisha, INDIA; **Sher Singh**, Sr. Scientist (Agronomy), Crop Production Division, ICAR-VPKAS, Almora, INDIA; **M D Tuti**, Scientist (Agronomy), same; **J K Bisht**, Pr. Scientist and Head, same

In hills, women are generally involved in weeding operation which is very drudgery oriented and time consuming as carried out manually with traditional tools such as *kutla*, *kudal* etc. A light weight manual weed wiper (1.85 kg weight & 180 mm roller width) based on the principle of wiping (or brushing) was developed for weed control in between crop rows by using non-selective herbicides i.e. glyphosate (roundup) to the targets (weeds) by direct contact without damaging the crops. The herbicide solution is supplied to an absorbent surface i.e. spongy roller in weed wiper. The weed wiper was calibrated for herbicide dose and volume of water and tested at Vivekananda Hill Agriculture Research Institute (ICAR), Almora in pea and finger millet crops. The capacity of wiper was 0.032-0.035 ha h^{-1} with weeding efficiency 78-83% after 12-15 days of application of weedicide. It was found that application of glyphosate @ 2.16 litres ha^{-1} in 432 litres of water and @ 1.98 litres ha^{-1} in 395 litres of water through weed wiper was sufficient to wipe out the weeds in between the rows of pea and finger millet crop in one hectare area without any injury to crop. The time and labour requirement of weeding with weed wiper was observed 76-81% less as compared to *kutla*. However, after operation of wiper, some time and labour was required for weeding near plants. The cost of weeding with wiper was also observed 67-74% less as compared to *kutla*. Hence, wiper was observed very effective in labour, time, drudgery and cost saving for weed control in between crop rows.

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1533

Effect of Raised Bed, Zero and Conventional Till System on Performance of Soybean Crop in Vertisol: **Atul Kumar Shrivastava**, Prof. and Head, Dept. Farm Machinery and Power Engg., College of Agricultural Engineering, JNKVV, Jabalpur, 482 004, INDIA, atul_jnkvv@yahoomail.com; **Ajeet Kumar**, M. Tech Student, same, ajeetkumat978@gmail.com; **K. S. Kushwaha**, Associate Professor, Dept. Mathematics and Statistics, College of Agriculture, same; **Amit Jha**, Asstt. Professor, Department of Agronomy, College of Agriculture, same, amitagcrewa@rediffmail.com

The study was conducted to evaluate the performance of raised bed planter, zero till seed cum fertilizer drill and seed cum fertilizer drill systems for the sowing of soybean crop in vertisol. The experiments was conducted at J.N.K.V.V., Research Farm, Jabalpur, (India). Randomized block design was used for conducting the experiments. It was found that the total time and cost required for making raised bed and sowing operations by the raised bed planter was 1.85 h/ha which was 4.60% less than conventional (seed cum fertilizer drill) but it was 74.80% more time than zero till seed cum fertilizer drill. The average yield with the raised bed planter was obtained 31.37 q/ha, whereas, with seed cum fertilizer drill and zero till seed cum fertilizer drill it was 21.35 and 19.31 q/ha respectively. The soil conditions were found to be better for raised bed planter.

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1540

Extent of Present Status of Indigenous Farm Tools Utilization and Potential of Farm Mechanization in Uttrakhand State of India: **V. P. Chaudhary**, ICAR- Indian Institute of Farming Systems Research, Modipuram, Meerut (UP), INDIA; **M. Shamim**, same; **Nisha Verma**, Scientist (FRM), IIFSR, same

Agriculture is major source of livelihood in Uttrakhand state because of more than three-fourths of population depends directly and indirectly on it. The crops, livestock and horticulture enterprises are the main part of agricultural scenario in the region. Mechanization in agriculture increase the productivity of land and labour by meeting timeliness operations and increase work out put per unit time. It also enables efficient utilization inputs such as seeds, fertilizer and irrigation water. Appropriate mechanization in hill farming saves time, energy and also reduces drudgery of women farmers. Hill farming in Uttrakhand state, the level of mechanization is very low in the view of mechanical power use, efficient implements availability and post- harvest technology. Mechanization in hill farming is a very difficult task due to its unique topography (i.e. steep slope, small terrace), small holding and plot size, lack of unskilled man power, poor facilities of repair, maintenance and manufacture, non-availability of suitable tools as operation-wise and poor economic condition of farmers. Small and marginal farmers dominate in the state. The adequate and appropriate power source with suitable matching equipment is required to be intervening as per the topography for mechanization. Most of farm operations are performed by women farmers ranged from 55 to 85%. The various field operation viz., tilling of small plot, clod breaking, sowing, planting of seeds and transplanting of paddy as well as vegetable crops, weeding and interculture, harvesting, threshing and shelling, digging of tuber root crops, transportation /material handling are mostly executed by women workers by indigenous tools and equipment. The livestock rearing, maintenance and collection of green grasses as fodders, making silage are done by the women. The mechanization in fruit crops are very low such as digging of pit for transplanting, pruning/cutting branches, plucking of fruits and transportation is done by traditional methods.

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1547

A Study on Wear Characteristics and Material Composition of ADI Blades Used in Rotavator: **Sumit Tewari**, Student M. Tech, Dept. of Farm Machinery and Power Engineering, College of Technology, Pantnagar-263145, Uttarakhand INDIA; **R. N. Pateriya**, same; **T K Bhattacharya**, Prof. and Prof. & Head, same; **Manish Tewari**, Assistant Prof. Department of Industrial and Production Engineering, College of Technology, GBPUA & T, Pantnagar Distt. U. S. Nagar, same

The primary cause that limits the persistence of many agricultural tools is wear. Rotary tillage implements are being projected as important tools that result in production of fine tilth of soil The wear of agricultural soil cutting tools have their own characteristics, which are different from other types, since they interact with soils of various textures, moistures and other unpredictable conditions in the field. The study was undertaken to compare the wear characteristics and material composition of ADI rotavator blades with the indigenous and imported rotavator blades.

The results indicated that the average width of ADI (Austempered Ductile Iron) ADI blades was greater than the indigenous and imported blades. The ADI blades were rich in iron content, had 85% Fe initially which decreased to 60% after 100 h of run. Elemental analysis and imaging of selected rotavator blades that with increase in working hours

there were decrease in percentage of elements along the blade sections. Average dimensional wear rate of indigenous I blade at S,B and E points was 0.28 mm/h, 0.195 mm/h and 0.06 mm/h respectively. Average dimensional wear rate of Indigenous II blade at S,B and E points was 0.33 mm/h, 0.23 mm/h and 0.25 mm/h respectively. Average dimensional wear rate of ADI blade at S,B and E points came out to be 0.209 mm/h, 0.08 mm/h and 0.029 mm/h respectively. ADI blades have very less wear rate as compared to the indigenous and imported blades. Wear pattern of ADI blades is also a smooth curve and uniform in nature.

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1550

Pre-Slaughter Logistics Management in Brazilian Pigs' Chain: A Case-Study of Fasting Time, Transportation Process and Lairage Period: **Sivanilza Teixeira Machado**, Paulista University-Graduate Program in Production Engineering. R. Dr. Barcelar 1212, São Paulo, SP, BRAZIL, irenilza.naas@unip.br; **Irenilza de Alencar Nääs**, same; **João Gilberto Mendes dos Reis**, same; **Pedro Luiz de Oliveira Costa Neto**, same

The study aimed to determine the effects of pre-slaughter logistic management (PSL) on pigs' thermal comfort and surface temperature. Air temperature (AT), relative humidity (RH), wind speed (WS), and surface temperature (ST) were registered at fasting time, transportation, and lairage for three periods in the stage. General Linear model was used to analyze the variables and their interactions. The environmental change caused an increased on pigs' ST. Temperature humidity index (THI) during transportation (93.9 ±3.5) impacted the rise in the pigs' ST. Controlling the environment in tropical condition is crucial to improving pork quality and supply chain competitiveness.

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1553

Performance Evaluation of Commercial Rotary Knife Roller Gin for Ginning Indian Cotton: **V. G. Arude**, Scientist (FMP), ICAR-Central Institute for Research on Cotton Technology, Mumbai-400 019, INDIA; **S. K. Shukla**, Sr. Scientist (Mech. Engg.), Ginning Training Centre of ICAR-Central Institute for Research on Cotton Technology, Nagpur-440 023, INDIA; **P. G. Patil**, Director, ICAR-Central Institute for Research on Cotton Technology, Mumbai-400 019, INDIA

Double Roller (DR) ginning technology is widely used in India despite low productive and there is limited scope for improvement in the productivity. Advanced rotary knife roller ginning technology is so far not practiced in India for ginning Indian cotton. Therefore to understand the difficulties in adoption and for finding its suitability for efficient ginning of Indian cotton, the performance of a commercial rotary knife roller gin was evaluated in terms of capacity, power, energy consumption and effect on fibre physical properties and spinning performance. The results were compared with double roller ginning. The rotary knife roller gin was operated at the roller speed of 200 rpm, rotary knife speed of 400 rpm, feeder roller speed of 16 rpm and at 80 bar pressure between the roller and stationary knife. The capacity of the single stand of rotary knife roller gin (425 kg lint/h) was found to be about six times that of the Jumbo double roller gin (70 kg lint/h). Energy consumption was found to be 28 kWh/bale as against the 22 kWh/bale for rotary knife and DR ginning plant of capacity 25 bales/h. Physical properties tested by HVI indicated marginal increase in 2.5% span length in rotary knife ginning as compared to DR ginning and other fibre properties remain unaffected. AFIS results showed higher fibre neps and seed coat neps in rotary knife gin than DR gin. Fibre neps were found to be 263 cnt/gm and 162 cnt/gm and seed coat neps were found to be 42 cnt/gm and 21 cnt/gm for rotary knife gin and DR gin respectively. Full spinning of rotary knife and double roller ginned cotton was done at 50s counts and the yarn properties were evaluated. The lea strength and CSP values were found to be higher for rotary knife ginning than DR ginning. Study revealed that from a capacity standpoint, the rotary knife roller gin is a higher capacity option than double roller gin without compromising fiber and spinning quality for processing Indian cotton. However rotary knife roller gin machine and process parameters needs to be optimised to bring down the fibre neps and cut seed percentage to the level acceptable to the spinning industry.

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1554

Fuel Measuring Devices, Systems and Tractor Fuel Consumption Pattern on the Field – A Review: **Harvinder Singh Dhingra**, Associate Prof. of Agril. Engg., Deptt. of Farm Machinery and Power Engg., P A U, Ludhiana, Punjab, 141-004, INDIA

The agriculture is boosted by the mechanization by improving efficiency of the field operations, which enhanced the

crop productivity. This intensification in mechanization in agriculture, however, resulted in higher energy costs . Therefore, it became necessary to evaluate the tractor fuel consumption, by varying various other factors. There were number of sensors or transducers which could be utilized for the measurement of fuel consumption of tractor implement system like - piston-type area meter, glass tube flow meter, propeller type fuel flow meter, etc. The various methods used in agricultural tractors for measuring fuel consumption included most simple method of tank filling to the most accurate method like on board data acquisition with electronic sensor including the most sophisticated instrumented tractors. The fuel consumption ranged between 14.96 to 19.7 l/h for the draft of 13.54 to 24.13 kN while operating the MB plow. The fuel consumption was found to be less in stubble mulch system than MB plow system . The sensors installed on the tractor and connected to data logger showed that the fuel consumption varied with type of soil. The fuel sensor based on fuel level were the simple sensors to measure fuel consumption. Bio diesel fuel consumption was measured through an instrumented tractor the sensors fitted in the tractor gave a real time curve between fuel consumption, draft with time and was similar to the diesel fuel.

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1561

Design and Development of Cup Feed Metering Mechanism of a Paddy Seed Drill: **M. K. Ghosal**, Prof., Dept. of Farm Machinery and Power, College of Agricultural Engineering and Technology, O. U. A. T., Bhubnaneswar-751003, Odisha, INDIA, mkghosal1@rediffmail.com; **M. Din**, Principal Scientist (Agril. Engg.), Central Rice Research Institute, Cuttack, Odisha, INDIA

Line sowing of seeds in time is necessary for enhancing production and productivity of crops in an agricultural field. In order to promote line sowing, there is a need to design and evaluate cup feed type metering device which ultimately helps in developing a multi crop seed drill for sowing of various seeds with replaceable cups. The present investigation deals with the seed pattern characteristics of the most prevalent variety of paddy i.e. Pathara in the state of Odisha. The modification in the dimensions of cup in cup feed metering device was done for their suitability in a seed drill for achieving effective sowing operation of paddy. The spatial dimensions of paddy variety, Pathara were studied and accordingly the cup dimensions were fixed. An experimental test rig was developed in the laboratory to study the seed sowing pattern characteristics i.e. seed rate deviation, seed distribution and percentage seed damage for various dimensions of cups for Pathara variety of paddy. Five different sizes of cups with depth and diameter of 14.83 × 8 mm, 11.71 × 9 mm, 9.48 × 10 mm, 7.84 × 11 mm and 6.58 × 12 mm were prepared keeping the volume constant and were used for the study. Similarly, five different peripheral speeds of the cup discs of 6.28, 9.42, 12.55, 18.84 and 23.56 m/min were selected for evaluating the most suitable dimensions and peripheral speed of cup for better performance of the seed drill. The belt speed in the test rig was also calculated and maintained to study the seed pattern characteristics. It was observed that the dimensions of cup with depth and diameter of 9.48 × 10 mm were found most suitable with a permissible peripheral velocity up to 23.56 m/min and an overall efficiency of 80.94%. The cup of size 9.48 × 10 mm was recommended for seed metering mechanism of the seed drill for sowing of the paddy seed.

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1562

Constructive-Regime Parameters Of Rotor-Brush Cleaner of Tuberous Roots: **Maxut Dussenov**, Zhangir Khan West Kazakhstan Agrarian-Technical University, REPUBLIC OF KAZAKHSTAN

Results of researches of modern technologies of tuberous roots cleaning process showed that efficiency increase of cleaning quality in the form of connected soil with vegetable remains depends on rational constructive-technological scheme and optimum constructive-regime parameters of device. Major factors influencing quality and power consumption of cleaning process is theoretically reasonable rational constructive-technological scheme and experimentally certain optimum constructive-regime parameters of cleaner. Constructive-technological scheme of rotor-brush cleaner with justification of constructive-regime parameters is offered: tilt angle of brush, frequency of brush rotation, frequency of disk rotation. Quality of cleaning in this cleaner increases due to the application of rotor brush as working body which clears product in cleaning channel formed by disk, propeller and brush. Power consumption decreases as a result of application of propeller rational form and compact arrangement of working bodies.

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EVENT CALENDAR

◆ **EIMA Agrimach India 2017**
December 7-9, New Delhi, INDIA
http://eimaagrimach.in/

◆ **5th ADDIS AGROFOOD**
December 8-11, Addis Ababa, ETHIOPIA
http://www.addis-agrofood.com/

◆ **KISAN 2017**
December 13-17, Pune, INDIA
http://pune.kisan.in/

◆ **The International Conference on Agricultural & Bio-system Engineering (ICABE)**
December 19-21, Ho Chi Minh City, VIETNAM
http://www.istdst.org/ABE

◆ **ISAE 2018**
52nd Annual Convention of ISAE
January 8-10, 2018, Gujarat, INDIA
http://www.isae.in/

◆ **Fieragricola 2018**
January 31-February 3, Verona, ITALY
http://www.fieragricola.it/

◆ **2018 Agricultural Equipment Technology Conference**
February 12-14, 2018, Kentucky, USA
http://www.asabe.org/meetings-events/2018/02/agricultural-equipment-technology-conference.aspx

◆ **ALLSENSORS 2018—The Third International Conference on Advances in Sensors, Actuators, Metering and Sensing—**
March 25-29, 2018, Rome, ITALY
http://www.iaria.org/conferences2018/ALLSENSORS18.html

◆ **Autonomous Trucks—2nd International VDI Conference—**
April 10-11, Dusseldorf, GERMANY
https://www.vdi-wissensforum.de/en/event/autonomous-trucks/

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

◆ **Caspian Agro 2018—12th Azerbaijan International Agriculture Exhibition—**
May 16-18, 2018, Baku, AZERBAIJAN
http://caspianagro.az/en-main/

◆ **GreenTech**
June 12-14, 2018, Amsterdam, NETHERLANDS
http://www.greentech.nl/amsterdam/

◆ **EURAGENG 2018 Conference**
July 8-12, 2018, Wageningen, THE NETHERLANDS
http://ageng2018.com/

◆ **2018 ASABE Annual International Meeting**
July 29-August 1, Detroit, USA
https://www.asabe.org/meetings-events/2018/07/2018-asabe-annual-international-meeting.aspx

◆ **Agritechnica Asia 2018**
August 22-24, 2018, Bangkok, THAILANS
http://www.agritechnica-asia.com/

◆ **EIMA 2018**
November 7-11, 2018, Bologna, ITALY
https://www.eima.it/en/index.php

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NEWS

2017 Kishida International Award Went to G.S. Vijaya Raghavan

This year's Kishida International Award was presented at the ASABE 2017 Annual International Meeting. The recipient was G.S. Vijaya Raghavan, a James McGill Professor in the Bioresource Engineering Department of the Faculty of Agricultural and Environmental Sciences. He's the 40th receipient of the award.

The Kishida International Award serves to recognize outstanding contributions to engineering mechnization-technological related programs of education, research, developments, consultation or technology transfer outside the United States. It is endowed by Shin-Norinsha Co., Ltd. of Japan in honor of Yoshikuni Kishida, founder of the firm.

■■

Yoshisuke Kishida (R) gave the award to G.S. Vijaya Raghavan (L)

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S E Abdallah


A A K El Behery


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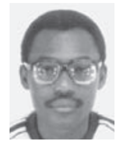
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N G Kuyembeh


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A B Saeed


A I Khatibu


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E J Hetz


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S M Farouk


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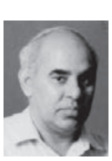
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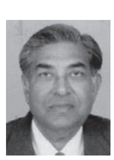
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M P Pariyar


H P W Jayasuriya


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A Q A Mughal


M S Mirjat


N A Abu-Khalaf


R M Lantin


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


N Hay


P V Lang


T H Katardjiev


P Kic


J Müller


K P Ferentinos


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Retirement Co-editors' Name List

Co-editor's name	Nationality	Inaugural year	Retired year	Co-editor's name	Nationality	Inaugural year	Retired year
Adrian Moens	Netherlands	1972	1989	Allan L. Phillips	U. S. A.	1981	2004
Bala Krishna Shrestha	Nepal	1972	1991	Julien G. Van Lancker	Brundi	1981	1989
Chul Choo Lee	Korea	1972	2014	Suppiah Kathirkamathamby	Sri Lanka	1981	1991
Chau Van Khe	Vietnam	1972	1980	Armed Hossain Mirdha	Mexico	1982	1991
Manbahadur Gurung	Bhutan	1972	2006	A. A. Valenzuela	Chile	1982	2013
Merle L. Esmay	U. S. A.	1972	1990	David Boakye Ampratwum	Ghana	1982	2011
Giuseppe Pellizzi	Italy	1973	2012	Kshirode Chandra Roy	Bangladesh	1982	1985
Mohamed A. Bedri	Sudan	1973	1987	M. H. Abdel Aziz	Saudi Arabia	1982	1991
Shahansha-Uddin Choudhury	Bangladesh	1973	1991	Krishna Prakash Srivastava	Ethiopia	1983	1989
T. B. Muckle	U. K.	1973	1978	Muhammad Siddique Chaudhry	U. S. A.	1983	1991
Chang Joo Chung	Korea	1975	2014	Wimala Tissa Weerakoon	Zambia	1983	1985
T. Touggaard Pedersen	Denmark	1975	1990	Harry D. Henderson	Lebanon	1984	1985
Bilash Kanti Bala	Bangladesh	1976	1982	Mohammad Afzal	Pakistan	1984	1994
George B. Hanna	Egypt	1976	1988	A. P. Kaloyanov	Bulgaria	1985	2013
Jun Sakai	Japan	1976	2015	Soedjatmiko	Indonesia	1986	2014
Siswadhi Soepardjo	Indonesia	1976	1985	Aalbert Anne Wanders	Netherlands	1988	2007
Tieng-Song Peng Taiwan	Taiwan	1976	2015	Ali Mahmoud El Hossary	Egypt	1988	2010
Mohammad Ilyas	Pakistan	1977	1981	Chanchai Rojanasaroj	Thailand	1988	2011
Amala Prasad Sharma	Fiji	1978	1981	Edward A. Baryeh	Zimbabwe	1988	2014
Arumugam Kandiah	Ethiopia	1978	1989	T. P. Ojha	India	1988	2015
Bherulal T. Devrajani	Pakistan	1978	2004	Eltag S. Eldin Mahmoud	Sudan	1990	2011
John Kilgour	U.K.	1978	2014	Henrik Have	Denmark	1990	2009
Satish Chandra	Fiji	1979	1990	Graeme Ross Quick	Australia	1995	2015
Jitendra P. Mittal	Nigeria	1980	1993	Rafiq ur Rehman	Pakistan	1995	2015
Naresh Chandra Saxena	India	1980	1988	Abdulsamad Abdulmalik Hazza'a	Yemen	1999	2014
Paris Andereou	Lebanon	1980	1984	Yunus Pinar	Turkey	1983	2016
Wang Wanjun	China	1981	2012	William J. Chancellor	U.S.A	1972	2017
Allah Ditta Chaudhry	Pakistan	1981	2015	Kunihiro Tokida	Japan	2016	2017

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INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

Criteria for Article Selection

Priority in the selection of article for publication is given to those that –

a. are written in the English language;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written in MS DOS format.

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. The AMA does not pay for articles published.
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article needs to be sent to Co-operating Editor in the writer's neighboring country. Please note that it is AMA Chief Editor that decide whether publish each submitted paper on AMA or not. Even if Co-operating Editor found your manuscript suitable for publication on AMA, it can not the case with AMA Chief Editor.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
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Format/Style Guidance

a. Article must be sent by E-mail with Word File and PDF File attached.
b. The data for graphs and photographs must be saved into piecemeal data and enclosed (attached) with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
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(iii) an abstract following ii) above;
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d. Tables, graphs and diagrams must be numbered. Table numbers must precede table titles, e.g., "Table 1 Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Fig. 1 View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
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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