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FARM MACHINERY INDUSTRIAL RESEARCH CORP.

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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;
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h. written on CD-R.

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   (v) conclusion/recommendation; and a
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g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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This is the 150th issue since its maiden isue in the Spring of 1971

EDITORIAL

I wish all the readers of AMA a happy new year. Last year, the world was hit by a number of disasters, such as the great flood in Thailand. Japan experienced the Great East Japan Earthquake; a horrible earthquake followed by a huge tsunami that was said to be a once in a thousand years occurrence. Many people in Tohoku are still forced to live a refugee life. The quake and tsunami damaged the nuclear power plant, and serious radioactive contamination spread inside and around Fukushima. Nuclear power is a type of energy that can prevent global warming, but we have realized that if we misuse it, it can result in dangerous accidents.

According to the growing global economy, the world needs a great amount of energy, and the needed amount is growing rapidly especially in the developing countries. In China, the number of automobiles sold grew so fast that it overtook the U.S., and now China is the world's number one country selling cars. They continue to grow even more today. This means that China needs much more oil than before.

In Japan, after the nuclear plant accident, replacing the existing energy by renewable types of energy became a very important topic. One of them was biomass energy. People have been using biomass as energy for a long time as they burn wood or make charcoal. However, looking at history, people have destroyed many forests by using biomass energy. Sadly, the destruction is still continuing today. The main reasons are because of expanding farmlands, making furniture from wood, and using wood as fuel for energy.

At the end of October last year, the world population had reached 7 billion and it is continuing to grow. By looking at the macroscopic point of view, the most important issue is how a human being can coexist with the other vital systems on this planet Earth. Without this coexistence, people cannot live long here. We still have many points unclear as to how to coexist smoothly with the other systems. We are not even sure what kind of microbes exists in the most basic part of vital systems. It is no exaggeration to say that almost no research has yet been made. For example, inside a human bowel, there are thousands of coliform groups, but we are still not sure of their details. These coliform groups should have important relationships with the microbe systems.

Harmonization of human and other life is, in an expanded sense, agriculture itself. It gives bountiful forests, beautiful environment, plenty of food to save the lives, energy, fiber, medicine, and all the other blessings to humans. Looking at the long-term point of view, what is mostly important for the human being is the mind, or some kind of software that appears in peoples' heart when they care about other vital systems. I think that this is what makes the human a humanlike being.

When looking at agricultural mechanization, we also need to look at human beings at the same time. We need to think of how the human can coexist with the vital system, and what types of work we need for this to be a reality. There is still plenty of room left for agriculture to develop as a way to utilize vital systems efficiently. Two examples are making energy by using microbes, and agriculture utilizing vast areas of the ocean. Making underground plant factories may also develop in the long term. However, as I have noted firstly, what we have to mostly care about is to think of how we can coexist, balance, and harmonize totally with the other vital systems. To realize this idea, we must not only think of producing, but how to consume. This is to say, that we should eat in moderation. By humanly controlling consumption correctly, we can live our lives with the least amount of resources. I think this is the most important idea. There are still many tasks in front of us, but to maximize the land productivity, we need to mechanize the agriculture. Let us all think of the best way to promote it to the world.

Yoshisuke Kishida
Chief Editor

January, 2012

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Utilization Pattern of Tractors in Nalanda District of Bihar- A Case Study

by

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Abstract

Farm mechanization is a very important input in agricultural production. The number of tractors has increased rapidly and population of draft animals has been decreasing in Bihar in recent years. A study was undertaken to find the tractor utilization pattern and their economics in Nalanda District of Bihar.

The average annual use of farm tractors was 1,772.62 hours, in which about 70.47 % were used in custom hiring and only 29.53 % used for personal work. Maximum use of the farm tractor was 54 % in transportation. The average cost of operation of a tractor was Rs. 145.20 per hour for an 18.65 kW tractor and Rs. 168.15 per hour for a 26.11 kW tractor. The cost of operation decreased with the increase in annual use of the tractor. Also, the total operational cost per hour increased with the increase in size of the tractor. The annual use of tractors in tillage, threshing, agricultural purpose transportation, custom use and miscellaneous use was 14.69, 1.18, 5.59, 70.47 and 8.06 % of total annual use, respectively. The average Break-Even Point (BEP) of a tractor was about 596.42 h/year for an 18.65 kW tractor and 685.20 h/year for a 26.11 kW tractor. Average annual use in each case was higher than their break even points, indicating that their purchase and use in the study area was profitable.

Introduction

Bihar has one of India's most fertile tracts of land. Nearly three-fourths of its population depends on agriculture for survival. Yet the productivity of the state is below the national average, and much lower than green revolution states like Punjab and Haryana.

In the process of farm mechanization, a large number of machines are required to be used on the farm. Among them, the use of a tractor is very important and has its specific place because the animal power available with the cultivators may be incapable of coping with the situation. Certain agricultural operations, such as land development, particularly leveling and threshing, can not be carried out effectively with bullock power. During the peak period of the agricultural season (harvesting, sowing, and paddy transplanting) the labour wages shoot up 2 to 3 times more than average wages. Thus, farm mechanization/machinery help farmers perform farm operations timely and, relatively, at lower cost. Gupta (1984) reported that about six times more energy is needed to rear and maintain a pair of bullocks compared to producing a tractor of 25 hp. The cost of wheat production on tractor farms was 20 % lower.

Singh and Singh (1991) stated that the highest utilization of tractors occurred up to 10,000 working hours, though this was up to 15,000 h for some higher kW tractor. During the first year of use 22.38-37.30 kW tractors had higher utilization percentage than 37.30-67 kW tractors. However, the opposite was true after this period.

Dhawan and Singh (1995) cited that average power availability per hectare was 2.69 kW. Paddy and wheat accounted for 33.16 and 39.60 %, respectively, of total tractor use on tractor farms. The order of importance for which tractors were used was seedbed preparation, sowing, transportation, puddling and threshing. The fixed and variable cost of tractor use was Rs. 95.06/h and about 37.20 % of tractor use was for less than 300 h/yr.

The tractor population in Bihar increased from 9,000 in 1977 to about 70,505 in 1993 (HMT tractor limited). It can be clearly understood by this figure that the farmers are inclined to use tractors for their farming operations. This study was conducted to obtain useful information for understanding the tractor utilization pattern, attitude of the farmers, cost of operation and economics of tractor use in the study areas.

Methodology

The study was carried out in an alluvial plain zone-III of south Bihar in Nalanda district. During the selection of the study areas, the ecological condition of the district, availability of the tractor and its use were duly considered. It was not possible to consult all the tractor owners in the district, hence, a random sampling of 95 tractor owners were done. A comprehensive survey questionnaire was prepared.

All the data were collected from the farmers through personal interviews. The questionnaire was designed to provide necessary information regarding tractor utilization pattern, annual use of tractors, farm size, effect of size group of the tractor, age of the tractor and cost involved in operation and maintenance of the tractor. The information was collected regarding various operations such as tillage, planker, sowing, harvesting, threshing, and transportation. The data were also collected regarding use on the farmer's own field as well as in custom hiring work. The cost of operation of the tractor was determined considering depreciation, interest, shelter, taxes and insurance, fuel and lubricants, labour, repair and maintenance charges. The break-even point was also determined.

The information about educational details, land holding and size, soil type, cropping pattern and socio-economic aspects were also collected through an interview schedule. Most of the farmers have a low education level and they did not keep records at all. Therefore, most of the information collected was based on mainly upon the farmer's recollections. The questionnaire was simple and sequentially connected to each other. The interviews were held with the owner and tractor operator. Tractor mechanics were also consulted in certain cases.

Unit Cost of Operation

Unit cost of operation of a tractor was calculated on the basis of fixed cost and variable or operating cost. Fixed cost depreciation was calculated by the diminishing balance method (declining balance method). This method resulted in higher depreciation charges during the earlier life of the machine and lower charges in later years.

Using

$$D_n = C\,[(1-r)^{n-1} - (1-r)^n]$$

Where,

D_n = Depreciation in the n^{th} year, Rs/h

C = Present value of tractor, Rs.

r = rate of depreciation

n = useful service life of tractor, yr.

The expected service life of a tractor was assumed to be 10 years with a rate of depreciation of 20 %.

Results and Discussion

General Characteristics of the Farmers

Socio-economic profile of farmers revealed that the average age of the heads of the farm family ranged from 35 to 52 years. Among the sample farmers, 55 % had education up to middle school level, 21 % high school education, 12 % higher secondary/college education and the remaining were illiterate. The majority (97 %) of large farmers (more than 10 ha), 86 % semi medium farmers (4-10 ha) and 67 % medium size farmers (2-4 ha) preferred purchasing of tractor over power tiller followed by 16 % small farm category (less than 2 ha). This may be due to versatility of the tractor for performing most of the farm operations as well as transportation work. Only about 15.2 % of the farmers had proper training for use and maintenance of tractor and about 55 % of them had a license to drive the tractor. Ninety percent of farmers were facing difficulty in maintaining animals, about 64 % of the farmers had problems related to non availability of labour during peak periods/agricultural seasons and about 61 % had problems of timeliness of farm operations. These were the main reasons given by the farmers for buying a tractor.

Tractor Utilization Pattern

Table 1 shows that the tractors were used from 1,500 hours to 2,240 hours per year for various operations. It is clear from **Table 1** that the tractor use pattern shows a normal distribution curve, where a maximum number of tractors (47.37 %) was used for 1,700 to 1,900 hours. Only 4.21 % tractors were used between 2,100 to 2,300 hours. Most of the tractor farmers had their own cultivators, plankers, trolleys and threshers. **Table 1** reveals that the average annual use of a tractor was about 1,772.62 hours of which 70.47 % of the time the tractors were used for custom work and only 29.53 % for the farmers own work (**Fig. 1**). It is also clear from the **Fig. 1** that the owner used the tractor

Table 1 Number of tractors and percentage at various level of annual use of tractors

Annual use, h	Number of tractors	Tractor, %
1500-1700	32	33.68
1700-1900	45	47.37
1900-2100	14	14.74
2100-2300	4	4.21

mainly for tillage, which amounted to 14.69 % of the annual use. Minimum use of the tractor was for threshing (1.18 %) since most of the farmers had their own thresher. The main reason for this might have been that, generally, threshers were operated by electric motor or stationary diesel engine. Very few farmers were used a tractor as a power source to operate a thresher. In addition to tillage and threshing, tractors were used for transportation (5.59 %) and for other work (8.06 %).

Tillage Pattern

The average annual use of the tractor was 1,772.62 hours (**Table 1**). The average annual use for tillage was 1,036.10 hours (58.45 %), which included both the farmers own work as well as that of custom work. Custom work included two main operations like tillage and transportation. It is clear from the **Fig. 2** that farmers used tractors mainly for tillage, which amounted to 58.45 % of the annual use out of which 83.11 % were for the cultivator, 16.21 % for the planker and 0.68 % for the M.B. plough. Low percentage use of the M.B. plough was due to its non-popularity in the study area. The custom hiring rate in this district was about Rs.225 per hour. The small size tractors had less use under custom hiring than the medium sized tractors.

Effect of Annual Use on Operating Cost

The cost was determined from the working hours for agricultural operations and total working hours of the tractor. Total operating cost per hour varied from Rs.163.34 to Rs.175.55 for the 26.11 kW tractor and Rs.134.66 to 151.52 for the 18.65 kW tractor for an annual use of 1,720 hours to 2,240 hours and 1,500 hours to 2,020 hours, respectively. There was a significant correlation ($r_{35} = -0.95747$ and $r_{25} = -0.95675$) between annual use and cost per hour of the tractor. The curves shown in **Figs. 3** and **4**, had a quadratic relationship and show the inverse relationship between annual use and cost per hour of the tractor.

Table 2 Cost per hour for different size group of the tractor

Group	Power, kW	Cost, Rs/h
Small Size	18.65	145.20
Medium Size	26.11	168.96

The relationship was:

For 35 hp (26.11 kW):

$$y = 3E - 05x^2 - 0.1315x + 318.23 \quad (1)$$

$R^2 = 0.9559$, and

for 25 hp (18.65 kW):

$$y = -2E - 05x^2 + 0.044x + 130.98 \quad (2)$$

$R^2 = 0.9292$

where,

Y = Cost per hour, Rs/h

X = Annual use, h

The cost decreased with the increase in annual use of the tractor. The tractors were also used for social work, arrangement of fuel, lubricating oil and spare parts from one place to another in addition to

Fig. 1 Tractor Utilization Pattern

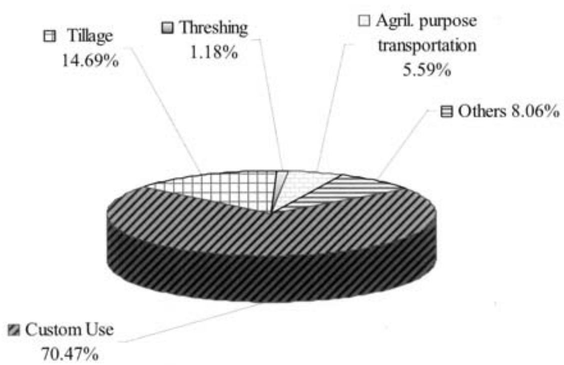


Fig. 2 Tillage pattern

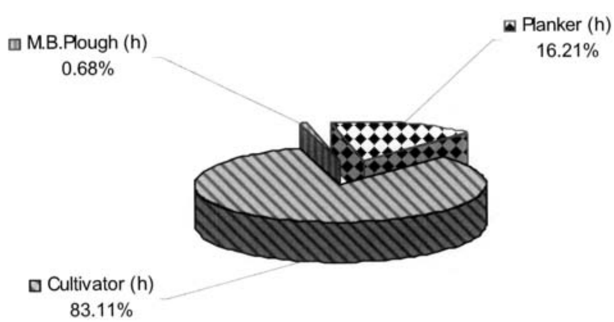


Fig. 3 Relation between total annual use and cost per hour for 35 hp. tractor

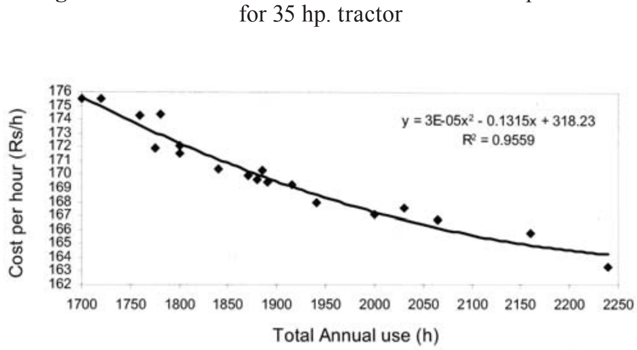
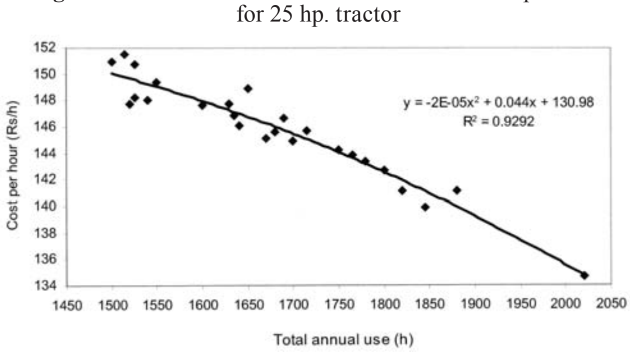


Fig. 4 Relation between total annual use and cost per hour for 25 hp. tractor



the actual agricultural operations.

Effect of Size of Tractor on Operating Cost

The cost per hour for different sizes of tractor is shown in the **Table 2**. The farmers used mainly 18.65 kW (25 hp) and 26.11 kW (35 hp) tractors. Total cost per hour increased with the increase in size of the tractor. This was due to the fact that fixed cost as well as variable cost increased for higher hp of the tractor. The average cost per hour was Rs.145.20 for 18.65 kW of the tractor and Rs.168.96 for 26.11 kW of the tractor (**Table 2**).

Effect of Tractor Age on Operating Cost

The cost per hour for different ages of tractors is shown in **Table 3** and **Fig. 5**. The average operating cost was Rs.159.72 per hour for the tractor up to 2 years old and decreased to Rs.152.12 per hour for the age group of 5 to 6 years old. Then, the operating cost increased as the age of the tractor increased to Rs.159.86 per hour for 11 to 12 year old tractors. This was due to higher maintenance cost for older tractors.

The operating cost was more in the beginning because of the high depreciation and non-setting of various tractor systems. The operating cost decreased with the age of the tractor due to less depreciation in the later ages of the tractor up to six years. Then, the operating cost increased due high maintenance cost.

There was a significant correlation r = −0.95 between the age of the tractor and cost per hour of the tractor. The nature of the curve was quadratic (**Fig. 5**) and the relationship is shown in equation (3).

$$Y = 1.0823X^2 - 7.4874X + 166.26 \quad (3)$$

where,

Y = Cost per hour, Rs/h

X = Age of tractor, years

Break-Even Point for Different Sizes of the Tractor

The break-even point was determined for different sizes of tractors (**Table 4**). The break-even point increased with the increase in tractor size (kW). For 596.42 hours, it was 18.65 kW and increased to 685.20 hours for 26.11 kW. The fixed cost and operating cost increased with the increase in kW of the tractor. Therefore, the break-even point also increased.

The average annual use of the tractor was 1,772.62 hours in this district, whereas the maximum break-even point was 685.20 hours for the 26.11 kW tractor. Therefore, it was clear that tractor operation was very profitable in the district.

The annual use could be increased further by use of more improved implements such seed-cum?fertilizer drill, ridger, potato planter and diger, tractor operated reaper and thresher. Farmers in this district use stationary diesel engines for threshing. Instead of this they could have performed threshing by the tractor. By this mode of operation, annual use could have increased significantly. In this way, purchase of a tractor should be very profitable in this particular area.

Conclusions

The following conclusions may be drawn from the present study:

1. Average annual use the tractor was 1,772.62 hours. However, tractors were used for less time in actual agricultural operations. This may further be increased if threshing were also carried out through the tractor engine.
2. Tractors were used for the farmers own work as well as for custom work. The percentage tractor use for their own work was 29.53. For rest of the time the tractor was used for custom work.
3. Maximum use of the tractor was for tillage, which was 58.45 % of the total annual use of the tractor and 14.69 % for the farmers own tillage work. Whereas, the minimum use was for threshing was only 1.18 %.
4. Average hourly cost of operation of the tractor was Rs.145.20 and Rs.168.96 for 18.65 kW and 26.11 kW tractors, respectively.
5. For the calculation of depreciation, the diminishing balance method was most suitable since the term "total annual use of the tractor" was achieved in seven years and the tractor was still under use after seven years.
6. Average cost of operation of the tractor was more initially and, thereafter, decreased with in-

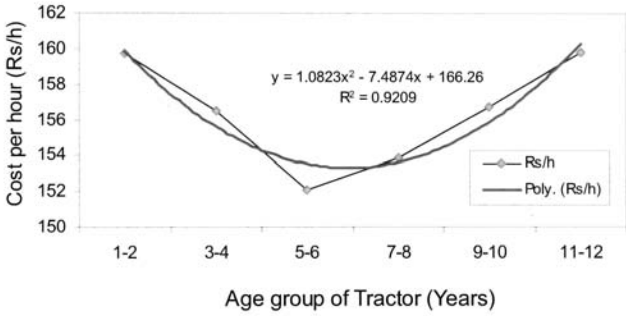
Table 3 Cost per hour for different age group of tractors

Age group, Years	No. of tractor	Cost per hour, Rs/h
1-2	11	159.72
3-4	15	156.5
5-6	22	152.12
7-8	21	153.9
9-10	17	156.71
11-12	9	159.86

Table 4 Break-even point for different size groups of the tractor

Group	Power, Kw	Break-even point, h
Medium	18.65	596.42
Large	26.11	685.20

Fig. 5 Relation between age of tractor and cost of operation per hour



crease in age.

7. Break-even point increased with the increase in size of the tractor. The maximum break-even point was 685.20 hours for the 26.11 kW tractor.
8. Since average annual use in each case was higher than the break-even point, the purchase and use of a tractor was profitable in the study area.

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■■

NEWS

Year 2011 has passed by very successfully for ISAE. Under the great leadership of our President we have many firsts to the credit of the executive in this year and coming next few months. I just want it put it for record so that our members will appreciate these facts. First time ISAE organized an international symposium and it was on a very relevant topic of water. The second one is on anvil and that too very important topic of grain storage. The membership of CIGR and ECI are another important feat which was achieved during this year. Two new chapters of ISAE one at Dehradun and another at Thanjavur were established. Up to date website and regular executive council meetings were other features. Four of our members this year got the NASS fellowship, which is 4/22 and that is also remarkable achievement for the profession and congratulations to all of them. Similarly the awards received by Dr. Bisht and Er. Pund brought glory to our profession. The TNAU chapter was very active in professional activities and other chapters need to follow them.

Unlike other years this time the awards have been announced well in advance and awardees do not have to wait for one full year to get the awards. I hope next executive will also follow the footsteps of this executive and carry forward the good things started by them including that of awards. Grain storage is one of the biggest problems of India and there is an urgent need that we should adopt some alternate temporary storage practices as followed worldwide and for that in history of grain storage polyethylene membrane bag technology has been highlighted. The mulching is another important farm operation which is being appreciated by the vegetable farmers and hence mulching machine was highlighted in the machine of the month category. Farmers are also innovators and that has been amply proven by Mr Nandakumar Shankarrao Jadhav who has developed a Motorcycle Operated Spraying Unit to take care of acute power problem as well rising cost of fuel to operate high powered machines. The unit can cover about 4-5 ha in a day compared to ordinary knapsack sprayer where one person sprays only about 0.4 ha in a day. The CIGR-AgEng2012 that will be held in Valencia, Spain on July 8-12, 2012 is another important coming up event and I hope many ISAE members may get opportunity to attend it. It would be good if ISAE leads the delegation of Indian engineers whose papers will be accepted and who get the sponsor's for this event. This period also saw growing interest of members in ISAE activities and we have 28 new Life Members registered between October and Dec 2011, congratulations and welcome to all of them.

WISHING YOU ALL A VERY HAPPY AND PROPSPEROUS NEW YEAR 2012

R.T. Patil
Chief Editor

from News Letter of Indian Society of Agricultural Engineers www.isae.in

Design and Development of a Single Screw Fish Pellet Extruder

by
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Abstract

A single screw extruder used for fish pellet production was designed, developed and tested. The major components of the machine included the hopper, the conditioning chamber, the barrel that was a stationery pipe member housing and the screw with the die and die holder fitted at the extreme end of the barrel for the extrusion process. Various mechanisms such as the Archimedean screw characteristics, the horizontal ribbon mixing mechanism and belt drive system of power transmission were chosen to give the required motion. The axial compressive force acting on the screw, the circumferential force acting on the barrel and the longitudinal force acting on the die plate were 59.27 kN, 337.26 kN and 49.28 kN, respectively. The total power required to operate the single screw extruder was 2.01 kW: 539 W to operate the conditioning chamber and 1.48 kW to operate the screw in the barrel and extrude the pellets through the die. The designed parameters for the screw shaft were 30 mm, die thickness 10 mm and a barrel thickness of 5 mm. The machine was tested with compounded feed at two screw shaft speeds, 254 and 761 rpm at three moisture contents levels of 15, 20 and 25 % (w.b.). At 761 rpm a maximum output capacity of 64.07 kg/hr was obtained at 25 % (w.b.) moisture content. A maximum output of 63.63 kg/hr was obtained for 254 rpm at a moisture content of 25 % (w.b.). Minimum output capacities of 61.633 kg/h and 61.100 kg/hr at 761 rpm and 254 rpm, respectively, were obtained at 15 % (w.b.) moisture content.

Introduction

In Nigeria, fish alone contribute, on the average, 20-25 % per animal intake and this could be as high as 80 % in coastal communities (FAO, 2000). Tobor (1990) and Ajana (2002) reported that the average annual demand for fish in Nigeria between 1995 and 2000 was estimated at 1.22 million metric tons and that this might increase to about 1.425 million metric tons by the year 2005. FAO (2000) estimated the projected population and fish demand from 1997 to 2025, with domestic fish production by the year 2007 as 0.77 million ton.

However, Adamu (2007) gave the actual total domestic fish production in 2005 as 579,500 tons, while production from aquaculture alone was 56,300 tonnes in the same year. Fasasi (2003) put the demand-supply gap of fish in Nigeria as 1.0 million metric tons. From the above analysis, less than 50 % of the total annual fish consumed by Nigerians is produced locally. There is, therefore, the need to maximize the exploitations of fish production.

Fish farming has generated a lot of interest in Nigeria in the last two decades. Many investors have rushed into commercial fish farming with the aim of maximizing profit on investment. However, only very few have been successful. Many others have abandoned their farms due to the high cost of fish feed (Omitoyin, 2007).

Although, there has been a lot of research on production of fish feed to meet the nutrient requirements of culturable fish in Nigeria, (Faturoti and Akinbote, 1986, Falaye, 1988), good quality fish feed pellets are still sparingly used by farmers. This is due to the fact that there are few commercial fish feed producers in the country. A lot of farmers depend on imported fish feed, which is expensive and not affordable. This increases their cost of production and reduces their profit margin.

There is a need for more commercial fish feed producers in the country to reduce fish production cost and dependence on expensive imported fish feed. There are different types of equipment used to produce fish feed pellets and one is a single screw extruding machine. Thus, a low-cost, locally manufactured, power-operated, single screw extruder was designed and constructed (Okoro, 2009) in view of reducing the cost of fish rearing for the local farmer. It is believed that this will go a long way to fulfill the need of having more commercial fish (pellet) feed produced in Nigeria at affordable cost.

Design and Development

The single screw extruder consisted of a power transmission system, a hopper, a conditioning chamber, a barrel made of a stationery pipe member that housed the screw with the die and die holder fitted at the extreme end of the barrel for the extrusion process (**Figs. 1** and **2**).

The Power Transmission System

With reference to **Figs. 1** and **2**, a single-phase electric motor (11) of 2.238 kW with rated speed of 1450 rpm mounted on a base inside the frame was fitted with an 80 mm pulley (15). A bigger pulley (14) mounted on the screw shaft that rotated inside the barrel received its drive through a V-belt (18) from the electric motor. A second pulley (17) fitted to the screw shaft drove the conditioning chamber shaft (2) through a V-belt (19).

The total power required to operate the single screw extruder was that required to operate the conditioning chamber and the screw press in the barrel.

Power to Operate the Conditioning Chamber (P_c)

The power requirement for the conditioning chamber (a propeller stirrer mixing the material inside a vessel) was given as a function of the Reynolds number (Toledo, 1980) as shown below.

$P_c = aR_e^b$ .... (1)

where P_c = power required by the conditioner, hp; R_e = Reynolds number; and a and b are constants.

$R_e = \rho VD/\mu$ .... (2)

where ρ = density of the material, kg m^{-3}; v = velocity of the material, ms^{-1}; D = diameter of the propeller stirrer, m; μ = viscosity of the material, Ns m^{-1}.

Power to Operate the Screw Press (P_e)

The power (P) required to rotate the screw was given by Crawford (1981) as

$P_e = \mu\gamma\pi^2 D^2 NL$ .... (3)

where P_e = power consumption, W; μ = material viscosity, Ns m^{-2}; γ = shear rate at the barrel, S^{-1}; D = diameter of the barrel, m; N = speed of shaft, rpm; and L = length of the barrel, m.

To obtain the material viscosity, equation 4 (Fenner, 1979) was used,

$\mu = \mu_0 \, (\gamma/\gamma_0)^{n-1} \, exp \, [-b \, (T_b - T_0)]$ ... . (4)

where μ = mean viscosity, Ns m^{-2}; μ_0 = viscosity at a reference temperature, T_o, and a reference shear rate γ_o, Ns m^{-2}; γ = mean shear rate, s^{-1}; γ_o = reference shear rate s^{-1}; T_b = barrel temperature, ºC; T_o = reference temperature, ºC; b = temperature coefficient of viscosity at constant shear rate, c^{-1}; and n = power law index.

Also, the appropriate shear rate used in the calculation of viscosity was given by **Eqn. 5**,

$\gamma = V_Z / H$ .... (5)

where

V_Z = velocity of the material along the barrel, ms^{-1};

H = channel height, m.

The velocity is given by,

$V_Z = \pi \, DN \cos ø$ .... (6)

$ø$ = pitch angle of screw, degrees.

The Hopper

The hopper is mounted on top of the conditioning cylinder and shaped to facilitate the flow of the material and ensure complete emptying of its contents into the conditioning chamber.

The Conditioning Chamber

The conditioning chamber was a cylinder with made of 1.5 mm mild steel sheet 300 mm long and a diameter of 150 mm. A spiral ribbon on a 350 mm long shaft was mounted in the conditioning chamber. The conditioning chamber was mounted on the feeding channel leading to the screw barrel.

The Feeding Channel

The feeding channel was made of a vertical rectangular channel (90 mm × 70 mm × 130 mm high) that connected the conditioning chamber to the screw press barrel. There was

Fig. 1 A Single Screw Fish Pellet Extruder

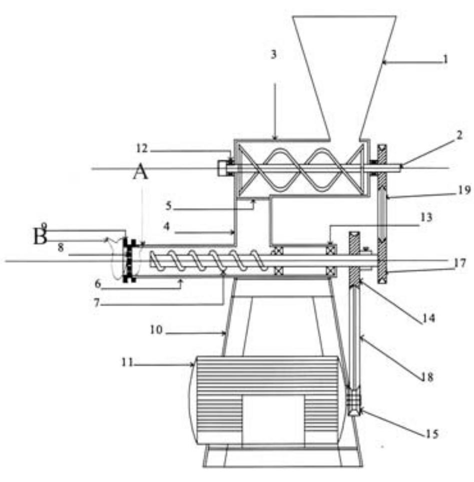
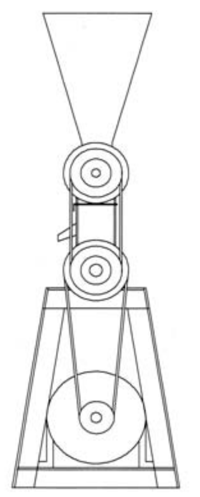


Fig. 2 Side View of the Extruder



1: Hopper, 2: Conditioner Shaft, 3: Conditioning Chamber, 4: Feeding Channel, 5: Shutter, 6: Screw Press barrel, 7: Screw Press, 8: Die, 9: Die Holder, 10: Frame, 11: Electric motor 12: Conditioner Shaft Bearing, 13: Screw Press shaft Bearing, 14: Screw Press pulley, 15: Electric Motor Pulley, 16: Driven Pulley of Conditioner, 17: Driver Pulley of Conditioner, 18: Screw Press Belt Drive, 19: Conditioner Belt Driver an opening at the top of the feeding channel and this had a shutter plate to constrain the raw material moving into the barrel until the materials were well mixed with water in the conditioning cylinder.

The Barrel

The barrel was a metal tube having an internal diameter of 73 mm and length of 480 mm. It housed the shaft carrying the screw press and the bearings. The die was located at the extreme end of the barrel for the extrusion. The bearing housing was 150 mm from the opposite end of the die.

The Screw Press

The screw press, located inside the barrel, was made of a 30 mm diameter shaft 600 mm long. It carried a continuous spiral (screw flight) 10 mm high from one end to a distance of 300 mm on the shaft. The end carrying the flight was fitted into the barrel toward the die end while the other end was mounted on two bearings, which were housed opposite the die end.

The Die

The die was a circular plate 80 mm diameter and 10 mm thick. It was fitted to one end of the barrel and held in place by a die holder ring and four bolts. The die had fifty-one holes 5 mm diameter each drilled on the die. The compressed dough-like feed passed through the holes in the form of pellets.

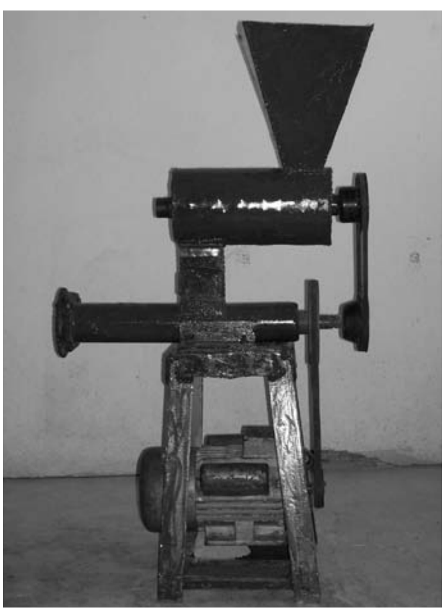
Operation of the Fish Feed Pelletizer

The feed materials were introduced manually into the hopper that flow by gravity into the conditioning chamber. Hot water was also poured manually through the hopper into the conditioning chamber. This was mixed with the feed materials into a dough mass with a spiral ribbon. A shutter was used to close the conditioning chamber until the feed material mixed with hot water formed dough. The shutter was removed and the material flowed through the feeding channel into the barrel with the screw press. During operation, the screw conveyed the feed material, subjecting it to shear stress and forced it out through the die plate holes. The drive from the electric motor powered the shaft of the screw. The extruder was operated as a batch system. **Fig. 3** is a picture of the constructed single screw extruder. **Table 1** gives the specifics of the developed fish pellet single screw extruder.

Table 1 The specifics of the developed fish pellet single screw extruder

1. Type	Electric Motor Driven
2. Over all dimensions	
Length	640 mm
Height	1,130 mm
Width	380 mm
3. Conditioning Chamber	
Type	Spiral ribbon
Length of conditioning cylinder	300 mm
Length of conditioner shaft	420 mm
Length of spiral ribbon	300 mm
4. Screw Barrel	
Type	Screw conveyor
Length of Barrel	480 mm
Length of screw shaft	560 mm
Length of screw	300 mm

Fig.3 Side view of the single screw extruder



Conclusion

Within the considered speeds of 254 and 761 rpm and moisture content levels of 15, 20 and 25 % (w.b.) for the dough, the extruder operated best at a speed of 761 rpm and moisture content level of 25 % (w.b.). The extruder operated best at 761 rpm that could be because of the increased pressure and subsequent increase in temperature of the paste. These increases resulted in a better gelatin nature of the paste that enhanced easy flow and formation of pellets. The output capacity of the extruder at this speed (761 rpm) and moisture content (25 %) was 64.07 kg/hr.

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Effectiveness of the Aeration Method and Pile Shape during Composting Process

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Abstract

This investigation studied the effectiveness of the aeration method and pile shape during the composting process. Six piles of about 6 m^3 were formed under Egyptian climatic conditions from a mixture of rice straw and cow dung during the composting process. Three piles had the shape of a pyramidal frustum and three others had the semi-cylindrical one. Each geometrical shape of pile had three different methods of aeration; static pile, turned windrow and passive aeration. The results showed that the composting process was accomplished with the highest rate in the semi-cylindrical pile with the passive aeration method. The pyramidal frustum with the static pile showed the lowest values of composting parameters as compared to all the investigated treatments. During the mesophilic phase, the pile temperature declined to the ambient quicker in the semi-cylindrical pile with the passive aeration by 166.67 % as compared to the pyramidal frustum with the static pile. During the thermophilic phase, the semi-cylindrical pile with the passive aeration achieved lower peak temperature by 19.37 % as compared to the pyramidal frustum with the static pile. During the cooling down phase, the semi-cylindrical pile with the passive aeration hastened the composting period by 143.75 % as compared to the pyramidal frustum with the static pile. The C/N ratio of the finished compost in the semi-cylindrical with the passive aeration was lower by 77.87 % as compared to the pyramidal frustum with the static pile. The germination index was higher in the semi-cylindrical pile with the passive aeration by 30.81 % as compared to the pyramidal frustum with the static pile. In general, the semi-cylindrical pile with the passive aeration achieved lower final moisture content and shortened the composting period by 109.38 % as compared to the pyramidal frustum with the static pile.

Introduction

Composting is the biochemical degradation of organic materials to a sanitary, nuisance-free, humus-like material. Composting has been defined as a controlled-microbial aerobic decomposition process with the formation of stabilized organic materials that may be used as soil conditioners and/or organic fertilizers. Composting process must be passed through four successive phases: mesophilic (warming up, 20-40 ºC), thermophilic (peak temperature, 40-75 ºC), cooling down and maturing (Golueke, 1973; Wilson and Dalmat, 1986; Dalzell *et al*., 1987; Buchanan and Gilessman, 1991; Garcia *et al*., 1992; Schlegel, 1992 and Negro *et al*., 1999). The main factors affecting the composting process include environmental parameters (temperature, moisture content, aeration and pH) and substrate natural parameters (Carbon/Nitrogen ratio "C/N ratio", particle size, and nutrient content) (Diaz *et al*., 2002). Aerobic composting is the decomposition of organic substrates in the presence of oxygen (Liang *et al*., 2003). The main products of biological metabolism are carbon dioxide, water and heat (Bari and Koenig, 2001). Oxygen is essential for the microbial activity in composting since it is an aerobic process. Aeration is defined as the most important factor in composting systems (Diaz *et al*., 2002). The lack of oxygen (anaerobic conditions) during composting will lead to different types of micro-organisms developing, causing either acidic preservation (similar to silage making) or putrefaction of the pile producing bad odors (Dalzell *et al*., 1987 and Brodie *et al*., 2000). Compost can be aerated by one of three methods: natural or windrow (static pile), passive and active (forced) aeration. Natural aeration is the cheapest and simplest one as it requires no installations. It occurs simply by diffusion and convection governed by the exposed surfaces and their respective properties (Fernandes *et al*., 1994). Although natural aeration can be rate limiting, passive aeration has proven just as efficient as active aeration, while being less costly. Passive aeration requires the installation of ducts under the compost piles to enhance the convective forces, created by the temperature differences between the composting material and the ambient air (Sartaj *et al*., 1997 and Barrington, *et al*., 2003). Sartaj *et al*. (1997) found that passive aeration had a higher composting rate than active aeration and did not produce adverse cooling effects and high N losses as with active aeration. The biological nature of composting demands an understanding of the key factors influencing the microbial ecosystem in order to achieve optimum composting process. One of these important factors affecting microbial metabolism during composting is temperature. It is either a consequence or a determinant of microbial activity (Vallini *et al*., 2002). Controlling process temperature optimizes the rate of composting provided that other parameters fall within reasonable limits in the starting material (McKinley and Vestal, 1985). Moisture content of the composting blend is an important environmental variable as it provides a medium for the transport of dissolved nutrients required for the metabolic and physiological activities of microorganisms (Stentiford, 1996; McCartney and Tingley, 1998). Very low moisture content values would cause early dehydration during composting, which will arrest the biological process, thus, giving physically stable but biologically unstable compost (Bertoldi *et al*., 1983). On the other hand, high moisture may produce anaerobic conditions from water logging, which will prevent and halt the ongoing composting activities (Tiquia *et al*., 1996). Many investigators have conducted experiments and identify that 50-60 % moisture content is suitable for efficient composting (Suler and Finstein, 1977; McKinley *et al*., 1986 and Tiquia *et al*., 1998). In addition to temperature, moisture content and aeration, other factors such as C/N ratio (nutrient balance), pH and available nutrients have been shown to have a significant impact on composting performance (Bertoldi *et al*., 1985; Jackson and Line, 1997). In Egypt, 3-4 million tons of rice straw are produced annually. About 55 % from its total production is burnt by the farmers to clear the fields causing the environmental pollution (MALR, Agricultural Statistics, in Arabic, 2006). An adequate supply of air to all parts of a compost pile is the essential problem. Aeration is achieved by natural movement of air into the compost pile. One of the most important and rewarding problems during composting process is the use of unsuitable method for aerating the compost pile. However, this can fail to supply adequate oxygen in the phases of the process, leading to anaerobic conditions in the lower central regions of the pile of composting material. Therefore, the overall aim of the present study was to characterize the influence of three aeration methods (static pile, turned windrow and passive aeration) and two geometrical shapes of pile (Pyramidal frustum and semi-cylindrical) on the effectiveness of composting process.

Materials and Methods

Six experimental piles were constructed at the Animal Production Research Station, Sakha, Kafr Elsheikh governorate, Egypt in October 2007. These piles were formed from the mixture of rice straw and cow dung with a percent of 59.5 and 40.5 %, respectively. The dimensions of each pile were of 2.5 m long, 2.5 m wide and 1.25 m high. After harvest, rice (Giza 178 variety) straw was chopped into about 5-8 cm segments for all the experimented treatments. Some physicochemical parameters of the composted raw materials and their mixture are listed in **Table 1**.

The six investigated piles were classified into two geometrical shapes and three different aeration methods. The two geometrical shapes were of the pyramidal frustum and semi-cylindrical piles. Besides, each pile had three aeration methods, namely; static pile, turned

Table 1 Some physicochemical parameters of the composted raw material and its mixture

Parameter	Raw material		Initial composting mixture
	Rice straw	Cow dung	
Moisture content, % w.b.	61.28	67.34	63.42
pH	7.2	7.5	7.6
Electrical conductivity, dS/m	3.21	3.46	3.67
Total organic carbon, % d.b.	51.43	20.67	69.95
Total nitrogen, % d.b.	0.804	1.02	1.74
C/N ratio	63.97	20.26	40.20
Total organic matter, %	88.66	37.83	95.43

Table 2 Mathematically calculated values of the two geometrical shapes used in composting piles

Geometrical pile shape	Total surface area (S), m^2	Volume (V), m^3	S/V ratio, m^2/m^3	Mass of 1 m^3 from composted material, kg	Total mass of pile, kg
Pyramidal frustum	11.6228	6.1138	1.90	134.13	820.04
Semi-cylindrical	14.7262	6.1359	2.40	134.13	823.01

windrow and passive aeration with perforated pipes. The volume of the composted materials was fixed for all the experimented piles. With respect to the turned windrow, the composted materials were agitated weekly by a front-end loader. While in the passive aeration, the perforated pipes were placed in the four horizontal directions of the pile with another vertical pipe forming one unit. The material of the pipes was resistant to high temperatures. These pipes were fixed 30 cm high from the bottom of pile and in the middle of the pile along the horizontal direction. The diameter of the pipes was of 7.5 cm. The holes of the pipes were 50 cm long for the horizontal pipes and 20 cm long for the vertical one, measured from the center of intersecting pipes. The diameter of the holes was 2 cm. The perforated pipes were extended outside the pile for about 20 cm through the horizontal and vertical directions of the pile to enhance aeration passages (**Figs. 1** and **2**). **Table 2** indicates the mathematically calculated values of the pyramidal frustum and semi-cylindrical piles during composting process.

Investigated Variables:

The present study was conducted to investigate the following compost factors:

a) Two geometrical shapes of compost pile, namely; pyramidal frustum and semi-cylindrical (Quonset or hoop) and
b) Three aeration methods of compost pile, namely; static pile (without any agitation), turned windrow (with weekly agitation) and passive aeration (with perforated pipes).

The influence of the investigated factors on the compost temperature and moisture content with the composting time was studied. As well as, some physicochemical properties of compost were measured and the germination assay was conducted for all the investigated treatments.

Methods

Calculation of Total Surface Area and Volume of the Compost Pile:

The total surface area (S) and volume (V) of the pyramidal frustum pile are given by the two following relationships:

$$S = 1/2\ (a + b)\ \sqrt{1/2\ (a + b)^2 + h^2} \quad (1)$$

$$V = 1/3\ (a^2 + ab + b^2)\ h \quad (2)$$

where

a = base side length of the truncated pyramid, m;
b = top side length of the truncated pyramid, m and
h = height of the truncated pyramid, m.

Similarly, the total surface area (S) and volume (V) of the Semi-cylindrical pile are given by the two following relationships:

$$S = 1/2\ (2\pi r^2 + 2\pi rh) \quad (3)$$

$$V = 1/2\ (2\pi r^2 h) \quad (4)$$

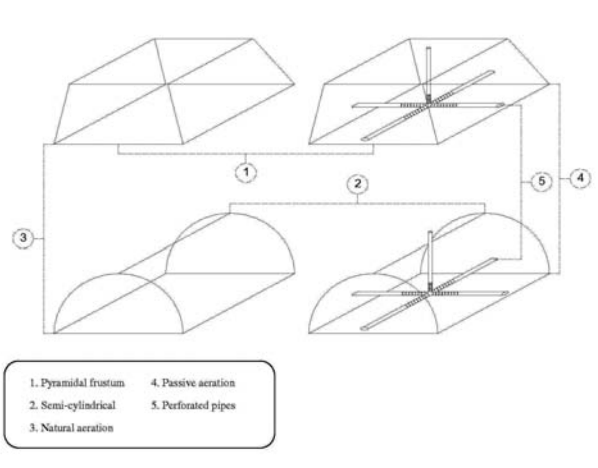
where

r = height of the Semi-cylindrical pile, m and
h = side length of the Semi-cylindrical pile, m.

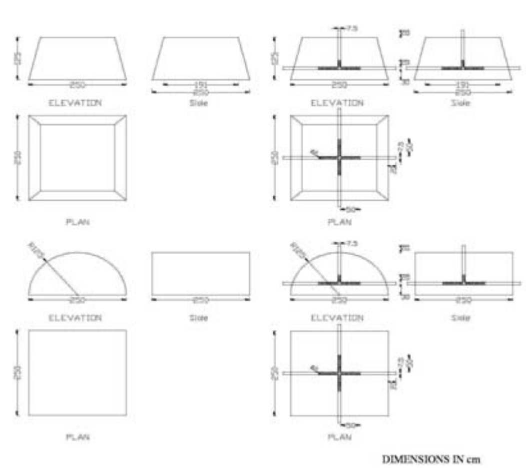
Determination of the Quantity of Cow Dung Added to Rice Straw (Mixture Ratio)

The process of decomposition is hastened by adding nitrogenous material like cow dung to rice straw. This places a balance between the

Figs. 1 A perspective drawing of the compositing piles



Figs. 2 A geometrical drawing of the composting piles



carbon ratio in the rice straw and nitrogen ratio in cow dung, and consequently obtain the convenient C/N ratio in the given mixture. The quantity of nitrogen or cow dung, which must be added to one ton of rice straw, can be calculated according to the following formula (Elgala, in Arabic, 2002).

$$N = [NRS - (ANRS/100 \times 1000)] \times (100/ANCD) \qquad (5)$$

where

N = quantity of nitrogen or cow dung which must be added to one ton of rice straw on dry basis, kg;

NRS = quantity of nitrogen which is actually existed in one ton of rice straw, (15kg according to Elgala, in Arabic, 2002);

$ANRS$ = the average percentage of nitrogen in rice straw, % and

$ANCD$ = the average percentage of nitrogen in cow dung, %.

Pile Shape Forming

For building the pile shape of the pyramidal frustum and semi-cylindrical, two models for the geometrical shapes were designed using the flexible ditch-reed and thread forming the same dimensions of piles (2.5 × 2.5 × 1.25 m). Each model was placed on the ground and, thereafter, the compost mixture was placed in the form of successive layers inside the model to obtain the required geometrical shape of each pile. The bottom surface of each pile was declined by 0.03 m/m lengthwise for facilitating the drainage of excessive water in the pile (if existed). For accumulating the drainaged water from the pile, there was a small pit along the circumference of the bottom of each pile. For the turned windrow, the pile shape was reformed after agitation immediately. For the passive aeration method, the perforated pipes were first fixed and then the model formed around the pipes and, finally, placing the composting mixture inside the designed model to build the required pile.

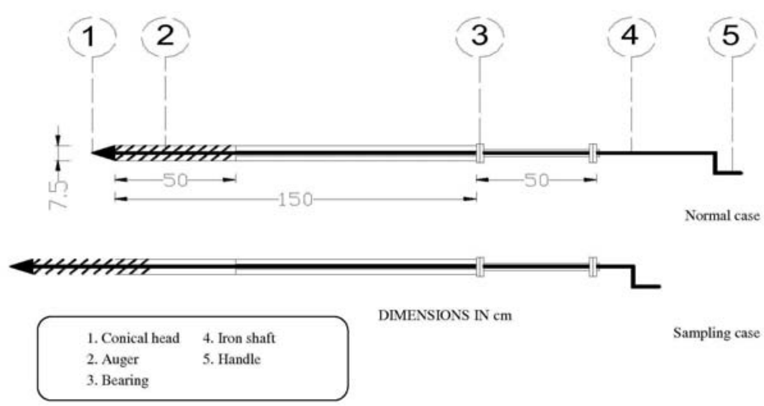
Compost Temperature

Three thermocouples were fixed in the middle of each pile at 35, 70 and 105 cm deep from the bottom surface of the pile to measure the compost temperature in the pile core,. The J-type thermocouples were connected with a digital thermometer (Model: HH-26J-USA) to record the compost temperature at the three different levels and, thereafter, the averaged values could be obtained. Two thermocouples were connected with the digital thermometer to record the ambient temperature and the average values were calculated. Compost temperature was measured every three days at 12 noon during the composting process.

Compost Moisture Content

Triplicate compost samples were taken every six days for determining the moisture content on a wet basis by the oven-drying method (AOAC, 1990). The three samples were taken in the middle of each pile at 50, 80 and 110 cm deep from the bottom surface of the pile and the average values were calculated. Because the moisture content reduced to less than 50 %, a specific quantity of water was added to the pile to keep 60 to 55 % through the mesophilic to thermophilic phases respectively. The highest microbial activity during composting process was maintained in the range of 55-60 % moisture according to Suler and Finstein, 1977; McKinley *et al*., 1986 and Tiquia *et al*., 1998. A sprinkler was employed to add water the next day after taking the compost samples.

Fig. 3 Compost sampler



Compost Sampler

A cylindrical tool, for compost sampling from the pile core, was manufactured in a workshop at the Industrial Region, Kafr Elsheikh city. The total length of the sampler was of 270 cm and the effective length at sampling was 150 cm. The maximum capacity of compost samples inside the sampler was about 2,209 cm^3. The front of sampler was manufactured from a conical head to facilitate its penetration into the pile. The iron shaft of the sampler was fixed on two bearings to move the shaft manually in and out easily. A specific auger was attached to the end of the shaft before the conical head 50 cm long. The outer tube of the sampler was accurately graduated to determine the right position of compost sampling inside the pile (**Fig. 3**).

Determination of the Physico-chemical Properties for the Composted Materials

pH: samples 5 g from each composting material were shaken in 50 ml distillated water (1 : 10 dry weight/volume) for 30 min, then pH was measured using a Bekman pH meter as reported by Page *et al.* (1982). Electrical conductivity (EC, dS/m) was determined according to the method described by Chen *et al*. (1988). A 5 g sample was mixed with 50 ml distilled water, shaken for 2 h and filtered. The EC was measured in the filtrate using a conductivity meter (Jenway PcM^3, Germany). Total organic carbon (C, g/kg) was determined by Walkley-Black method as outlined by Page *et al*. (1982). Total organic matter (%) was calculated from the total organic carbon as described by Page *et al*. (1982). Total nitrogen (N, g/kg) was determined by the semi-micro Kjeldahl method as described by Page *et al*. (1982). C/N ratio was calculated as the ratio between total organic carbon and total nitrogen. The compost samples were analyzed at the Animal Production Research Laboratories, Sakha, Kafr Elsheikh governorate.

Germination assay

Plant bioassays are considered the most direct test for compost maturity, since it shows the effect of compost maturity on plant growth and other maturity tests are correlated with plant growth performance (Iwegbue *et al*., 2006). The germination experiment (in quintuplicate) was carried out on filter paper in Petri dishes. Two milliliters of the corresponding aqueous extract from the composts were introduced into dishes, with distilled water used as control in the other dishes. Ten seeds of rice (Oryza sativa L.) were then placed on the filter paper and the dishes placed in a germination chamber maintained at 20-30 ºC in darkness (Morsi and Abdelgawad, in Arabic, 1964). Results were expressed as percentages of germination and root elongation. The germination percentages with respect to the control and root lengths were determined after 10 days. The germination index (*GI*, %) was calculated according to the formula proposed by Zucconi *et al*. (1985) as follows:

$GI, \% = G\,(L_e/L_c)$ ....(6)

where

G = percentage of germinated seeds in each extract with respect to the control, %;

L_e = mean total root length of the germinated seeds in each extract, mm and

L_c = mean root length of the control, mm.

Results and Discussion

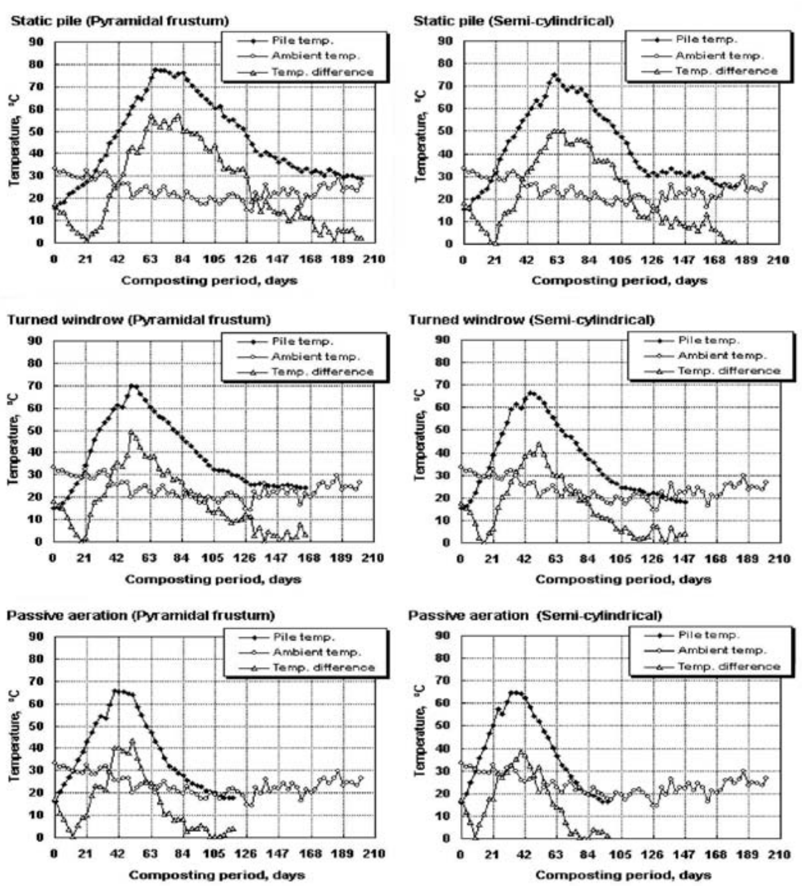
Temperature Profile

Temperature has been widely recognized as one of the most important parameters in the composting process. The rise and fall of temperature have been reported to correlate with the rise and fall of microbial activities (Tiquia *et al*., 1996 and Tiquia and Tam, 2002). The changes in temperature within the composting material during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods are illustrated in **Fig. 4**. The piles went through four phases: mesophilic (warming up), thermophilic (peak temperature), cooling down and maturing (**Fig. 4**). At the beginning of composting process, the temperature of the piles fell with the ambient temperature. For the pyramidal frustum pile, the temperature of composting material reached the ambient temperature after about 24, 18 and 12 days of composting for the static pile, turned windrow and passive aeration, respectively. For the semi-cylindrical one, it reached ambient temperature after about 21, 15 and 9 days of composting for the static pile, turned windrow and passive aeration, respectively. On the other hand, for the passive aeration method, the temperature of composting material reached the ambient temperature after about 12 and 9 days of composting for the pyramidal frustum and semi-cylindrical piles, respectively. This meant that temperature differences between the temperature of composting material and ambient temperature reached its minimum values and they were 0.73, 0.12 and 0.23 ºC for the pyramidal frustum pile and 0.59, 0.01 and 0.57 ºC for the semi-cylindrical one under the conditions of static pile, turned windrow and passive aeration respectively. This implied that the aeration modes might have significant effects on the pile temperature, and passive aeration was the most effective way to provide aeration passages for the pile among the aeration methods. During the mesophilic phase (warming up), the pile temperature tended to increase and reached about 40 ºC. For the pyramidal frustum pile, the compost temperature reached 44.85, 40.55 and 42.79 ºC after 36, 24 and 21 days of composting under the conditions of static pile, turned windrow and passive aeration, respectively. For the semi-cylindrical pile, the compost temperature reached 41.57, 44.28 and 40.25 ºC after 27, 24 and 15 days of composting under the same conditions of the three successive aeration methods. In addition, the compost temperature rose rapidly for the semi-cylindrical pile and hence shortened the mesophilic phase by 40 % as compared to the pyramidal frustum one under the passive aeration method. In contrast, the compost temperature rose rapidly for the passive aeration method and, consequently, shortened the mesophilic phase by 60 and 80 % as compared to the turned windrow and static pile, respectively, for the semi-cylindrical pile. During the thermophilic phase (peak temperature), the temperature exceeded the tolerant limit of the mesophilic phase (above 40 ºC) and promoted the development of the thermophilic one. In this study, the thermophilic phase proceeded about 3-4 weeks in all piles. In all the investigated piles, the peak temperature and the rate of increase during the thermophilic phase were different. The temperature in the pyramidal frustum pile increased to a peak of about 77.46, 69.78 and 65.78 ºC at day 66, 51 and

39 and remained at a peak temperature for about 30, 27 and 18 days for the static pile, turned windrow and passive aeration, respectively (**Fig. 4**). Meanwhile, the temperature in the semi-cylindrical pile increased to a peak about 75.13, 66.35 and 64.89 ºC at day 60, 45 and 36 and remained at a peak temperature for about 33, 21 and 21 days for the static pile, turned windrow and passive aeration, successively. In the case of the semi-cylindrical piles, the peak temperatures were reached at a faster rate (3-9 days earlier) and lower peak temperatures were achieved as compared to the pyramidal frustum ones. In addition, the passive aeration method was able to reach maximum temperature faster than the static pile and turned windrow, presumably because increased aeration maximized the decomposition rate common in the initial phases of composting. Under the condition of turned windrow, the semi-cylindrical pile hastened the thermophilic phase by 28.57 % as compared to the pyramidal frustum one. On the other hand, for the pyramidal frustum pile shape, the passive aeration method hastened the thermophilic phase by 50 and 66.67 % as compared to the turned windrow and static pile, respectively. In this work, the geometrical pile shape proved to be an essential factor, but its effect was less influential than the aeration method on the composting process. The temperature of pile decreased sharply after the thermophilic phase and entered a cooling phase. In other words, it starts after the highest peak temperature of each pile. During the mesophilic phase (warming up), the pile temperature tended to be increased and reached about 40 ºC.

For the pyramidal frustum pile, the compost temperature reached 44.85, 40.55 and 42.79 ºC after 36, 24 and 21 days of composting under the conditions of the static pile, turned windrow and passive aeration, respectively. For the semi-cylindrical pile, the compost temperature reached 41.57, 44.28 and 40.25 ºC after 27, 24 and 15 days of composting under the same conditions of the three successive aeration methods. In addition, the compost temperature rose rapidly for the semi-cylindrical pile and hence shortened the mesophilic phase by 40 % as compared to the pyramidal frustum one under the passive aeration method. In contrast, the compost temperature rose rapidly for the passive aeration method and consequently shortened the mesophilic phase by 60 and 80 % as compared to the turned windrow and static pile respectively for the semi-cylindrical pile. During the thermophilic phase (peak temperature), the temperature exceeded the tolerant limit of the mesophilic phase (above 40 ºC) and promoted the development of the thermophilic one. In this study, the thermophilic phase proceeded about 3-4 weeks in all piles. In all the investigated piles, the peak temperature and the rate of increase during the thermophilic phase were different. The temperature in the pyramidal frustum pile increased to a peak of about 77.46, 69.78 and 65.78 ºC at day 66, 51 and 39 and remained at a peak temperature for about 30, 27 and 18 days for the static pile, turned windrow and passive aeration, respectively (**Fig. 4**). Meanwhile, the temperature in the semi-cylindrical pile increased to a peak of about 75.13, 66.35 and 64.89 ºC at day 60, 45 and 36 and remained at a peak temperature for about 33, 21 and 21 days for the static pile, turned windrow and passive aeration, successively. For the semi-cylindrical piles, the peak temperatures were reached at a faster rate (3-9 days earlier) and lower peak temperatures were achieved

Fig. 4 Variation of temperature during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods



as compared to the pyramidal frustum ones. In addition, the passive aeration method was able to reach maximum temperature faster than the static pile and turned windrow, presumably because increased aeration maximized the decomposition rate common in the initial phases of composting. Under the condition of turned windrow, the semi-cylindrical pile hastened the thermophilic phase by 28.57 % as compared to the pyramidal frustum one. On the other hand, for the pyramidal frustum pile shape, the passive aeration method hastened the thermophilic phase by 50 and 66.67 % as compared to the turned windrow and static pile, respectively. In this work, the geometrical pile shape proved to be an essential factor, but its effect was less influential than the aeration method on the composting process. The temperature of pile decreased sharply after the thermophilic phase and entered a cooling phase. In other words, it started after the highest peak temperature of each pile. During this phase, the composting temperature dropped and remained at a lower level (**Fig. 4**). In the pyramidal frustum pile, the cooling down phase lasted 117, 87 and 69 days of composting for the static pile, turned windrow and passive aeration, successively. While in the semi-cylindrical pile, the cooling down phase lasted 117, 90 and 48 days of composting for the same three successive aeration methods. In contrast, for the passive aeration method, the compost temperature could reach the ambient temperature after about 69 and 48 days of composting in the pyramidal frustum and semi-cylindrical piles, respectively. In addition, the semi-cylindrical pile hastened the cooling phase by 43.75 % as compared to the pyramidal frustum one for the passive aeration method. As well as, in the semi-cylindrical pile, the passive aeration method hastened the cooling phase by 87.5 and 143.75 % as compared to the turned windrow and static pile, respectively. As depicted in **Fig. 4**, the maturing phase could be reached when the compost temperature declined to be very close to the ambient one. At the beginning of maturing phase, the temperature differences were of 0.83, 0.08 and 0.62 ºC in the static pile, turned windrow and passive aeration, respectively, for the pyramidal frustum pile. While in the semi-cylindrical pile, those differences were of 0.88, 0.21 and 0.03 ºC for the same three successive aeration methods. In the pyramidal frustum pile, the composting periods were of 201, 165 and 117 days of composting for the static pile, turned windrow and passive aeration methods, respectively. Meanwhile, in the semi-cylindrical pile, the composting periods were 180, 147 and 96 days of composting under the same three successive aeration methods. In addition, the semi-cylindrical pile accelerated the composting period by 11.67, 12.24 and 21.88 % for the static pile, turned windrow and passive aeration methods, respectively, as compared to the pyramidal frustum one. On the other hand, the passive aeration method accelerated the composting period by 53.13 and 87.5 % as compared to the turned windrow and static pile, respectively, in the semi-cylindrical pile. In other words, the composting process proved more efficient in the semi-cylindrical pile than in the pyramidal frustum one and in the passive aeration than in the turned windrow and static pile methods. The semi-cylindrical shape was the most effective as compared to the pyramidal frustum one. This can be attributed to the fact that as the pile volume was fixed at about 6 m^3, the surface area to volume ratio was greater in the semi-cylindrical shape by 26.32 % than in the pyramidal frustum one. For this reason, the chance of heat exchanging between the pile surface and the surroundings was enhanced in the semi-cylindrical pile more than that in the pyramidal frustum.

Moisture Content

Because of the strong relationship of moisture content with the decomposition rate, moisture content provided an important indicator of composting process efficiency. **Fig. 5** shows the variation of moisture content during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods. In the initial phases of composting, the initial moisture contents of about 63 % w.b. decreased in all piles during the composting process. The moisture content decreased gradually, and reached 48.43, 48.26 and 48.05 % w.b. at the 54th, 42nd and 30th day in the static pile, turned windrow and passive aeration, respectively, for the pyramidal frustum pile. Whereas, in the semi-cylindrical pile, the moisture content reached 47.25, 46.78 and 47.31 % w.b. at the 48th , 36th and 24th day. In the order to maintain perfect microbiological activity, water was sprayed to keep 50-60 % w.b. moisture content. So the water was added to adjust moisture content back up to approximately 60 % w.b. on the days stated above. As depicted in **Fig. 5**, the compost moisture content in the semi-cylindrical pile decreased more rapidly than in the pyramidal frustum one for all the investigated aeration methods. Besides, the compost moisture content in the passive aeration also decreased more rapidly than in the turned windrow and static pile for the two investigated pile shapes. In the semi-cylindrical pile, the compost moisture content decreased faster by 25 % than in the pyramidal frustum one for the passive aeration method. On the other hand, for the semi-cylindrical pile, the compost moisture content decreased faster in the passive aeration method by 50 and 100 % than in turned windrow and static pile, respectively. During the medium phases of composting, the moisture content decreased again gradually, and reached about 48 % w.b. in all piles. The enhancement of composting activities induced by temperature increases can be realized by increasing moisture content alone. Therefore, the water was added at the 90th, 72th and 54th day in the static pile, turned windrow and passive aeration, respectively for the semi-cylindrical pile. In addition, for the passive aeration method, water was added at the 60 th and 54 th day in the pyramidal frustum and semi-cylindrical piles, respectively.

In the last phases of composting, the compost moisture content decreased rapidly until it reached 44.72, 37.11 and 35.41 % w.b. at the 204th, 168th and 120th day in the static pile, turned windrow and passive aeration, respectively, for the pyramidal frustum pile. Meanwhile, the moisture content reached 41.23, 36.86 and 33.25 % w.b. at the 180th, 150th and 96th day, respectively, for the semi-cylindrical pile in the same three successive aeration methods. As outlined in **Fig. 5**, in the semi-cylindrical pile, the final moisture content was lower in the passive aeration method by 10.86 and 24 % than in the turned windrow and static pile, successively. In contrast, in the passive aeration method, the final compost moisture content was lower in the semi-cylindrical pile by 6.5 % than in the pyramidal frustum one. In short, both of the pile geometrical shape and aeration method proved to be important factors affecting the compost moisture content, but the effect of pile shape was less influential than that of the aeration method.

The Physicochemical Characteristics of the Finished Compost

Table 3 indicates the most important parameters of the initial and finished compost for the pyramidal frustum and semi-cylindrical piles and three different aeration methods. For the pyramidal frustum pile, the C/N ratio was lowered in the passive aeration method by 5.12 and 40.82 % as compared to the turned windrow and static pile, respectively. Whereas, for the semi-cylindrical pile, the C/N ratio was reduced in the passive aeration method by 7.55 and 42.41 % as compared to the turned windrow and static pile, successively. This meant that the semi-cylindrical pile had achieved lower values for the C/N ratio as compared to the pyramidal frustum one. As well as, the nearest values to the optimum for the C/N ratio were obtained in the case of the passive aeration method with the semi-cylindrical pile.

Compost Maturity Evaluation

Compost stability can be taken as an indicator of maturity. Compost maturity was tested by the seed germination index. The averaged seed germination index of the finished compost for the pyramidal frustum and semi-cylindrical piles and three different aeration methods is shown in **Fig. 6**. In the semi-cylindrical pile, the seed germination index was of 78.35, 93.25 and 98.45 % for the static pile, turned windrow and passive aeration methods, respectively. Meanwhile, in the pyramidal frustum pile, their values were of 75.26, 91.72 and 97.63 % for the same three successive aeration methods. In the passive aeration method, the seed germination index was of 97.63 and 98.45 % for the pyramidal frustum and semi-cylindrical piles, respectively. This meant that the seed germination index was higher in the semi-cylindrical pile by 4.11, 1.67 and 0.84 % than in the

Fig. 5 Variation of moisture content during composting period of the pyramidal frustum and semi-cylindrical piles for three different aeration methods

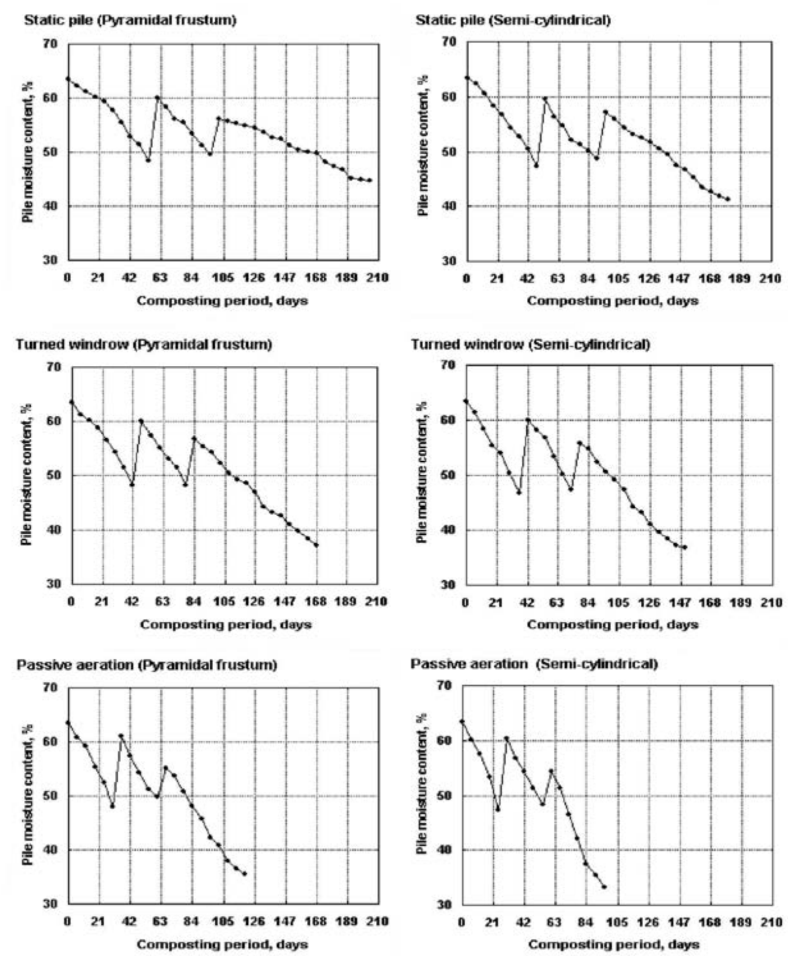


Table 3 The composting parameters of the initial and finished compost

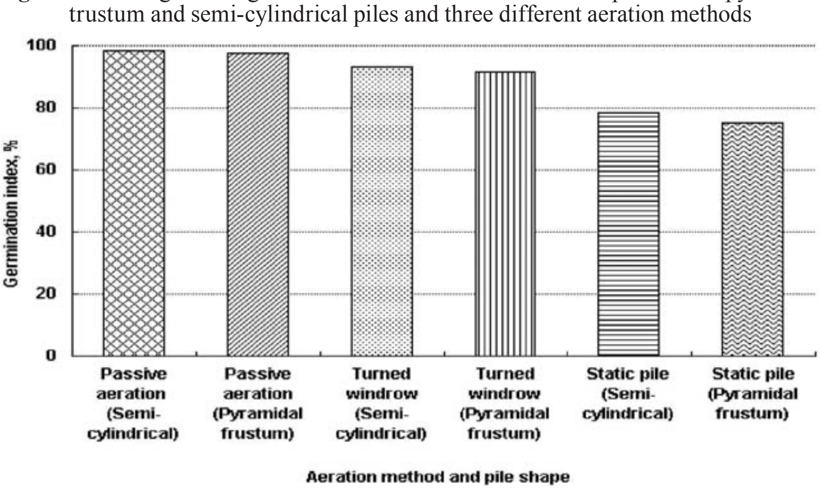
Parameter	Initial composting mixture	Finished compost					
		Pyramidal frustum pile			Semi-cylindrical pile		
		Static pile	Turned windrow	Passive aeration	Static pile	Turned windrow	Passive aeration
Moisture content, % w.b.	63.42	44.72	37.11	35.41	41.23	36.86	33.25
pH	7.6	8.6	8.1	7.9	8.5	7.9	7.8
Electrical conductivity, dS/m	3.67	4.81	4.25	3.98	4.75	4.16	3.95
Total organic carbon, % d.b.	69.95	51.78	34.31	33.95	51.41	33.99	33.74
Total nitrogen, % d.b.	1.74	1.76	1.87	1.95	1.79	1.90	2.04
C/N ratio	40.20	29.42	18.35	17.41	28.72	17.89	16.54
Total organic matter, %	95.43	89.12	59.11	58.45	88.54	58.47	58.16

pyramidal frustum pile for the static pile, turned windrow and passive aeration method, respectively. On the other hand, the seed germination index was higher in the passive aeration method by 5.58 and 25.65 % than in the turned windrow and static pile, respectively, for the semi-cylindrical pile.

Conclusion

From the outlined results, it can be concluded that the semi-cylindrical pile with the passive aeration method achieved the best indicators during the composting process. In contrast, the worst parameters were obtained in the pyramidal frustum with the static pile as compared to all the investigated treatments. The most important indices during the composting process have been outlined below in **Table 4**.

Fig. 6 The averaged seed germination index of the finished compost for the pyramidal trustum and semi-cylindrical piles and three different aeration methods



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Tiquia, S. M., N. F. Y. Tam, and

Table 4 The most important indices during the composting process

Composting phases and indices	Semi-cylindrical pile with the passive aeration method	Pyramidal frustum pile with the static pile
Temperature:		
1) Mesophilic phase:		
Composting period, days	15	36
Pile temperature range, ºC	15.86 - 40.25	15.74 - 44.85
Time through which pile temperature declined to ambient one, days	9	24
Temperature difference (ambient and pile), °C	0.57	0.73
2) Thermophilic phase:		
Peak pile temperature, ºC	64.89	77.46
Time through which pile temperature reached to the peak one, days	36	66
Composting period, days	21	30
3) Cooling down phase:		
Composting period, days	48	117
4) Maturing phase:		
Temperature difference (ambient and pile), ºC	0.03	0.83
Time through which pile temperature declined to ambient one, days	84	183
Final moisture content, % w.b.	33.25	44.72
Final composting period, days	96	201
Final C/N ratio	16.54	29.42
Final pH	7.8	8.6
Final electrical conductivity, dS/m	3.95	4.81
Germination index, %	98.45	75.26

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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.

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Agricultural Land Disaster Due to Disposal of Marble Slurry in Fields: **Ishwar Chand Sharma,** Head, Civil Engg. Dept. Arya College of Engg. and Research Center Kookas Jaipur(Rajasthan), INDIA; **Naresh Chandra Saxena**, Prof., same.

Rajasthan marble industry has a major portion of marble reserves in India but losses in processing produce quite a considerable quantity of wastes including slurry. The disposal of slurry is dangerous to agricultural lands resulting in to environmental degradation. Agricultural disaster is distinctly damaging on a wide scale. Since slurry is alkaline with a pH value of 9.1, it gives hope of its effective utilization in concrete industry as an admixture thereby rural construction gets boost up. Moisture contents were determined and found very low. Similarly water absorption property was also extremely low. This is harmful to agricultural lands/crops, because of state of dryness and fine particles. The study of marble slurry investigating the effect on crops and lands was done in three phases viz on existing crops like garden grass, wheat crops and sunflower, pregermination and post germination. On all counts, damage observed and plotted on graphs distinctly draws the attention of severity of the problem. Barren land which is damaged by slurry can be reclaimed by ponding provided the extreme of damage is determined by experiments.

The very structural properties of marble slurry are disastrous to agricultural land and some are found with their effects. Disposal of marble slurry is different vis a vis city solid waste disposal. Creating awareness and ascertaining in agriculturists and authorities managing disposal is essential. Conclusively it is a hazardous (potential danger) and disasterous (damage done already where it has been spread).

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Ergonomical Evaluation of Pedal Operated Paddy Thresher with Farm Women: **S. P. Singh,** Senior Scientist (FMP) and Scientist-in-charge, Sub-centre of Directorate of Research on Women in Agric., CIAE, Nabi bagh, Bhopal-462 038, INDIA; **L. P. Gite,** Project Coordinator, AICRP on Ergonomics and Safety in Agric., same.

Rice is a staple food for a large part of the world's human population, making it the second-most consumed cereal grain. The paddy is being threshed in most part of the country by beating on wooden platform. This practice involves more time and labour in addition to the occupational health problems to the workers. Pedal operated paddy thresher refined by OUAT, Bhubaneswar was taken for ergonomical evaluation with 12 farm women to see the suitability for them. Kanti variety of paddy was used for threshing with the equipment. Each woman worker operated the equipment for 30 minutes. Mean heart rate of women workers during threshing was 136 beats/min and work pulse was 53 beats/min. The estimated oxygen consumption rate was 0.87 l/min which is 54.3% of her aerobic capacity. Rest of 11-12 min may be provided to worker with the equipment after 30 min of continuous work. Thus, two workers may be engaged with the equipment to operate in shift for alternate operation of the equipment during day long work. The force required in operation of pedal thresher was found to be 162 N at 5.8 m/s. The metabolic efficiency of worker in operation of this equipment was found to be 14.77%. Output in terms of throughput capacity per hour and paddy grain per hour was 79 and 23.8 kg, respectively. The equipment could be promoted for use by farm women as it also have safety cover provided over wire loop protects scattering of paddy grain and also face of operator from hitting of grain.

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Economical Moisture Measurement System for Dried Longan Aril Using Electrical Capacitance

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Abstract

Presently, there is no specific instrument for moisture content measurement of dried longan aril. It can only be measured directly by an extensive measurement method. It takes at least 8 hours and must be performed by a skilled agriculturist. This research has developed a system to measure the moisture content. A new circuit design for measuring capacitance and the design and construction of a longan aril container to mimic a capacitor were proposed and, subsequently, a prototype moisture measurement system for dried longan aril was successfully invented. The estimated capacitance yielded the moisture content and dielectric constant of dried longan aril inside the container. The system was tested on the total of 1,500 samples to determine the relationship among moisture content, dielectric constant, and electrical capacitance of dried longan aril. The results showed that the electrical capacitance and the dielectric constant of dried longan aril increased with moisture content. The moisture content could be calculated from the capacitance of the dried longan aril-based capacitor by using a specific polynomial equation. The 1,500 samples tested had a very low mean absolute error of 0.652 % w.b. The system worked very well and achieved a mean absolute error of 0.721 % w.b. in the blind test experiments. The total budget to build this economical moisture tester was less than 60 US Dollars.

Introduction

Longan fruit (Dimocarpus Longan Lour.) is a non-climacteric subtropical fruit. It has been grown commercially in many countries including China, Thailand, India, Vietnam, Australia, and the United States (Jaitong, 2007). One of the factors that affect the deterioration of dried agricultural products, including dried longan, is moisture content (Jorgensen *et al*., 1970). It is the major factor affecting quality and price of dried longan. The moisture content of dried longan must not exceed 13.5 % w.b. (wet basis) of the whole fruit or 18 % w.b. of aril (National Bureau of Agricultural Commodity and Food Standard, 2005). Presently, there is no specific instrument for moisture content measurement in dried longan. Farmers can subjectively estimate the moisture from the surface of the skin, the aril, and the seed by their experience.

For grain products, an indirect moisture measurement method can be determined accurately in the ranges of 7 to 17 % w.b. for electrical resistance and 6 to 21 % w.b. for capacitance (Nelson, 1982). The measurement of dielectric properties (capacitance) has gained importance because it can be used for non-destructive monitoring of specific properties of materials undergoing physical or chemical changes. A moisture content measurement system for grains was proposed based on dielectric properties (Venkatesh & Raghavan, 2004). Early measurements of food dielectric properties were published for carrots at frequencies in the range of 18 kHz to 5 MHz (Dunlap & Makower, 1945). Dielectric properties of apples at frequencies of 300 to 900 MHz varied with maturity, and decreased in the process of aging (Thompson & Zachariah, 1971). The dielectric properties of selected vegetable and fruits were also tabulated at a frequency range of 0.1 to 10 GHz (Tran *et al*., 1984).

The dielectric properties of the common bean increased with moisture and bulk density and decrease with frequency (Berbert *et al*., 2002). The dielectric constant of chickpea flour and loss factor increased with higher temperature and moisture content (Guo *et al*., 2008). A study of the dielectric constant of pea puree was conducted using electric frequency that varied from 915 MHz to 2,545 MHz with a temperature between 25 to 125 ºC (Tong *et al*., 1994). The dielectric constant decreased when temperature and frequency increased. The dielectric constant of garlic (Allion sativum L.) was reported to have a linear regression relationship with temperature (Sharma & Prasad, 2002). Dielectric constant of oats had a linear regression with bulk density (Nelson & Charity, 1972). Electrical frequency from 1 to 50 MHz was applied in wheat, corn, oats, and barley and when moisture content increased, dielectric value increased (Nelson, 1982). The potential was considered for microwave finished drying of potato chips, and energy absorption at 1.0 and 3.0 GHz increased at higher moisture contents and temperature (Pace *et al*., 1968). An example of the commercial moisture measurement systems is the moisture tester model 465 by Vomax company that measures the moisture of dried products like nuts and cotton using a low power radio frequency resonance technique (Vomax Pty. Ltd., 2009).

The dielectric properties of the material affect the capacitance and the moisture of the material affects the dielectric constant (Ryynanen, 1995). The dielectric constant of the material is in direct proportion to the moisture. Accordingly, the determination of capacitance is an indirect moisture content measurement for products. This method is convenient, quick, and not subjective. If a method for quick and accurate moisture content measurement of dried longans is developed, farmers can use the method to produce good quality products that can be stored for a long time. Estimation of moisture content from capacitance measurements has been done by many research groups and many commercial testers are widely available as mentioned in this section. However, there are many possible ways to measure capacitance or resistance, especially when the dielectric materials are different. There are several commercial moisture testers available in the markets, even though they all share the same basic idea. The room for improvement based on this simple idea is always possible.

A prototype moisture measurement system for dried longan aril was proposed in this research. It was based on the dielectric measurement of dried longan aril by measuring the electrical capacitance of the dried longan-based capacitor.

Materials and Methods

Design of Moisture Measurement System for Dried Longan Aril

As aforementioned, one of the most popular indirect methods for moisture measurement is by using the electrical properties including resistance and capacitance. The electrical capacitance is dependent on the dielectric properties of the material inserted between the plates of a capacitor as follows:

$C = \varepsilon_0 KA / d$ .... (1)

where C is capacitance in Farad (F), A is the surface area of the plates in square meters (m^2), d is the distance between the plates in meters (m), ε_0 is the permittivity in a vacuum (8.854×10^{-12} F/m), and K is the dielectric constant of the dielectric material.

The proposed moisture measurement system for dried longan aril was composed of five components: a direct-current power supply circuit, an oscillator circuit, a frequency divider circuit, a computation unit and an LCD display circuit. The moisture measurement system worked with a direct current power supply. This system used the direct-current voltages (V_{dc}) of +5 volts, +10 volts and 2 amperes of current on the average. The system used a direct current of +5 volts for two microprocessors and +10 volts for an oscillator circuit (ICL 8038). The operation of the system was based on the principle of waveform generation and measuring technique. An oscillator circuit was applied to generate a waveform for this system. In this research, an integrated circuit ICL8038 (IC) was used as a waveform generator (Intersil, 2009). The oscillator circuit operated with an external capacitor and resistors as shown in **Fig. 1**. Different signals could be generated using an ICL8038 IC by setting the values of the external components. There were three main components of the oscillator circuit, i.e., R_A, R_B and C. A generated signal frequency depended on the waveform timings. Adjustment of the frequency was by setting the values of the timing resistors R_A and R_B. A 50 % duty cy-

Fig. 1 ICL8038-based oscillator circuit using dried longan aril as dielectric material

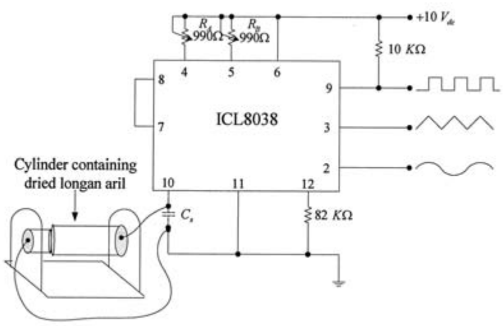
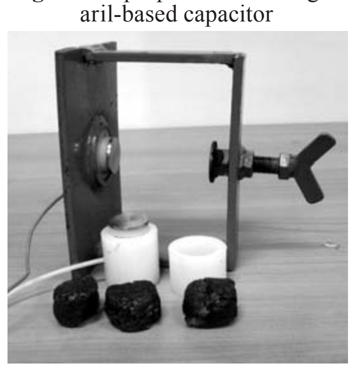


Fig. 2 The proposed dried longan aril-based capacitor



cle could be achieved by setting $R_A = R_B = R$, then the frequency could be computed from Intersil (2009).

$f = 0.33 / RC$ ....(2)

The principal idea of the design was to use dried longan aril as dielectric material inserted between parallel plates of an external capacitor in the oscillator circuit. Dried longan aril was packaged in a cylindrical plastic container with a diameter of 25 millimeters and a length of 14 millimeters with a connecting lead attached to both sides of the cylinder as shown in **Fig. 2**. This dried longan aril-based capacitor was connected to the oscillator circuit as shown in **Fig. 1**. Before connecting the cylinder containing dried longan aril to the circuit, the stray capacitance in the system was measured by generating a pulse signal without a capacitor connected. The frequency of the pulse signal was read by a PIC16F877 microprocessor. This frequency was compared with the frequency yielded by an oscilloscope to confirm that the microprocessor gave the correct frequency. Without a capacitor connected, the frequency of the oscillator circuit output was 1014.7 kHz. From equation (2), the stray capacitance was approximately 328.50 picofarads.

Fig. 3 Inside the real prototype moisture measurement system

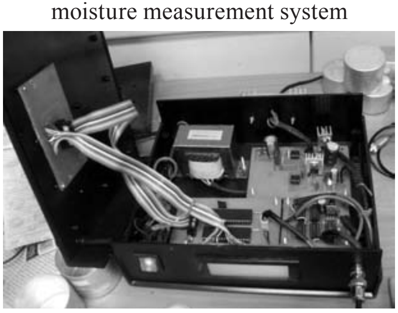
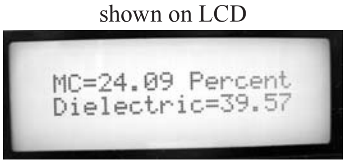


Fig. 4 Information of moisture content and dielectric constant shown on LCD



When the cylinder containing dried longan aril was connected to the system, it acted as a capacitor in parallel connection to the stray capacitor Cs. Therefore, **Eqn. 2** was modified to

$f = 0.33 / R (C_S + C_l)$ ....(3)

where C_l was the capacitance of the longan-based capacitor to be estimated.

A PIC16F877 microprocessor was designed to read a signal frequency below 50 kHz. Because the oscillator circuit generated signals with frequency much more than this specification, a divider circuit was applied to divide the generated frequency by 32. The frequency information from the PIC16F877 microprocessor was sent to a PIC18F458 microprocessor for further processing. The PIC18F458 microprocessor computed the capacitance of the longan-based capacitor using **Eqn. 3**. It also computed the dielectric constant and the moisture content of dried longan aril in the cylinder. Moreover, it was applied to display the derived information to users via a 4-line LCD.

The real prototype moisture measurement system for dired longan aril is shown in **Fig. 3**. The dried longan aril-based capacitor was connected from outside the system box via a cable. The LCD was set to display the moisture content and the dielectric constant of the sample inside the cylinder as shown in **Fig. 4**.

Dried Longan Preparation

Based on the conventional drying process, fresh longan fruits (cv. Daw) were dried at 70 ºC for 13 hours, and then at 75 ºC for 20 hours. After that, the temperature was adjusted to 65 ºC for 15 hours, or until the moisture content was reduced to 10 % w.b. However, in our experiments, 25 hours after the beginning of the drying process, random samples were taken every 2 hours. They were further dried at 70 ºC under vacuum for about 8 hours or until their weights were constants. This was according to the official methods and recommended practices of the Association of Official Analytical Chemists (AOAC, 2005). Their actual moisture contents were calculated by

Moisture content (% w.b.) = [(Weight before drying − Weight after drying) / Weight before drying] × 100 %..(4)

In the meantime, the capacitances of longan arils were measured by the proposed moisture measurement system at room temperature. Dried longan aril was placed between 2 stainless steel discs inside a cylindrical plastic container. The weights of aril placed into the cylinder varied from 9, 10 to 11 grams (equivalent to the bulk densities of 1.30, 1.45 and 1.60 g/cm^3). Five different moisture contents of 10, 14, 18, 22, and 25 % w.b. were considered. For each of the five moisture contents and each of the three bulk densities, 100 samples of dried longan aril were tested. Therefore, a total of 1,500 samples were tested. The information from these 1,500 samples was used to create the relationship among the dielectric constant, bulk density, and moisture content of dried longan aril in the system. In addition, to verifying that the proposed moisture measurement system worked in general, blind testing experiments were performed on 47 samples of dried longan aril with 7 different moisture contents. Blind testing meant the longan aril samples being tested were not used in any step of the system creation. The numbers of samples are 9, 5, 4, 7, 9, 6, and 7 for 11, 12, 13, 14, 15, 16 and 18 % w.b. moisture contents, respectively.

Results and Discussion

Electrical Capacitance of Dried Longan-Based Capacitor

The relationship between the electrical capacitance and moisture content at three bulk densities are shown in **Table 1**. It shows the capacitance measured by the proposed moisture measurement system in terms of the bulk density of dried longan aril at 1.30, 1.45, and 1.60 g/cm^3 and five different moisture contents of 10, 14, 18, 22, and 25 % w.b. The electrical capacitance of dried longan aril increased with the moisture content. Polynomial functions could be applied as predictive equations for the moisture content from the electrical capacitance. These predictive equations are shown in **Table 2**.

Dielectric Constant of Dried Longan

The relationship between dielectric constant with the moisture content of dried longan aril at three different bulk densities is shown in **Table 3**. Because the areas of the two stainless steel plates and the distance between them were known, the dielectric constants could be calculated based on the capacitances in **Table 2** using **Eqn. 1**. We can see that the dielectric constant of aril dried longan aril increases with the moisture content. **Table 4** depicts the predictive equations for the moisture content from the dielectric constant.

Bulk Density Effects

It is noticeable from **Tables 1** and **3** that, for both capacitance and dielectric constant, the bulk densities of 1.45 and 1.60 g/cm^3 yielded rather similar values. However, if the bulk density was too low (1.30 g/cm^3 in this case), the capacitance and dielectric constant were underestimated. This underestimation will lead to an underestimated moisture content. Therefore, the bulk density of dried long aril in the cylinder should be high enough to be applied to the system. It was recommended that the aril sample weight be set to 10 grams for the moisture measurement system. This would give a bulk density of 1.45 g/cm^3. The moisture content could be estimated from the capacitance by using the equation, $y = -0.104x^2 + 3.397x - 1.927$, where x denotes the electrical capacitance (pF) and y denotes the moisture content (% w.b.).

Moisture Measurement System Testing

To evaluate the system performance quantitatively, use of the mean absolute error was made (MAE), which is defined as:

$$\text{MAE} = \frac{1}{n}\sum_{i=1}^{n}\left|\text{Actual MC} - \text{Measured MC}\right| \quad \text{.......................(5)}$$

where n is the number of the test data. The bulk density and predictive equation mentioned in section 3.3 were applied. The 1,500 samples were tested and achieved a very low MAE of 0.652 % w.b. The blind testing experiments were made on 47 samples of dried longan aril with 7 different moisture contents to verify that the proposed system worked in general. These longan aril samples were not used in any step of the system creation. The numbers of samples were 9, 5, 4, 7, 9, 6, and 7 for 11, 12, 13, 14, 15, 16 and 18 % w.b. moisture content, respectively. The proposed system worked very well in the blind testing experi-

Table 1 Relationship among electrical capacitance, bulk density and moisture content of dried longan aril

Moisture content (% w.b.)	Electrical capacitance (Mean ± Standard deviation, pF)		
	Bulk density (g/cm^3)		
	1.30	1.45	1.60
10	4.0443 ± 0.1351	4.3269 ± 0.2080	4.4420 ± 0.2080
14	5.2406 ± 0.0537	5.2463 ± 0.0863	5.2769 ± 0.0817
18	7.5007 ± 0.2319	7.5785 ± 0.2620	7.5836 ± 0.2923
22	10.2100 ± 0.2379	10.9261 ± 0.1228	11.1206 ± 0.1170
25	12.2879 ± 0.2409	13.0128 ± 0.1248	13.2098 ± 0.1184

Table 2 Predictive equations for moisture content from electrical capacitance [x : electrical capacitance (pF) and y: moisture content (% w.b.)]

Bulk density (g/cm^3)	Predictive equations for the moisture content	Coefficient of correlation (R^2)
1.30	$y = -0.095x^2 + 3.293x - 1.310$	0.994
1.45	$y = -0.104x^2 + 3.397x - 1.927$	0.984
1.60	$y = -0.109x^2 + 3.481x - 2.384$	0.980

Table 3 Relationship among dielectric constant, bulk density and moisture content of dried longan aril

Moisture content (% w.b.)	Dielectric constant (Mean ± Standard deviation)		
	Bulk density (g/cm^3)		
	1.30	1.45	1.60
10	13.0222 ± 0.4351	13.9323 ± 0.6696	14.3028 ± 0.6696
14	16.8742 ± 0.1729	16.9002 ± 0.2778	16.9913 ± 0.2629
18	24.1517 ± 0.7467	24.4022 ± 0.8437	24.4185 ± 0.9412
22	32.8753 ± 0.7662	35.1811 ± 0.3953	35.8076 ± 0.3766
25	39.5661 ± 0.7756	41.9003 ± 0.4017	42.5346 ± 0.3813

Table 4 Predictive equations for moisture content from dielectric constant of dried longan aril [x : dielectric constant and y: moisture content (% w.b.)]

Bulk density (g/cm^3)	Predictive equations for the moisture content	Coefficient of correlation (R^2)
1.30	$y = -0.009x^2 + 1.023x - 1.310$	0.994
1.45	$y = -0.010x^2 + 1.056x - 1.947$	0.984
1.60	$y = -0.010x^2 + 1.081x - 2.384$	0.980

ments. The MAE was 0.721 % w.b. moisture content.

Conclusions

A prototype moisture measurement system for dried longan aril was successfully invented based on electrical capacitance of the dried longan-based capacitor. The proposed method included a new circuit design and the special way for measuring the capacitance and the design and construction of the longan aril container. This was the first known moisture tester designed to work with the dried longan aril. The moisture content obtained using electrical capacitance was determined by a relationship between the moisture content and the electrical properties of longan aril. The results showed the polynomial relationships among the moisture content, dielectric constant, and electrical capacitance of dried longan aril. The electrical capacitance and the dielectric constant of dried longan aril increased with moisture content. The system achieved the mean absolute error of 0.652 % w.b. on 1,500 samples of dried longan aril. The system also worked very well and achieved the mean absolute error of 0.721 % w.b. in the blind test experiments. Built on a budget of less than 60 US Dollars, this indirect measurement system will provide a quick and convenient measurement of moisture contents for the dried longan trade, rather than using the inconvenient direct method or the subjective farmer's experiences.

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In Situ Hyperspectral Measurements and High Resolution Satellite Imagery to Detect Stress in Wheat in Egypt

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Abstract

Mapping and detecting stress at both local and regional scales are very important in site specific management. Launching the first generation of high spatial and spectral resolution remote sensing satellite at the beginning of the 21st century provided the opportunity to have better understanding of crop stress and the extent of stress in a specific environment. This work was carried out to assess the ability of hyperspectral and high spatial resolution remote sensing imagery to detect stress in wheat in the Nile Delta of Egypt. A field work visit was made during winter season of 2007, in March, (5-30: wheat) to collect ground reference data including soil samples, vegetation samples, water samples, chlorophyll estimates, reflectance measurements and GPS coordinates. The work visit was timed to coincide with the acquisition of QuickBird satellite imagery (April 7, 2007). The results further showed that the QuickBird image successfully detected stress within the field and local scales, and therefore can be a robust tool in identifying issues of crop management at a local scale. A strong linear relationship existed between RVI derived from in situ and RVI derived from satellite data (R = 0.75; p = 0.000). The results further showed that MLC was an effective classification algorithm for differentiating different crops within the study area.

Introduction

Maximising crop production at a minimum cost is very important for farmers. Mapping and predicting yield at an early growth stage is therefore essential for farmers to make decisions to improve their agricultural practices. Monitoring plant status by means of remotely sensed data will enable farmers to maintain optimal levels of soil moisture and nutrients and avoid overuse of different chemicals, which potentially contaminate soil and water. A further advantage is the possibility to quantify the amount of grain needed to satisfy population demand. It is, therefore, evident that using satellite imagery could be a robust tool in site specific management in the Nile Valley and Delta of Egypt. The improvements and advances in satellite sensor technology providing higher resolution (e.g. QuickBird and Ikonos sensors) can perhaps provide a useful tool in site specific management. These two satellite sensors have significantly narrowed the gap in spatial resolution between satellite and airborn imagery (Yang *et al*., 2006). The advantage of these satellites is the revisit period (1-3 days), which was difficult to be accomplished with many other satellite systems (Moran, 2000). Some researchers used QuickBird satellite images for detecting biochemical and biophysical properties in crops (Wu *et al*., 2007a; Wu *et al*., 2007b). Yang *et al*. (2006a and 2006b) investigated the potential of QuickBird satellite images to predict and map cotton and grain sorghum yield patterns; they established strong correlations between vegetation indices derived from QuickBird images and both crop yields. Recently, hyperspectral satellite images such as Hyperion have been used in monitoring vegetation. This satellite had more than 200 spectral bands, which enabled the construction of effective continuous spectra for every pixel in the scene. This will enable researchers to develop new vegetation indices for detecting stress in crops and facilitate the process of distinguishing different sources of stress in crops such as moisture induced stress from salinity induced stress. Bannari *et al*. (2008) developed several spectral indices to quantify chlorophyll concentration of wheat crops at both the canopy and the leaf scales using remotely sensed data. These chlorophyll indices were derived from Hyperion imagery and the results demonstrated that NDPI was the best index for estimating wheat chlorophyll concentration. The overall aim of our research was to assess the efficiency of in situ hyperspectral measurements and high resolution satellite remote sensing imagery to detect stress in wheat in the Nile Delta of Egypt.

The specific objectives of this study were to:

1. evaluate whether in situ hyperspectral measurements can detect stress in wheat
2. Assess the efficiency of classification algorithms to map different crop types and
3. having mapped individual crop types through remote sensing, predict wheat biophysical and biochemical properties via remotely sensed data.

Material and Methods

Study Area

The study area was located in south-west Alexandria, Egypt (latitude of 30º 55' 50" and longitude of 29º 53' 35.6"). To have a range of stress levels in fields, three study sites were chosen; Naser, Kahr and Bangar. The soil at these sites was a sandy loam with low concentration of nitrogen, as these sites have been reclaimed recently from the eastern desert. The majority of the fields within the study area used flood irrigation with a few farms irrigated by sprinkler or trickle irrigation, especially at the Bangar site. The weather in this area was characterised by hot summers and mild winters.

In Situ Hyperspectral Measurements and Sampling Strategy

An in situ hyperspectral survey was undertaken in the study area during the winter growing season of 2007 (8-30 March) concurrent with the acquisition of satellite imagery. The hyperspectral survey was conducted in random fields depending on the size of the field and the status of these fields in terms of stress. An ASD FieldSpec hand-held spectroradiometer was used to measure reflectance from plant canopies. The reflectance measurements were restricted between 10 am and 3 pm to minimise the influence of changes in solar zenith angle. During the in situ hyperspectral survey, the sensor was kept at a constant distance from the soil surface using an iron stand 2 m high. Vegetation samples were collected immediately after measuring reflectance from plant canopies to quantify biomass, plant height and Leaf Area Index (LAI). Soil and water samples at each site were also collected for chemical analysis.

Chlorophyll Determination

For the measurement of chlorophyll concentrations during field work in Egypt, a hand-held SPAD 502 meter (Minolta, Osaka, Japan) was used due to difficulties accessing laboratory equipment. Twenty apical leaves were sampled and put in a plastic bag then kept cool in an ice box after which the chlorophyll concentration was measured in the laboratory.

Spectral Data Analysis

Following the measurements of reflectance by ASD FieldSpec Pro spectroradiometer, the data were downloaded to a PC and preprocessed with ASD software. The in situ hyperspectral and laboratory darkroom spectral data were interpolated to a final spectral resolution of 0.5 nm then truncated between 300 and 1,000 nm. Finally the reflectance was smoothed to further reduce the noise at the start and the end of the magnetic spectrum by passing a 5 nm running mean filter over the whole spectrum.

Remote Sensing Data Acquisition and Analysis

The April 7 QuickBird multispectral image was acquired covering wheat crops of the 2006-07 growing season. QuickBird satellite is a high spatial resolution satellite comprised of four multi spectral bands (blue, green, red and near-infrared) of 2.4 m spatial resolution. The QuickBird image of wheat fields was acquired at 09:06 h GMT on April 7, 2007 for the study area. The image was geo-corrected using image to image technique by infoterra (the image supplier). The image was atmospherically corrected using the dark pixel method (Tyler *et al*., 2006). The image was also classified using both unsupervised classification (k-means) and supervised classification (MLC) to identify different crops in each image.

Calculating Spectral Vegetation Indices

To achieve the objectives of this research twelve commonly used broad band vegetation indices (**Table 1**) were derived from both in situ hyperspectral and satellite imagery to assess the ability of remotely sensed data to detect stress in wheat.

Statistical Analysis

Data were checked for normality using Anderson-Darling method with 95 % significance level. The Pearson Product Moment correlation coefficient was used to test the association between different vegetation indices and crop properties and to identify optimum vegetation indices. Simple linear and multiple regression analyses were used to derive regression equations to the retrieval of grain yield under moisture and salinity stressors.

Results and Discussions

Identifying Different Crops in the Study Area

K-means unsupervised and Maximum Likelihood (MLC) supervised algorithms were used to identify different crops within the study area. Both algorithms were performed on QuickBird image using ENVI v4.4. **Fig. 1** shows different classes of crops using MLC and it is noticeable that the spectral signature from wheat fields was different from clover, bare soil and water. To evaluate the classification methods, a confusion matrix was derived for both k-means and MLC of the QuickBird image. In supervised algorithm, a validation dataset, which was independent from the training data set, was created manually. The validation data set composed at least 1,000 pixels for each class.

The classification produced two distinct crops (wheat and clover) and two more classes (water surfaces and bare soil). The results of the confusion matrix showed that the overall accuracy of the k-means classification was slightly high at 77.4 % even with poor classification for specific targets. The classification accuracy varied for identifying different classes ranging from 42.24 % (for bare soil) to 97.60 % (for wheat crops). The classification accuracy for clover and water were 94.36 and 72.45 %, respectively (**Table 2**). The slightly low classification accuracy for water may be a result of the spectral confusion between water and shadows. The low classification accuracy for identifying bare soil may be a result of spectral confusion between dry soils and wet soils. However, the k-means produced high classification accuracy and might produce too many misclassified pixels. For example the > 0.95 accuracy for identifying wheat crops might lead to high percentage of misclassified pixels.

The confusion matrix derived for MLC (**Table 3**) showed that the overall classification accuracy was high (91.77 %) associated with high kappa coefficient (0.89). The classification accuracy for different classes was also high, ranging from 85.95 % (for classifying clover) to 97.79 % (for classifying water).

Detecting Stress in Wheat

Different broad band vegetation indices derived from both in situ hyperspectral and satellite imagery data established strong relation-

Fig. 1 MLC of QuickBird image acquired on April 7, 2007 for different crops in south-west Alexandria, Egypt

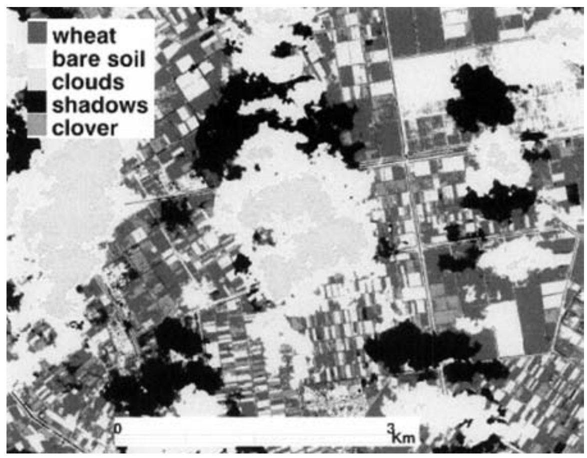


Table 1 Formulae of different vegetation indices and references collected from the literature

Notation	Formulae	Reference
NDVI	(NIR-Red)/(NIR+Red)	Rouse *et al.*, 1974
RVI	NIR/Red	Pearson &Miller, 1972
SAVI	[(NIR-Red)/ (NIR+Red+L)]*(1+L)	Huete, 1988
$GNDVI_{br}$	(NIR-green)/ (NIR+green)	Yang *et al.*, 2006a
DVI	NIR-Red	Tucker, 1979
SR	NIR/Red	Aparicio *et al.*, 2002
SLAVI	NIR/(Red+NIR)	Lymburner *et al.*, 2000
OSAVI	[(NIR-Red)/ (NIR+Red+L)]*(1+L), L = 0.16	Rondeaux *et al.*, 1996
VI1	NIR/(green-1)	Vina, 2003
RDVI	√NDVI × DVI	Reujean & Breon, 1995
SI	Red/NIR	Jiang *et al.*, 2003
IPVI	NIR/(NIR+Red)	Crippen, 1990

NDVI, Normalized Difference Vegetation Index; RVI, Ratio Vegetation Index; SAVI, Soil Adjusted Vegetation Index; GNDVI, Green Normalized Difference Vegetation Index; DVI, Difference Vegetation Index; SR, Simple Ratio; SLAVI, Specific Leaf Area Vegetation Index; OSAVI, Optimized Soil Adjusted Vegetation Index; VI1, Vegetation Index One; RDVI, Renormalized Difference Vegetation Index; SI, Stress Index; IPVI, Infra-Red Percentage Vegetation Index

Table 2 Confusion matrix results for k-means algorithm of wheat and other crops in south-west Alexandria, Egypt

Class	Ground truth, %					User's Accuracy
	Wheat	Water	Bare soil	Clover	Total	
Unclassified	0.00	0.00	0.00	0.00	0.00	(%)
Wheat	**97.60**	25.82	12.65	4.17	35.09	69.90
Water	2.02	**72.45**	45.1	0.28	29.43	61.74
Bare soil	0.38	0.29	**42.24**	0.93	10.42	96.06
Clover	0.00	1.45	0.00	**94.63**	25.06	98.55
Total	100.0	100.0	100.0	100.0	100.0	100.0
Producer's Accuracy, %	97.60	72.45	42.24	94.63		
Kappa Coefficient	**0.698**					
Overall Accuracy	**0.774**					

ships with different biochemical and biophysical properties including chlorophyll concentration, biomass and LAI (**Table 4**). The results at the three sites demonstrated that vegetation indices successfully showed the potential of predicting biophysical and biochemical properties of wheat. OSAVI derived from in situ data produced the strongest correlation with the measured chlorophyll whilst RVI and SR derived from satellite imagery produced the strongest correlation with the measured chlorophyll (r = 0.667). RDVI produced the strongest correlation with biomass and LAI (r = 0.92). The results, therefore, revealed that QuickBird satellite imagery successfully mapped the spatial variability of above ground biomass, chlorophyll, LAI and plant height, which were closely linked to crop grain yield. These results were in agreement with those obtained by Reyniers and Vrindts (2006) and Yang *et al*., 2006b. Grain yield can therefore be predicted using this type of satellite imagery. Successful mapping of agricultural grain crops at early stages will provide a useful tool to detect areas suffering from stress and therefore enable remediation to be implemented to increase yield. Avoiding and managing crop stress in the Nile Valley and Delta may increase crop productivity, which is crucial to a country like Egypt to sustain the rapid population growth.

The combined data set collected from different sites was also used to assess the relationship between different vegetation indices derived from in situ hyperspectral data and those derived from satellite data. **Fig. 2** shows that there was a strong linear relationship between RVI derived from in situ and RVI derived from satellite data (R = 0.75; p = 0.000). The results further showed a decrease in the relationship between the calculated indices from both platforms, which may be attributed to (1) the time difference between collecting in situ data and satellite image acquisition (2) the in situ hyperspectral survey was restricted between 11 am and 3 pm whilst satellite image acquired mid morning and, therefore, different solar angles and (3) in situ data collected at nadir position whilst satellite data acquired at off nadir. The results further demonstrated that QuickBird had low spectral capabilities and subsequently it was not dependable for distinguishing moisture and salinity stress. In this context hyperspectral infrared imager (HyspIRI; 2013-2016) would be effective satellite imagery in detecting stress and distinguishing source

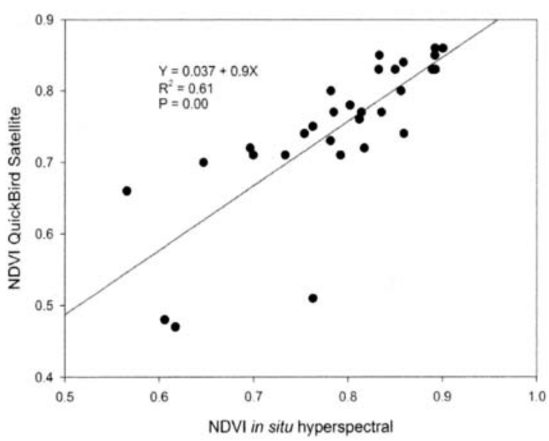
Table 4 Coefficient of correlation between different broad band vegetation indices derived from both in situ hyperspectral and QuickBird satellite data and wheat properties collected in March 2007 in south-west Alexandria, Egypt

Index	Chlorophyll		Biomass		Height		LAI	
	In situ	Satellite	In situ	Satellite	In situ	Satellite	In situ	Satellite
NDVI	**0.76**	**0.627**	**0.82**	**0.905**	**0.85**	**0.885**	**0.72**	**0.894**
RVI	**0.78**	**0.669**	**0.82**	**0.839**	**0.85**	**0.811**	**0.74**	**0.884**
SAVI	**0.79**	**0.627**	**0.78**	**0.905**	**0.69**	**0.885**	**0.51**	**0.894**
$GNDVI_{br}$	**0.79**	**0.627**	**0.82**	**0.884**	**0.87**	**0.836**	**0.76**	**0.884**
DVI	**0.73**	**0.498**	**0.63**	**0.919**	**0.53**	**0.856**	**0.38**	**0.916**
SR	**0.78**	**0.669**	**0.82**	**0.839**	**0.85**	**0.811**	**0.74**	**0.884**
SLAVI	**0.76**	**0.627**	**0.82**	**0.904**	**0.85**	**0.885**	**0.72**	**0.894**
OSAVI	**0.80**	**0.627**	**0.83**	**0.904**	**0.78**	**0.885**	**0.61**	**0.894**
VI1	**−0.30**	**0.666**	−0.11	**0.829**	0.02	**0.797**	0.12	**0.878**
RDVI	**0.77**	**0.544**	**0.82**	**0.927**	**0.85**	**0.873**	**0.74**	**0.919**
SI	**−0.75**	**−0.619**	**−0.82**	**−0.908**	**−0.84**	**−0.889**	**−0.72**	**−0.889**
IPVI	**0.76**	**0.627**	**0.82**	**0.905**	**0.85**	**0.885**	**0.72**	**0.894**

Table 3 Confusion matrix results for MLC algorithm of wheat and other crops in south-west Alexandria, Egypt

Class	Ground truth, %					User's Accuracy
	Wheat	Clover	Bare soil	Water	Total	
Unclassified	0.00	0.00	0.00	0.00	0.00	(%)
Wheat	**90.42**	1.28	2.04	0.00	22.75	96.29
Clover	4.26	**85.95**	3.99	0.09	22.63	90.67
Bare soil	5.32	11.10	**92.46**	2.12	28.92	84.51
Water	0.00	1.67	1.51	**97.79**	25.70	96.90
Total	100.0	100.0	100.0	100.0	100.0	100.0
Producer's Accuracy, %	90.42	85.95	92.46	97.79		
Kappa Coefficient	**0.890**					
Overall Accuracy	**91.77**					

Fig. 2 the relationship between NDVI derived from in situ hyperspectral survey and NDVI derived from QuickBird image collected from wheat fields in south-west Alexandria, Egypt



of stress at a regional scale since it provided images at 400-2500 nm with 45 m spatial resolution. Using this imager with the new advances in detectors, optics and electronics could acquire images with 210 spectral bands and, thus, calculating both broad band and hyperspectral vegetation indices.

Result and Conclusion

The results of this research showed that using high spatial resolution satellite remote sensing such as QuickBird can give a better understanding about stress at a local scale. Due to limited spectral resolution of QuickBird satellite images, it was difficult to distinguish different sources of stress. However, this may be resolved in the near future with the launch of new satellite systems (HyspIRI, 2013-2016) with high spectral resolution and low revisit cycles. The results also established the possibility for mapping different crops within the study area. Moreover, the results demonstrated the high efficiency of both in situ hyperspectral and high spatial resolution remote sensing imagery to predict wheat properties such as LAI, biomass, plant height and chlorophyll concentration. Using this technique in the Nile Valley and Delta will maximise the efficiency of water use and decrease input costs (pesticides, fungicides, fertilizers, seeds and irrigation). Remote sensing could therefore be used as a useful, quick and cost-effective tool in precision farming and regional analysis giving timely information about crops in specific areas.

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Development and Evaluation of Worker Friendly Arecanut Stripper

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Abstract

The arduous operation of lifting and beating each arecanut bunch on a solid surface several times and collection of stripped arecanut from ground level is usually performed in awkward postures which leads to high demands of energy expenditure and develops high work stress in the majority of the arecanut plantation workers. These results in musculoskeletal disorders, such as upper limb disorders, lower limb disorders and less job satisfaction. For minimizing drudgery with increased productivity at reduced human energy expenditure levels, an impact type, worker friendly arecanut stripper with safety features was developed. The hold-on type arecanut stripper unit consisted of a feed tray, a peg tooth cylinder, a stripping mechanism, and oscillating sieve powered by a 2.2 kW petrol start kerosene run engine. The stripping mechanism was a hollow peg tooth cylinder with 15 pegs equally spaced at 42 mm. The arecanuts were separated from bunches due to the impact force of the pegs of the rotating cylinder and the stripped arecanuts fell on the oscillating sieve. The oscillating motion of the sieve separated the arecanut from the chaff and other impurities. The entire unit was mounted on wheels for easy transportation inside the areca plantation. The stripper was suitable for stripping both green and ripe arecanuts. The stripping capacity varied from 650 to 950 kg per hour. The developed worker friendly arecanut stripper was evaluated for its performance and its suitability for male and female workers was assessed for reduced drudgery and adequate comfort. The damage caused to the stripped arecanut was eliminated. A striping efficiency of 99.5 percent was achieved. It resulted in 66 and 77 percent saving in cost and time compared to conventional arecanut stripping. The use of the worker friendly arecanut stripper enhanced the comfort of the subjects with reduction in physiological stress and body part discomfort when compared to conventional arecanut stripping.

Introduction

Labour requirement is an important component in agriculture. In our country, most of the agricultural practices are still being carried out with manual labourers. With the influx of a number of rural workers into urban areas in search of jobs and other opportunities, shortage of labour is a major problem, which almost every village and farmer faces, especially during the arecanut harvesting season. Once the green areca/areca fruit bunches are harvested from the trees, removing arecanuts from the harvested bunches is a difficult point of arecanut cultivation. Arecanut stripping is divided into three phases, viz., collecting the harvested bunches from the field in a stooping posture, lifting the bunches weighing 3 to 5 kg over shoulder height, beating the bunch on a solid surface and collecting the stripped arecanut from the field. In these postures, the energy consumption for a given load is 30 to 50 percent more when compared with standing and sitting posture (Grandjean, 1988). One of the serious health hazards associated with arecanut stripping is the insect bite. To alleviate the acute labour scarcity with reduction in drudgery for the workers, the need for mechanized arecanut stripper is keenly felt. For minimizing drudgery of the workers with increased productivity at reduced expenditure levels, an impact type worker friendly arecanut stripper with safety features was developed.

Methods and Materials

Traditional arecanut stripping demands enormous effort and energy from arecanut plantation workers as the arecanuts are separated from bunches by impact force. The two most commonly used methods for stripping arecanut from the bunches are lifting (**Fig. 1**) and beating the bunches on a wooden pole tied between two arecanut trees or striking the bunches at the bottom of the arecanut tree trunk (**Fig. 2**).

The hold-on type arecanut stripper unit consisted of a feed tray, a peg tooth cylinder, a stripping mechanism and an oscillating sieve (**Fig. 3**). The specifications of the worker friendly arecanut stripper are furnished in **Table 1**.

The prime mover was a 2.2 kW, 3,600 rpm petrol start kerosene run engine mounted on one side of the unit with a supporting frame. Power from the prime mover was transmitted through belt and pulley transmission to the stripping cylinder with a reduction ratio of 14:1. The stripping mechanism was a hollow peg tooth cylinder with 15 pegs equally spaced at 42 mm. The oscillating sieve was made of 7 mm mild steel rod spaced at 20 mm to retain the stripped arecanuts leaving the chaff to pass through the gap. The rotary motion obtained from the prime mover was converted to oscillating motion through an eccentric mechanism. The stripping cylinder was covered on all sides with GI sheet to avoid spilling of arecanuts during stripping and to ensure safety of the operator. A feed tray of 900 × 400 mm provided at a height of 1,010 mm from the operator platform. The feed tray was inclined at 15 degrees to facilitate easy handling of the arecanut bunch while feeding. The arecanut bunch was lifted and rested on the platform during feeding. The arecanuts were separated from bunches due to the impact force of pegs of the rotating cylinder and the stripped arecanuts fell on the oscillating sieve. The oscillating motion of the sieve separated the arecanut from the chaff and other impurities (**Figs. 6** and **7**). A platform for the operator was provided at a height of 290 mm from ground level so that two workers could conveniently stand and hold the bunches. The entire unit was mounted on wheels for easy transportation inside the areca plantation. The cost of the machine was Rs. 15,000/= (excluding engine or electric motor).

Results and Discussion

Field evaluation of the arecanut stripper was conducted on the arecanut plantation fields. The per-

Fig. 1 Arecanut stripping by beating the bunch on wooden pole

Fig. 2 Arecanut stripping by beating the bunch on tree trunk

Fig. 3 Arecanut stripper

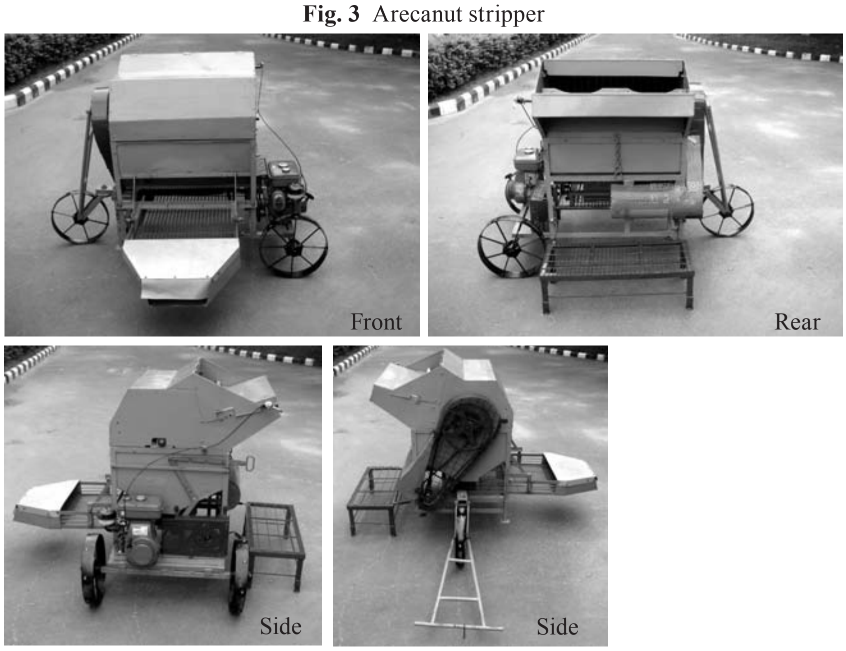

Table 1 Specifications of worker friendly arecanut stripper with safety features

Details	Value
Over all dimensions (L × B × H), mm	2090 × 1940 × 1430
Stripping mechanism	
Type of stripping mechanism	Impact type with peg tooth cylinder
Stripping drum dia, mm	330
Number of strips on the cylinder	8
Number of pegs per strip	15
Distance between the pegs, mm	42
Height of the pegs, mm	145
Diameter of pegs, mm	10
Feeding chute	
Length of feeding chute, mm	405
Width of feeding chute, mm	910
Height of feeding chute from operator's platform, mm	1010
Peripheral velocity of stripping cylinder, m s^{-1}	5.84
Size of operator's platform (L × B × H), mm	910 × 380 × 290
Cleaning assembly	
Oscillating sieve dimensions (L × B × H), mm	1,350 × 660 × 130
Opening size in sieve, mm	20
Drive for sieve assembly	Eccentric type
Transport arrangement	
Type of ground wheel	Plain rim type iron wheel
Number of ground wheels	3
Diameter of ground wheel, mm	460
Prime mover	3 hp petrol start kerosene run engine for portable unit or 3 hp single phase electric motor for stationary unit

formance evaluation of the worker friendly arecanut stripper was compared with the conventional method of arecanut stripping (**Table 2**).

Twelve male and female workers experienced in arecanut stripping were selected for the evaluation (**Figs. 4** and **5**). The benefits of the arecanut stripper in terms of output, saving in cost and time were analyzed. The observations, viz., quantity of arecanut stripped (kg h^{-1}), stripping efficiency (percent) and percent damage caused to arecanut kernel were recorded (**Table 3**).

The effectiveness of the worker friendly arecanut stripper was evaluated directly in terms of increased output (stripping capacity and stripping weeding efficiency) and indirectly in terms of savings in cost and time of arecanut stripping operation (**Table 4**).

The physiological stress imposed on the operator while stripping, viz., heart rate (beats per min), energy cost of work (kJ min^{-1}), over all discomfort rate (ODR) and body part discomfort score (BPDS), were recorded after 60 min of operation during the evaluation. The ease of

Fig. 4 Operational view of arecanut sripper with women workers

Fig. 6 Screened chaff and other foreign materials

Fig. 5 Operational view of arecanut sripper with men workers

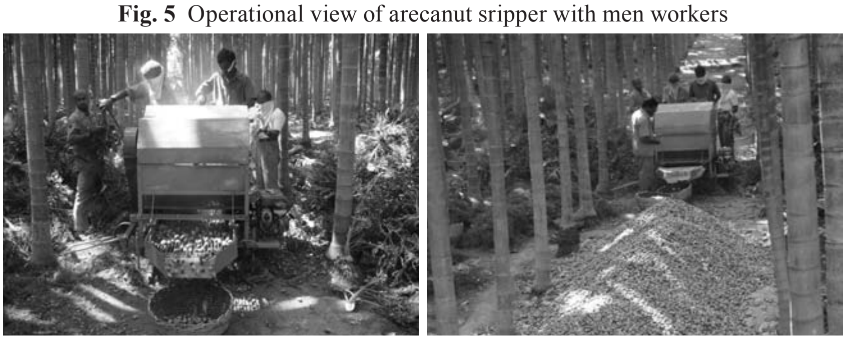

Fig. 7 Stripped areca bunches

operation of selected subjects in the traditional method of arecanut stripping operation and stripping with the arecanut stripper was assessed using a visual analogue scale. Based on physiological data and safety assessment, suitable ergo refinements in the arecanut stripper were made for reduced drudgery and operational comfort.

The worker friendly arecanut stripper resulted in 66 percent saving in cost and 77 percent saving in time of stripping when compared to conventional arecanut stripping.

A comparison of the conventional arecanut tree climbing and TNAU arecanut harvester was done with the measured ergonomic parameters to ascertain the improved comfort and safety of the operator and the results are furnished in **Table 5**.

The use of worker friendly arecanut stripper enhanced the comfort

Table 2 Trial results of the conventional method of stripping

S.No.	Details	Trial results				
1	Conventional method of stripping	Male or female workers lifting and beating the harvested bunches on a wooden pole tied between two trees until all the arecanuts were separated from the bunches.				
2	Number of bunches harvested per day	1,468	2,013	1,408	1,088	334
3	Number of workers employed per day	20 male	39 female	16 male	22 female	6 female
4	Total quantity of arecanut stripped, Kg per day	4,550	6,240	3,540	3,480	1,020
5	Quantity of arecanut stripped by workers, Kg per day	4,451	5,965	3,472	3,374	989
6	Quantity of arecanut left in the bunch and removed by hand plucking	99	275	68	106	31
7	Quantity of arecanut damaged, kg	38.2	87.4	37.2	36.1	12.2
8	Stripping efficiency,%	97.8	95.6	98.1	97.2	97.1
9	Percent damage caused	0.84	1.40	1.05	1.04	1.23
10	Time consumed for stripping, men/women hr	101	194	80	110	30
11	Cost of labour per day	2,200	3,120	1,760	1,760	420
10	Cost of stripping arecanut, Rs/kg	0.48	0.50	0.50	0.51	0.42
11	Stripping capacity, kg/hr	44.1	30.8	43.4	30.7	33.0

Table 3 Trial results of worker friendly arecanut stripper

S.No.	Details	Trial results				
5	Number of workers employed	2 male + 3 female	5 female	2 male + 3 female	5 female	5 female
6	Total quantity of arecanut stripped, Kg	6,230	5,820	6,750	5,460	1,220
7	Quantity of arecanut stripped by machine	6,197	5,773	6,729	5,421	1,216
8	Quantity of arecanut left in the bunch and removed by hand plucking	33	47	21	39	4
9	Quantity of arecanut damaged, kg	2.2	3.6	2.9	1.8	0.5
10	Stripping efficiency,%	99.5	99.2	99.7	99.3	99.7
11	Percent damage caused	0.04	0.06	0.04	0.03	0.04
10	Time consumed for stripping, min	390	506	455	460	109
11	Capacity of machine, Kg /hr	954	690	890	712	672
12	Cost of operation, Rs/hr	129.85	117.85	129.85	117.85	117.85
10	Cost of stripping arecanut, Rs/kg	0.14	0.17	0.15	0.17	0.18
11	Saving in cost when compared to traditional stripping, %	70.8	66.0	70.0	66.7	57.1
12	Saving in time when compared to traditional stripping, %	76.8	77.8	75.5	78.5	77.7

of the subjects with 5.8-8.0, 8.1-11.8, 8.2-9.2, 9.9-12.0 and 14.1-17.0 percent reduction in heart beat, energy expenditure, Limit of Continuous Performance, Overall Discomfort Rating, and Body Part Discomfort Rating when compared to conventional arecanut stripping.

Conclusions

Arecanut stripping is a highly labour intensive operation. Conventional stripping leads to serious health hazards for the workers. To minimize drudgery of the workers, an impact type mechanized worker friendly arecanut stripper was developed. The hold-on type arecanut stripper unit consisted of a feed tray, a peg tooth cylinder, a stripping mechanism and an oscillating sieve. The worker friendly arecanut stripper was evaluated for its performance and its suitability for male and female workers was assessed for reduced drudgery and adequate comfort. The field evaluation of the arecanut stripper was carried out on an arecanut plantation. The hold-on type arecanut stripper unit consisted of a feed tray, a peg tooth cylinder, a stripping mechanism an oscillating sieve and was powered by a 2.2 kW petrol start kerosene run engine. The stripper was suitable for stripping both green and ripe arecanuts. The stripping capacity varied from 650 to 950 kg of arecanuts per hour. The damage caused to the stripped arecanut was eliminated. A striping efficiency of 99.5 percent was achieved. It rresulted in 66 and 77 percent savings in cost and time when compared to conventional arecanut stripping. The use of worker friendly arecanut stripper enhanced the comfort of the subjects with 5.8-8.0, 8.1-11.8, 8.2-9.2, 9.9-12.0 and 14.1-17.0 percent reduction in heart beat, energy expenditure, limit of continuous performance, overall discomfort rating, and body part discomfort rating when compared to conventional arecanut stripping.

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Table 4 Cost economics of arecanut stripping

Parameters	Conventional arecanut stripping	TNAU Arecanut stripper
Stripping capacity, kg hr^{-1}	30 to 44	672 to 954
Damage caused to arecanut, %	1.11	0.04
Stripping efficiency, %	97.2	99.5
Cost of stripping, Rs kg^{-1}	0.48	0.16

Table 5 Comparison of ergonomic evaluational parameters

Ergonomic parameters	Conventional stripping		Worker friendly arecanut stripper	
	Male	Female	Male	Female
HR (beats min^{-1})	128.65	123.85	118.32	116.64
Energy cost, kJ min^{-1}	24.85	21.13	21.92	19.41
Energy grade of work	Heavy	Very heavy	Moderately Heavy	Moderately Heavy
Acceptable work load (AWL)	58.9	61.8	51.9	56.8
Limit of Continuous Performance	44.7	45.2	40.6	41.5
Over all discomfort rate (ODR)	6.51	6.58	5.73	5.93
Body part discomfort score (BPDS)	55.86	56.36	46.35	44.13

Farm Layout and Planting System for Sweetpotato Production in Malaysia

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Abstract

This paper looks at the needs and potential for mechanized operations in the production of sweetpotatoes in Malaysia, focusing on landscape planning to suit the field machinery used. It briefly explains the planning considerations and the availability of machines for these operations. Almost all field operations in the production of sweetpotatoes on mineral and problem soils, except peat soil, can be mechanized; however, a few operations may still need to be done manually. The scale of production determines the extent of mechanization to be adopted. Careful planning is required because mechanized production involves a large amount of capital. Planning should involve establishing a suitable schedule to carry out field operations and selecting the appropriate machines. Local environmental and topographical factors at the farm also need to be considered in the planning of mechanized sweetpotato production.

Introduction

In addition to cassava (Manihot esculenta Crantz) as one of the major sources of starch, the sweetpotato (Ipomoea batatas (L.) Lam.) is just as important in Malaysia with a long tradition of being a starch food. During world war II, the sweetpotato was used as a poor substitute for rice when the grain was in short supply. Currently sweetpotatoes not only provide carbohydrate (starch, to be exact), its potential processing possibilities are also numerous, especially its nutritional qualities.

More and more literature has emerged in recent years attesting to sweetpotatoes being a good source of anti-oxidants such as β-carotene (which makes the flesh orange), vitamins C and E, and anthocyanin (which gives it a purple hue). It also has a reasonable amount of dietary fibre and protein. Anti-oxidants have been associated with such health benefits as the slowing down of ageing, the prevention of certain types of cancers, and a safety measure against cardiovascular diseases. Dietary fibre (present in the sweetpotato at levels up to 4.4% on a fresh weight basis) (Hooloway *et al*., 1985) has its own role: the insoluble fraction having a useful purpose in keeping the bowels healthy and warding off colorectal cancers, while the soluble fraction has been reported to reduce hypertension.

NASA also certifies sweetpotato as a hygienic food for its aerospace program. In Malaysia about 2,000 ha of sweetpotatoes are grown yearly (Tan, 2004), and the area is expected to increase due to the present economic climate and to increasing diversifed uses of the sweetpotato (Tunku Mahmud, 1999). The aim for diversified uses of sweetpotato is not just for local consumption but also for export (Tan *et al*., 2000).

Production is expected to increase if sweetpotatoes are intercropped between young rubber and palm oil (Suboh, 1999).

Malaysia is now focusing on bringing back the agricultural sector to contribute to the GDP. The scenario in Malaysia is that more manpower is channeled into the industrial and service sectors. The agricultural sector is left mainly with aged farmers. With limited manpower, the only alternative is to replace labour with machines. Farmers must make the most out of the available sources. Productivity must be increased and correct application made when using machines. An example of a labour-intensive crop is sweetpotatoes. It is estimated that up to 750 man-hours are needed to grow and harvest one ha of the crop (Akhir and Tan, 2001).

Machines for field operations of sweetpotatoes, such as for land preparation, planting, fertilizer application, weed control, harvesting and transportation have been developed and reported (Akhir and Tan, 2002). In Malaysia mechanization for the sweetpotato is currently limited to land preparation, herbicide spraying, vine pulverizing and digging of roots. Mechanization for the other operations is needed for more cost-effective commercial production of the crop in view of labour shortages.

Currently, increasing agricultural production will face difficulties because of scarce labour. With proper machinery selection, such as a tractor with an air-conditioned cab, the laborious and hazardous jobs can be done safely, comfortly and fast. Such a change in the field working environment will bring about new perspectives when looking at farming as an enterprise in the near future. The main objective of this paper is to present a new approach in sweetpotato production. The aspect of landscape crop planning to suit machinery, planting systems and field production will be addressed.

Field Design for Mechanized Operation

The field layout for mechanized operation is different compared to the manual operations. Bed size and bed spacing in manual planting is not suitable for mechanized operation. Several factors need to be considered in the field landscape design for mechanization of sweetpotato production. Some of the factors that are important in mechanized field operations in sweetpotato production are given below.

Bed Spacing for Machinery Pathway

The arrangement of the beds is determined by the tractor wheel width so that it can pass through and for ease of mechanized operations. A good arrangement of beds and furrows can also reduce soil erosion. However, for mechanized operations, the current sweetpotato system (row spacing of 1.0 m) is not practical since a machinery path is required between rows. For a mechanized sweetpotato farm, planting beds require a machinery path of about 1.3 m between rows for movement of a mini tractor below 25 hp, and about 1.5 m for a standard tractor above 60 hp (**Figs. 1a** and **1b**). The row direction should follow the contour of the land or, if the land is flat, should be aligned in a north–south direction for better light interception by the crop.

Machinery Access Road

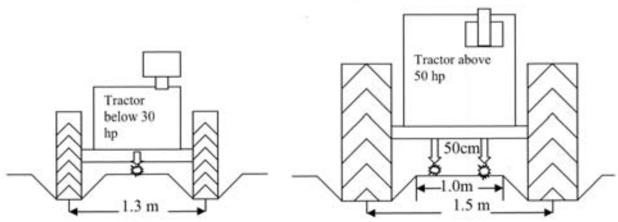
Bed layout design for mechanized operations has to consider machinery access roads in and out of the field. At both ends of the sweetpotato field, there should be sufficient space provided for the machinery to turn, especially in a big field. The best field layout for efficient machinery movement is rectangular with long rows of plants. The longer the row, the less time will be spent on turning, and the better machinery utilization time. The normal size for a turning road is 3.5 m wide at the both ends of the long beds.

Plant Density

Plant density for sweetpotatoes is currently recommended at 40,000 cuttings per ha (Tan, 1998). This system basically involves planting

Fig. 1a Sweetpotato in row planting with a machinery pathway which allows a tractor to pass between the rows (1.3 m between furrows for a small tractor <30 hp and 1.5 m for a standard tractor <50 hp)

Fig. 1b Bed spacing of 1.3 m for single row planting using a mini tractor of 18-30 hp, and 1.5 m for double row planting using a big tractor above 50 hp



and crop maintenance and management by the use of hand tools. It has reported high root yields and good quality roots, but also high labour requirement, leading to increased production costs. Since the system of double-row planting is a main component of mechanized production of sweetpotatoes, the cuttings are planted in rows spaced 50 cm within a bed, and 30-40 cm between plants within a row, using a bed size of 1.5 m between furrows. This plant density is the highest density that can be planted by machines on beds. The system plants close to 40,000 cuttings per ha as achieved by manual planting (Akhir and Tan, 2001).

There are three techniques of planting when using a machine: planting on a flat area either in double or single rows; single-row planting on beds; and double-row planting on beds.

Flat Planting:

This technique of planting places the cuttings on flat land without beds. The beds are built up after planting. The technique can be applied for the single or and double-row machines. For single-row planting, the beds are subsequently built up at a spacing of 1.3 m between rows, while for double-row planting, the beds are built up at 1.5 m spacing. The technique is not recommended by the agronomist because roots develop deeper into the soil, and low yields and small root size resulted (Tan, 1998). Also, machines cannot be used for harvesting because the roots develop too deep into the soil. The digger harvester can only dig up roots at an optimum depth of 50 cm.

Table 1 Machinery available for sweetpotato cultivation

Operation	Small farm (< 10 ha)	Medium farm (< 50 ha)	Large farm (> 100 ha)
Land clearing	Backhoe	Bulldozer	Bulldozer
Drains/roads	Backhoe	Backhoe, ditcher	Backhoe, ditcher
Land preparation	4w tractor	4w tractor	4w tractor
Planting	Tractor + single-row planter	Tractor + double-row planter	Tractor + double-row planter
Basic farm machines	Small air-cond. tractor (25 hp)	Small air-cond. tractor (30-45 hp)	Medium air-cond. tractor (> 50 hp and above)
Weed control	Power sprayer, bush cutter	Boom sprayer, tractor + inter-row cultivator	Boom sprayer, tractor + inter-row cultivator
Fertilization	Inter-row cultivator + fertilizer applicator	Inter-row cultivator + fertilizer applicator	Inter-row cultivator + fertilizer applicator
P&D management	Power sprayer	Boom sprayer	Boom sprayer
Harvesting	Small digger	Digger-conveyor	Digger-conveyor
Handling	Small trailer	One-tonne trailer	Three-tonne trailer
Packaging	Plastic containers	Bamboo baskets	Bulk load
Grading/ packaging	Manual	Semi-mechanized	Mechanized

Single-Row Planting on Beds:

The machine for single-row planting can be attached to a small tractor of 18-30 hp or a power tiller of 10-15 hp. The bed size is 1.3 m wide at the bottom and 0.75 m at the top. Plant spacing is about 30 cm within a row, and the numbers of cuttings required per ha is about 33,333.

Double-Row Planting on Beds:

A double-row planting machine is suggested for a sweetpotato farm of more than 30 ha. This machine will plant in double rows on each bed. The bed size should be 1.5 m wide at the base so that the tractor wheels can pass through the furrows between adjacent beds. Planting density at a spacing of 50 cm between rows on a bed and a plant spacing of 30-40 cm will provide an optimum of 40,000 plants per ha.

Machinery System for Sweetpotato Field Production

Several machines are available for

Fig. 2 Spreading granular fertilizer along the rows of sweetpotato and pulverizing the weeds and soil between the furrows

Fig. 3 Tractor-mounted single-row planter

Fig. 4 Weeding with an inter-row cultivator between the rows of sweetpotatoes (using a mini tractor or standard tractor)

various field operations in sweetpotato production. Proper selection and adaptation of the machinery makes the sweetpotato field operations more efficient, more comfortable and more safe. Commercial sweetpotato production has to rely on machinery for efficient management, especially in the future when the sweetpotato becomes an industrial crop. Some of the mechanized field operations are shown in **Table 1** and discussed below.

Land Preparation Machinery

The first step in sweetpotato establishment is clearing of the land. Large-scale land clearing can be done by bulldozers while smaller scale bush clearing can be done by a backhoe. The same machines can also be used for constructing farm roads and drains. After clearing, the land needs to be prepared for planting. Land preparation involves ploughing, harrowing, rototilling and ridging operations. Land preparation is important for improving soil structure and removing weeds. Standard four-wheel tractors can perform the land preparation operations.

Organic Fertilizer Applicator Machine

The organic fertilizer applicator was of local design. It can apply organic fertilizer at the centre of the bed (or ridge) before planting. This machine was designed by MARDI for use in the application of dried chicken dung along the bed. The machine was attached to the tractor, and the fertilizer dropped along the bed and worked in by a pto-tractor shaft (**Fig. 2**).

Planting Machinery

The normal practice is to cut planting materials (25-30 cm long cuttings) from existing crops or from plants specially raised in a nursery. The cuttings are then planted by hand. This method requires up to 150 manhours per ha. Manual planting is slow, affecting the time taken to plant as well as the cost, especially when carried out on a large scale.

A mechanical transplanter (**Fig. 3**) can reduce the amount of labour used as well as shorten the time required for planting. The transplanter also plants more uniformly. An adapted double-row vegetable transplanter was successfully tested at MARDI Serdang for planting sweetpotato cuttings. Three operators are needed: two for planting and one for driving the tractor. This machine can plant one ha in 8-12 hours, depending on the experience of the operators and driver in synchronizing the operations. The cuttings must be wilted before using the transplanter. Fertilizer application is undertaken simultaneously with planting, using the same machine. Granular fertilizer is applied in a band along the planting row.

The planting system has to match the machine setting. For a double-row transplanter, the spacing between the rows within a bed can be adjusted to a minimum of 50 cm, and the spacing between plants within 25-35 cm.

Weed Management Machinery

Weeds in sweetpotato fields can be controlled by a tractor-mounted inter-row cultivator, which cultivates between the rows (**Fig. 4**). This inter-row cultivator can be attached with a fertilizer applicator and a ridger. The ridger is used for lifting and pulverizing the soil and working in the fertilizer. If required, weeds or grass in the middle of the beds can be controlled by using a boom sprayer to apply weedicide. This boom sprayer must be used at the early stage of planting, or before planting, to control grass seed germination.

Pest and Disease Management Machinery

Pest and disease management is one of the major obstacles in operating large-scale production of sweetpotatoes. During the outbreak of disease, control measures have to be taken fast. Delays in controlling the spread of disease may cause substantial damage to sweetpotato yields. A tractor-mounted boom sprayer or power sprayer is one of the machines dedicated to sweetpo-

Fig. 5 Pesticide spraying using an air-conditioned tractor

Fig. 6 Slashing sweetpotato vines before harvesting

tato pest and disease management (**Fig. 5**). Both single and double-row planting is the best for the sprayer in terms of speed of operation and savings in chemicals. With a machine, spraying height and angle can be controlled according to the height of the crop from the ground and the canopy structure. With the help of a tractor pto shaft, chemical droplets can penetrate deep into the canopy preventing insects from breeding inside the dense canopy.

Fertilizer application machinery

Fertilizer application in the field can be done by a tractor-mounted fertilizer spreader (**Fig. 2**). The machine applies granular fertilizer on both the left and right sides of the tractor. The operation is relatively fast and suitable for a large field. Alternatively, a fertilizer hopper attached to the planter can apply fertilizer at the same time as the planting operation.

If the weeds have germinated within the rows, the inter-row cultivator can be used simultaneously with the fertilizer applicator. Fertilizer leaching can also be minimized by the mixing of the fertilizer into the soils. Optimum maintenance and fertilizer application ensure that maximum yields can be obtained. Observational studies on sweetpotatoes showed that the crops grew faster and produced higher yields with organic fertilizer.

Vine Slashing Machinery

The tractor-mounted flail or shredder with a specially designed blade is suitable for large scale use for slashing the sweetpotato vines before root harvest (**Fig. 6**). The flail blade design is suitable for use on bed crops such as sweetpotatoes. The vines and weeds on the beds can be shredded into smaller pieces by a heavy duty shredder. The pieces are then left on the ground to decompose.

Harvesting and In-Field Handling

Harvesting sweetpotatoes from small fields for the fresh market is generally done manually. Some machine aids such as a cangkul (hoe) and other hand tools are available. One method for easy manual harvesting is by slashing the vines from the roots, and rolling up the vines along the beds. The assam fork, or cangkul mata tiga, is then used to dig up the roots. By this method the roots can be lifted by the fork and placed on one side for collection by another group of workers. This traditional technique is slow and strenuous.

There are three types of harvesting machines which can be used in sweetpotato harvesting. The first type is simple and locally fabricated. It has three strong steel tynes to dig up the roots. The implement is attached to a medium-sized tractor and pulled along the bed. The roots will be lifted up and left on the bed. A group of collectors will follow after the tractor and collect the roots. The tine design consists of parallel blades adjusted to a certain angle for digging the roots (**Fig. 7**).

The second type is a digger-lifter machine. This machine is imported and needs to be attached to the primemover (a standard tractor). The machine will be pulled by the tractor, and the digger will dig into the soil and lift up the roots by a conveyor mechanism. The conveyor will convey the roots and drop them at the back. Any soil and gravel will drop and pass through the conveyor links. A group of collectors will follow at the back loading the roots into a trailer. The problem with this machine is that the soil will be deposited on the roots and cover them, causing the collectors to miss some roots.

The third type is a digger-lifter and elevator. This machine is imported and used for potato harvesting. This machine can be used for sweetpotato harvesting but needs some modifications. This machine also needs to be attached to a big tractor greater than 60 hp. The machine will do three operations at one time. The first operation is digging the roots, the second is to lift up the roots and shake them loose from the soil, and the third is to facilitate root collection, (where one or two people standing at both sides of the machine will collect the roots). The collected roots will then be put on both sides of the elevator and conveyed to the end and dropped into baskets (**Fig. 8**).

Fig. 7 Tine digger–pulling the vines to the side and digging the tubers

Fig. 8 Root digger-harvester machine

A tractor-trailer is suitable for in-field handling on a large farm. A smaller farm may use a wheelbarrow or other carts. The use of a shallow container is better than a deep container as the latter poses a greater possibility of sweetpotato roots being bruised when they are loaded. Sometimes the farmer uses bamboo baskets for sweetpotato handling.

Machinery System for Tin-Tailings and Bris Soils

Machinery for land preparation in the problem soils such as tin-tailings and bris soils is similar to those used for mineral soils, except for ploughing (**Table 2**). The soil structure in these problem soils is loose. For land clearing, a bucket scraper attached to a tractor can be used. A rotovator and ridger can be applied simultaneously during land preparation. The bed size is 1.3 m wide for single-row planting and 1.5 m wide for double-row planting.

A series of tests have been done on tin-tailings and bris soils by using the single-row and double-row planter machines, inter-row cultivator, slasher and harvester. The single-row planter needs to be attached to a mini tractor between 18-25 hp for beds 1.3 m apart, and a double-row planter needs to be attached to a standart tractor 50 hp and above to suit a bed spacing of 1.5 m. For the other maintenance work, the tractor track spacing should follow the bed spacing decided upon.

Cost Considerations

Table 3 shows the estimated cost for each machine in a complete machinery system. **Table 4** shows a comparison between production costs of a manual system and a machinery system. It may be seen that a machinery system on mineral soils will achieve a savings of about 5 sen/kg, or assuming a root yield of 20 tonnes, total savings amounting to RM1,000 per ha on mineral soils

Table 2 Machinery availability, problems and requirements for sweetpotato production on bris and tin-tailings soils

Operation	Machine requirement	Availability
Land Preparation		Suitable on bris soil, attached to a 30 hp 4 w tractor. Setting for ridger 1,016 mm for tractor operation
Tillage (rotor)	Rotovator	
Rotor + Ridger	Rotovator + ridger	
Planting		
Planting materials	Mechanical aid	Cuttings 300 mm long, short internode, 8 nodes per cutting.
Planting spacing	1,016 × 240 mm , 40,000 plants/ha	
Planting method	Transplanter attached to a 30 hp 4 w tractor, planting on beds, 1.3 m wide	Available
Fertilizer applications		
NPK (granular/ powder)	Spreader with some modifications	Available
Organic fertilizer (dry and granular/powder)		Modified, suitable for dry applications
Pesticide spraying	Boom sprayer attached to a 30 hp, 4 w tractor	Available, tractor tracks follow the furrows during sprayer
Water management		
Irrigation	Any type of sprinkler available, depending on field conditions	Available
Drainage	Ridger or disk furrow	
Harvesting		
Vine slashing	slasher or bale roller	Needs some modifications
Root digger	- Vibrator digger - Modified Houlon destroyer digger - Some use of plough/ mechanical implements but damage is high	Still under research/ manual collector is still needed
Root collection	Trailer attached to a tractor and manual collection	vailable

Table 3 Machinery package estimated cost/unit

Machine/implement	No. of units	Cost/unit
Prime-mover		
Tractor, 4-wheel, 60-80 hp	1	RM 74,000
Tillage		
Rotor-ridger	1	RM 19,000
Planting		
Planter, double-row	1	RM 18,000
Fertilizer application		
Organic manure spreader	1	RM 14,500
Inter-row spreader*	1	RM 14,500
Irrigation system		
Complete sprinkler system	1	RM25,000
Weed/pest management		
Boom sprayer**	1	RM 30,000
Inter-row rotary cultivator***	1	RM 35,000
Harvesting		
Rotary slasher (for vines)	1	RM 18,500
Root digger-collector	1	RM 29,000
Transport		
Trailer, 1-tonne capacity	1	RM 10,700
Total		RM 288,200

* Can be used for applying granular pesticides as well
** For use in spraying weedicide, insecticide or fungicide as well as for irrigation purposes
***Can be used for inter-row weeding and for mixing fertilizer in rows.

compared to a manual production system. **Table 5** compares the number of hours required between the two systems. Working hours for the mechanized system could be further reduced if the process of cutting of vines is mechanized.

Conclusions

Based on the earlier discussion, future commercial sweetpotato cultivation has to rely heavily on machinery to stay in business. To get the optimum advantage of mechanized sweetpotato production, the entire current planting system has to be changed to suit machinery requirements. The normal bed size needs to be changed to suit the tractor wheel spacing. The standard tractor wheel spacing is about 1.5 m. Early stage field design is important for easy management during crop maintenance and harvesting. Understanding and accepting the new changes in field design and agronomic practices will enable sweetpotato cultivation to be fully mechanized in the near future and become an attractive business venture.

Table 4 Estimated costs (RM) of producing 1 ha of sweetpotato on mineral soils, sandy soils and drained peat by manual means and on mineral soils by machines

Cost item	Manual production			Mechanical production on mineral soils [4]
	Mineral soils	Sandy soils	Drained peat	
Land preparation(contract)				
2 rounds of tillage	400		400	
1 round of tillage		200	200	
1 round of ridging	200	200	200	200
Planting				
Planting materials+	800	800	800	800
Labour* for planting	240	240	240	120**
Fertilizer application				
5 t of dolomitic lime			400	
Labour for lime application			75	
2.5 t of chicken dung	300		300	
10 t of chicken dung		1 200		
Labour for chicken dung application	75	150		45**
Chemical fertilizers				
34 N, 34 P_2O_5, 67 K_2O	185		185	185
17 kg $CuSO_4.5H_2O$			55	
Labour for application	75		75	30**
80 N, 60 P_2O_5, 120 K_2O		735		
Labour for 3 applications		225		
Weed control				
4.2 L of alachlor	90	90	90	90
Labour for spraying	150	150	150	30**
Pest control				
16 kg of endosulfan granules	50	50	50	50
Labour for application	150	150	150	45**
1 L of malathion	15	15	15	15
0.5 kg of benomyl	35	35	35	35
Labour for spraying	150	150	150	45**
Irrigation				
At plant establishment	180	180	180	180
Additional		180		
Harvesting				
Yield of 20 t @ RM33/t	660	660	660	150**
Total cost	3,755	5,410	3,710	2,720
Cost per kg roots (RM)	0.19	0.27	0.186	0.136

+ Non-recurrent cost after 1st crop of sweetpotato
*Labour cost: RM15 per man-day. **Machine operator paid RM15 per hour

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Table 5 Comparison of working hours for different operations in traditional and mechanized sweetpotato production systems on mineral soils (Fuel consumption estimated at 6 liters/hr)

Operation	Traditional		Mechanized	
	Method	Man-hours/ha	Method	Hours/ha
Ploughing		2-3		2-3
Rotortilling		2.5		2.5
Rotortilling/ ridging		2.5		2.5
Cutting vines	Hand tool	60-67	Hand tool	60-67
Planting	Manual with tool	150-160	Planter, clip type	13-15
Fertilizer application	Manual	40	Spreader (row)	2-2.5
Irrigation	Manual, watering can	50	Sprinkler	2-2.5
Weeding	Manual with tool	60	Inter-row weeder	2-2.5
Pesticide application	Knapsack sprayer	60	Boom sprayer	2
Harvesting:				
Vine slashing	Manual with tool	16	Rotor slasher	2-2.5
Root digging	Manual with tool		Digger-collector	
Root collection	Manual	352		6-10
Total		795-813		96-112

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NEWS

Report on the 4th Asian Conference of Precision Agriculture, 4-7 July 2011, Obihiro, Japan

The 4th Asian Conference of Precision Agriculture (ACPA) was held on 4-7 July 2011 at Tokachi Plaza in Obihiro, Hokkaido, Japan. It was well organized by the Asian Conference of Precision Agriculture with the co-operation of Obihiro city. One hundred and thirty seven participants from 10 countries attended the conference. It was consisted of an Openeing Ceremony, Keynote Addresses and Topic Sessions covering all the broad subject-areas that fall under the scope of Precision Agriculture. The conference was preceded by a special session called "International Workshop on Obihiro Food-Valley Strategy with Community-based Precision Agriculture" on July 2nd. The 5th conference will be held in Korea, 2013. People are looking forward to it.

Report of the CIGR International Symposium 2011 on Sustainable Bioproduction (WEF)

The CIGR International Symposium 2011 on "Sustainable Bioproduction – Water, Energy, and Food " was held from 19 to 23 September, 2011 at Tower Funabori, Edogawa in Tokyo, Japan. There were two hundred and seventy participants; 54 foreigners from 22 countries and 216 Japanese. The Presidium meeting, the Executive Board meeting and the Section Board meeting of CIGR were held on 19th of September. Following these meetings, welcome reception was held on the same day. Also, and excursion was arranged on the 21st, and the participants visited National Park of Nikko. The symposium ended successfully, and people are looking forward to the next World Conference in 2012, scheduled to be held in Valencia, Spain.

Performance Evaluation of Combine Harvester and the P.T.O. Tractor Operated Thresher for Stationary Threshing of Sorghum

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Abstract

The combine harvester is commonly used for sorghum harvesting in the mechanized rain fed agriculture of Gedarif, Sudan. Recently a great number of tractor operated threshers were introduced for sorghum threshing also. The objectives of the study were to evaluate and compare the performance of these two machines for stationary threshing of sorghum and to provide information for planners and investors who wish to produce sorghum in the rain fed sector. Forty four combine harvesters and 50 threshers, which were powered by the tractor P.T.O. were considered for obtaining the required data. The average threshing capacity of the combine harvester and thresher was 6.4 and 1.1 tons/h, respectively. Under the present sorghum yields, the respective value of the estimated covered area annually was about 11,300 and 1,700 ha. The thresher was suitable for small holdings, whereas the combine harvester was suitable for large commercial farms. The thresher resulted in better sorghum grain quality. The fixed cost of the combine harvester and thresher was about 5.3 and 0.8 US$/h, respectively, and the operational cost was about 39 and 10 US$/h, respectively. For the two machines, labor and fuel cost constituted the highest operational cost. The two threshing machines were profitable under the present crop yield and price; however, the combine harvester was more profitable than the thresher. The breakeven capacity for the combine harvester and thresher was 3.1 and 0.9 tons/h, respectively.

Introduction

Sorghum is the main crop grown in rain fed areas of Sudan. It is the stable food for the majority of people. In the mechanized rain fed areas of Gedarif, sorghum cultivated area increased from 1 million ha in 1981/1990 to 1.5 million ha in 1991/2000. Also, the annual production during these periods increased from 664,000 to 690,000 tons, respectively (MFC, 2000). The horizontal and vertical increase in sorghum necessitates the use of suitable machines, especially for crop harvesting. The harvesting operation is sensitive to time, tedious and laborious.

Manual, semi-mechanized and direct harvesting are the three methods of sorghum harvesting in Gedarif rain fed areas. Manual harvesting is the common practice in the small fragmented farms. The semi-mechanized harvesting system (mechanical threshing) is widely used in sorghum production areas. This system is usually accomplished in two steps. First, the crop heads are cut manually using sickles; left in the field to dry naturally and then collected in heaps. Secondly, the machine is introduced to perform the threshing operation. The threshing process is either carried out with a combine harvester or tractor operated thresher. Direct harvesting is practiced, in limited areas, where all requirements are available, such as the presence of combinable varieties, even crop maturity and drying, and large areas.

Most farmers prefer to tackle the stationary threshing of sorghum rather than mobile harvesting. They believe that stationary threshing results in fewer machine troubles. Moreover, uneven maturity of the mixed sorghum cultivars is strong evidence behind the use of stationary threshing. However, Bhutta, *et al.* (1997) mentioned that the stationary thresher is preferred to the combine harvester because of labor savings and time that leads to minimization of threshing operation cost. Due to the huge sorghum cultivated areas and scarcity of hand labors in rain fed areas, sorghum harvesting operation usually extends for three to five months. Moreover, the variation in crop maturity in the same field as the result of mixed crop varieties causes the harvesting machines to stay idle for many days during the harvesting period.

Although the combine harvester has been used for a long period of time to harvest sorghum (direct combining or stationary threshing) in the Gedarif mechanized rain fed areas, recently a large number of tractor operated threshers were introduced in rain fed and irrigated sectors. At the same time the number of combine harvesters decreased as the result of high initial cost. The possible reasons behind the high adoption rate of the thresher by farmers include: its lower initial price, its simplicity, availability of power source (tractor) at harvest time and lower sorghum yield.

In the irrigated and rain fed agriculture of the Sudan a lot of research work has been conducted for mechanical harvesting of field crops. Most of the research work dealt with evaluation of direct combine harvesting and losses on crops such as sorghum (El-Awad, 1986), wheat (Dawelbeit, *et al.*, 1994; and Bakhit, *et al.*, 2004) and sunflower (El-Awad, 1985; Dahab and Elsheikh, 2003). Moreover, El-Awad (2000) successfully modified the grain thresher to meet the requirements of groundnut threshing. Also, Dahab, *et al.* (2007) modified power transmission system of the grain thresher to improve machine performance and to minimize operational costs. However, much research work on the mechanical harvesting of crops has been published elsewhere. These studies evaluated and investigated the parameters that affect the performance of the threshing machine and the quality of the produced seed (Ige, 1978; Singh and Singh, 1981; Miah, *et al.*, 1994 and Alonge and Adegbulugbe, 2000). But, all the work dealt with crops other than sorghum such as cowpea, soybean, rice and maize.

No published work was found related to the quantitative and qualitative evaluation as well as economic analysis of stationary threshing of sorghum grain by combine and thresher in the rain fed agriculture of the Sudan. However, it was thought that the provision of information about performance and economics of sorghum threshing machines was needed for proper planning and management of harvesting in rain fed areas.

The objectives of this research were to compare and evaluate, technically and economically, the sorghum threshing operation with the use of the combine harvester and tractor operated thresher to provide information for planners and investors who wish to produce sorghum under rain fed conditions.

Materials and Methods

Data Collection

A survey was conducted among the owners of combine harvesters and P.T.O. (power-take-off shaft) tractor operated threshers that work in sorghum harvesting in the mechanized rain fed agriculture of Gedarif during the harvesting period of 2008/2009 season. A questionnaire was designed to obtain the required data about the performance and economics of the concerned harvesting machines.

Forty four combine harvesters and 50 P.T.O. tractor operated threshers were randomly selected. The surveyed samples were fairly representative and sufficient to fulfill the research objectives. The raw data were converted into forms suitable for calculations. Data from each group were analyzed separately and average values were obtained.

Harvesting Machine Evaluation

Threshing Machine Performance

For each threshing machine, the output capacity (ton/h) and the sorghum output quality (%) were calculated. The machine output was calculated with the following equation:

Machine output (ton/h) = 60 (min) / time taken to produce one ton (min) .... (1)

After machine threshing, random 100 g samples were taken to determine the percentage of full seeds, undernourished seeds (unfilled seeds), cracked seeds and impurities. These were sorted by visual inspection and weighed. The percentage of each item to the total sample weight was determined by the following formula:

Item% = [weight of item (g) / sample weight (g)] × 100 % ....(2)

Cost Calculation

Variable cost was the cost associated with the use of the combine harvester, thresher and tractor. It included fuel and filter, oil and filter, greasing, repair and maintenance, operator and labor costs. Fuel cost was calculated based on the price of fuel and the average fuel consumption rates of tractors and self-propelled combine using the following formula:

Fuel cost (US$/h) = Fuel consumption (l/day) × fuel price (US$/l) / working time (h/day)............... (3)

Fuel filter cost was determined based on the average price and the total number of filters according to the following formula:

Fuel filter cost (US$/h) = (Total number of fuel filters × filter price (US$) / annual working hours...................................... (4)

Oil and oil filter cost was determined based on the average annual oil and oil filter costs and annual working hours. The annual oil and oil filter cost was the sum of annual oil consumption multiplied by the oil unit price and the total number of oil filters multiplied by the oil filter price as follows:

Oil + oil filter (US$/h) = annual oil and oil filter cost (US$) / annual working hours................(5)

Greasing cost was calculated based on the price of grease and the average grease consumption rate of tractors and combine harvesters by the following equation:

Greasing (US$/h) = greasing consumption (kg/day) × greasing cost (US$/ kg) / working hours (h/day) ....(6)

Repair and maintenance (R&M) cost (US$/h) was determined based on the average annual R&M costs and annual working hours. The R&M cost included the cost of all other replaced parts other than filters, welding, puncture services and servicemen charge.

R&M (US$/h) = total repair and maintenance cost (US$) / annual working hours...............(7)

Hourly labor and operator costs were calculated independent of each other. This was because the labor was charged according to the number of tons produced, while the operator takes his salary on a monthly basis. The labor and operator costs were determined by the following equations:

Labor cost (US$/h) = Labor charge (US$/ton) × machine output (ton/h).........................(8)

Operator cost (US$/h) = Operator charge (US$/ month) × number of months / annual working hours (h) ....(9)

The total variable cost was the sum of fuel and filter, oil and filter, greasing, repair and maintenance, operator and labor cost, which was calculated by the following formula:

Total variable cost (US$/h) = (Fuel cost + fuel filter cost + oil + oil filters + greasing + R&M + labor and operator cost (US$/h)...(10)

The fixed cost was the cost associated with the ownership and included depreciation, interest on investment, housing and insurance. Based on the obtained information (table 1), the fixed cost was calculated by the following equation:

Fixed cost (US$/h) = (% of the fixed cost x purchase price) / annual working hours............. (11)

Therefore, the total cost was the sum of the total variable and the fixed costs as determined by the following equation:

Total cost (US$) = (Total variable (US$/h) + Fixed cost (US$/h) × annual working hours.......... (12)

The total income (US$/h) was calculated as follows:

Total income (US$/h) = output (ton/h) x price (US$/ton)............. (13)

Results and Discussion

Performance Evaluation of the Threshing Machines

The performance of the combine harvester and stationary thresher on threshing output of sorghum are shown in **Table 1**. The average threshing capacity of the combine harvester and stationary thresher was 6.4 and 1.1 ton/h, respectively. The high output capacity of combine harvester was due to longer feeding distance between the two windrowers (> 4m), which facilitated the work of a high number of labors for feeding than the thresher. Moreover, labors used the wooden forks for continuous feeding of the combine harvester (high feeding rate), while they used carry baskets for feeding the thresher (low feeding rate). However, the output capacities of both harvesting machines appeared to be acceptable under the currently grown sorghum cultivars and yields.

Although the available working time during sorghum harvesting period (5 months) was almost similar for both machines, the total production of the combine harvester was almost seven times more than the thresher. Usually, the total production of a threshing machine depended on complex factors such as readiness of the sorghum crop for threshing, which relied on the availability of hand labor and even maturity of the crop. If the average sorghum grain yield was as low as 455 kg/ha and the annual production of the combine harvester was about 5,005 tons and the thresher was about 773.5 tons (**Table 1**), then the respective estimated covered area annually would be 11,300 and 1,700 ha. This meant that the combine harvester was suitable for large areas, whereas, the thresher could be used in the small fragmented areas.

The results of the output quality are shown in **Table 2**. The average percentages of mature seed produced by the combine harvester and the stationary thresher were 93.8 and 97.1 %, respectively. The aver-

Table 1 Working parameters for combine harvester and thresher

Items	Combine	Thresher
Annual production (tons)	5,051	766
Daily production (tons/day)	68	13
Output capacity (tons/h)	6.4	1.1
Working hours per day	11	12
Working months	5	5
Required labors	12	4

One sack = 91 kg of sorghum grain

Table 2 Sorghum output quality by combine and thresher

Items %	Combine	Thresher
Mature seeds	93.8	97.1
Undernourished seeds	3.3	0.6
Cracked seeds	0.9	1.1
Impurities	2	1.2

age percentage of undernourished seed was 3.3 % and 0.6 for combine harvester and thresher, respectively. The difference between the two harvesting machines was probably due to the sorghum variety, applied cultural practices and the availability of soil moisture content in the field during the crop growth. The average percentage of damaged seed was 0.9 and 1.1 for the combine harvester and thresher, respectively. This damage percent was acceptable for both harvesting machines. Usually, the grain damage occurred as the result of narrow clearance between the concave and cylinder, higher speeds (rpm) of the threshing cylinder and lower moisture content of the sorghum grain. The result of impurities revealed that the thresher produced a clean grain compared to the combine harvester. In general, quality evaluation indicated that the thresher produced better sorghum quality than the combine harvester. This was one of the reasons behind the acceptance of thresher by farmers.

Economical Analysis of the Threshing Machines

Economical analysis of the threshing machines included calculations of fixed and operational costs as well as the final net return per hour. Additionally, for the thresher, the fixed and operational costs of the tractor were included.

The results of calculated fixed costs for the combine harvester and thresher are shown in **Table 3**. The combine harvester had a fixed cost of 5.25 US$/h, which was higher than the thresher fixed cost (0.76 US$/h). The high fixed cost of combine harvester was mainly due to the high purchase price. The lower purchase price of the thresher was the major factor behind its acceptance and adoption by farmers. However, additional sorghum grain production and additional use of each harvesting machine would lead to lower cost per hour, as the fixed costs would be spread over more hours.

The operational cost items for combine and thresher are shown in **Table 3**. For both machines, labor cost constituted the highest component followed by fuel cost. The results showed that the repair and maintenance cost was 2.07 and 0.30 US$/h for combine and thresher, respectively. The lower repair and maintenance cost of the thresher was mainly due to its simplicity, which enhanced its spreading in the area. Greasing cost represented the least cost for both harvesting machines. The total operational cost for combine and thresher was 38.79 and 10.10 US$/h, respectively. Because of the low operational cost of the thresher compared to the combine, farmers preferred to use the thresher rather than the combine harvester.

Results of stationary threshing of sorghum (**Table 3**) revealed that the combine harvester resulted in higher total income, total cost and net return in comparison with the thresher. This indicated that the combine harvester was more profitable than the thresher, but it required a lot of money to face its high total cost. The economic analysis of the two harvesting machines indicated that they were profitable under the present prices and sorghum grain yield. Although the profit of the tractor driven thresher was not as high as the combine harvester, it was not susceptible to the risks related to prices and yields fluctuation.

The breakeven output capacity was calculated using the total costs and current threshing price (**Table 3**). The breakeven output capacity indicated the minimum output capacity required to cover the total cost of the harvesting machine. The breakeven capacity was 3.14 and 0.91 tons/h for the combine harvester and thresher, respectively.

Table 3 Cost analysis of the threshing machines

Item	Combine	Thresher	Tractor
Fixed cost			
Purchase price (US$)	27,810	3,984	17,075
Fixed cost as % of purchase price	17	14	17
Annul working hours	900	732	1,500
Fixed costs (US$/h)	5.3	0.8	1.9
Operational Cost (US$)			
Fuel cost	5.71	-	1.98
Fuel filter cost	0.50	-	0.08
Oil + oil filter	1.47	-	0.23
Greasing	0.11	0.10	0.001
R&M	2.07	0.30	0.43
Labor	27.86	6.50	-
Operator	1.08	-	0.48
Total operational cost	39	7	3
Cost evaluation			
Threshing price (US$/ton)	14.1	14.1	-
Total income (US$/h)	89.6	15.4	-
Total cost (US$/h)	44.1	12.8	-
Break even output capacity (tons/h)	3.1	0.9	-
Net profit	45.6	2.6	-

General Comments

Farmers and machine owners mentioned the following general comments:

- Number of threshers exceeded the number of combine harvesters in Gedarif area.
- Move-ability and maneuverabil-

ity of the thresher was easier than the combine harvester, especially on a rough road.
- Sorghum crop variety and grain quality was one of the main factors affecting harvester work rate.
- The available working days for the crop threshing depended upon ready-ability of the crop to be harvested.

Conclusions

From this work the following conclusion could be drawn:

- The combine harvester had the higher productive capacity and required more labor compared to the thresher. However, the thresher produced better grain quality.
- For both machine types, the labor and the fuel costs constituted the highest operational cost items. However, the thresher resulted in the lower operational cost in comparison with the combine harvester.
- The simplicity and the lower purchase price of the thresher represented the major factors behind its acceptance and adoption among the farmers.
- The economic analysis of both harvesting machines indicated that they were profitable under the present market price and sorghum grain yield.
- The combine harvester was more profitable than the thresher, but it required a lot of money to compensate for its high total cost.
- Under the present farming conditions and sorghum yields, the combine harvester was suitable for the large commercial farms, whereas the thresher was suitable for the small fragmented areas.
- The breakeven capacity for the combine harvester and thresher was 3.14 and 0.91 ton/h, respectively.
- This information was considered useful for planners and investors who wished to produce sorghum under rain fed conditions.

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Aerial Spraying with Viscosity Modifer

by

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Abstract

Citrus trees were sprayed using two tests with and without a viscosity modifier (thickener). Samples were sprayed on the citrus trees to measure the droplet size, spraying uniformity, penetration inside the trees, and drift potential. Cards sensitive to the spray drops were used to collect the spray spectrum, either on the top or bottom leaf surfaces. Better spraying performance with a viscosity modifier was obtained by aerial application method.

Introduction

In recent years the aerial spraying of pesticides by aircraft became one of the essential tools for pest control. In spite of the presence of some limitations for using aircraft such as certain weather conditions for application, drift problems and some obstacles such as trees and high buildings there are advantages that include speed of application, elimination of out breaks, economics, and uniform distribution of insecticide.

The results of the first aerial spraying in A.R. of Egypt were encouraging; therefore, the sprayed cotton area has been increased. Now, large agricultural companies have replaced ground spraying with aerial spraying in the large orchard fields. They decided to have this kind of change after they faced some problems such as non-uniformity of spraying, low penetration, less coverage on the leaf surfaces, run off, labour shortage in the area, low field capacity, short seasons for spraying, machine problems, and high cost per feddan. Using aircraft spraying gave adequate (economic) control at a low cost per feddan compared with ground application.

The main objective of this research was to evaluate aerial spraying in the orchard fields with a viscosity modifier added to solve the drift problem.

Review of Literature

Drift (aerial transport) from the treated area may result in poisonous or toxic chemicals being deposited on adjacent crops intended for either human or animal consumption. Some insecticide chemicals, when eaten by dairy cows, tend to concentrate in the fats and milk, thereby creating a hazard in human consumption of these products (Yates and Akasson, 1973). Drift of patent herbicides such as 2,4-D may cause injury to adjacent, susceptible crops. The drift problem is most acute for aircraft applications but is also evident when dusting or spraying with ground rigs.

Size is by far the most important particle property affecting the rate of fall and associated drift distances. Small particles settle more slowly than large particles because the aerodynamic drag forces are greater in relation to particle mass. For example, the theoretical distances that water droplets would be carried while falling 3 m in straight air flow having a uniform horizontal velocity of 4.8 km/h would be only 15 m for 100 microns droplets, but about 1.6 km for 10 micron droplets (El Nahas, 1975). In actual practice, atmospheric turbulence would cause small particles, such as the 10 microns size, to be carried much farther than indicated by the theoretical, non turbulent.

The first attempt of increasing viscosity was studied by Yates *et al.* (1966) and Colthurst (1966). They used an “inverted” or water-in-oil emulsion in order to increase the spray mixture viscosity. However, the inverts had the disadvantages of being somewhat unstable, increasing photo toxicity and shifting rather than narrowing the droplet spectrum. Invert emulsions have been shown to reduce drift under many spraying conditions but was limited to use with phonexy acid-herbicides and certain insecticides where good coverage was not required.

Butler *et al.* (1969) used spray adjuvants to reduce drift. They compared the 2-percent volume diameters for the different tests that gave some indication of relative drift potential ranked from smallest to largest. These were: (a) the un-thickened

Table 1 Percentage of Droplet Size Data for Upper Leaf Surface of Helicopter-Spray

Classes in micron	Without Nalco-trol			With Nalco-trol		
	Helicopter heights, m					
	1	2	3	1	2	3
0 – 100	0.2	0.5	0.5	0.2	0.43	0.3
100 – 200	4.0	6.6	8.3	2.3	4.20	6.2
200 – 300	14.0	23.5	27.0	7.4	13.30	19.7
300 – 400	26.0	36.1	38.6	16.1	23.60	34.0
400 – 500	42.0	54.1	56.5	28.0	40.40	51.0
500 – 600	67.0	87.0	89.2	44.4	60.50	72.5
600 – 700	89.0	100.0	100.0	62.2	83.00	91.5
700 – 800	100.0	-	-	83.0	100.0	100.0
800 – 900	-	-	-	100.0	-	-

Table 2 Percentage of Droplet Size Data for Lower Leaf Surface of Helicopter-Spray

Classes in micron	Without Nalco-trol			With Nalco-trol		
	Helicopter heights, m					
	1	2	3	1	2	3
0 – 100	0.29	1.0	1.6	0.24	0.6	0.4
100 – 200	8.20	11.8	17.3	4.20	6.8	10.0
200 – 300	25.30	32.9	40.0	18.50	22.4	30.8
300 – 400	42.00	57.0	65.1	26.00	38.7	55.8
400 – 500	70.00	83.6	100.0	45.00	65.4	80.0
500 – 600	100.00	100.0	-	65.00	90.0	100.0
600 – 700	-	-	-	100.00	100.00	-
700 – 800	-	-	-	-	-	-
800 – 900	-	-	-	-	-	-

spray; (b) the Dacagin-modified spray; (c) the vistik modified spray; and (d) the Norbak-modified spray.

Later, Younis (1973) studied the effect of subatmospheric air density on liquid disintegration with thickener material (Nalco-E 102). This material was later named Nalco-Trol. The analysis showed a reduction in the fine drops and also a reduction in the evaporation rate even under high air velocity compared with water alone. It was recommended that Nalco B-102 could be used at about 0.1 % concentration.

Younis and El-Ashi (1978) studied the drift potential, and bioestimation test when a viscosity modifier was used. Adding a very low percentage of Nalco-Trol to the spraying fluid reduced the driftable size-less than 200 microns. Nalco-Troll, with the designed working pressure, gave less percentage of the driftable size with high spraying performance.

Materials and Field Tests

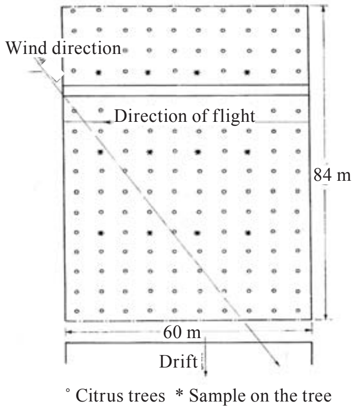
The main objective of this research was to compare the efficiency of aerial spraying. The viscosity modifier added to the spraying solution might improve the spraying process.

Aerial spraying was carried out with a Polish Helicopter model Mi-2. This type contained two rotors powered by two turbine engines. The tank capacity of the helicopter was 600 liters. The maximum operating speed of the aeroplane was 90 km/h. The helicopter contained a boom divided into three sections, one section was under the body and two sections were on the sides, The middle section contained 13 nozzles while the other sections contained 52 nozzles each. The nozzle type was hollow cone with a 70 degree spraying angle. The spacing between two adjacent nozzles was 12 cm and the nozzle tip diameter was 1.25 to 2.0 mm.

During a test, the recommended operating speed was 30 km/h due to the height of wind breaks in the area. The application rate was 40 liters/feddan at 4 kg/cm^2 working pressure. The spraying width was 35 m for a flying height 1-3 m above the tree surface.

Table 1 gives the summary of spraying conditions during the test.

Fig. 1 The complete layout of the experiment for aerial spraying



Viscosity Modifier

The thickener material that was used as the viscosity modifier was Nalco-Trol supplied from Nalco Chemical Company, Chicago, Illinois. This was used in liquid form and the viscosity was recorded by Youns *et al.* (2010). However, the recorded viscosity was for Nalco E-102 produced by the same company as Nalco-Trol and was indicated by the supplier.

Measurements of Droplet Size

The distribution of spray droplets and their size were measured by using special cards. These cards were distributed on the trees at three different positions: the first at the top

A) the second one in the middle

B) and the third one at the bottom

C) Each position included a sample

Fig. 2 Samples for Penetration test

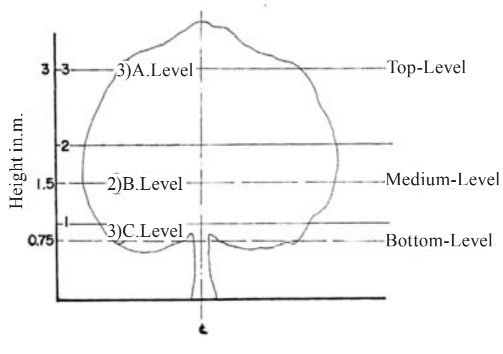


Table 3 Uniformity percentage for Aerial Application

Sample Levels	Helicopter heights,m	Upper Surface		LowerSurface	
		Without	With	Without	With
Top	1	96.0	98.5	96.9	99.0
	2	96.2	96.0	98.5	98.0
	3	98.5	96.0	98.0	97.0
Medium	1	95.8	95.5	95.6	95.0
	2	96.6	95.8	95.4	96.5
	3	97.6	96.0	95.0	97.7
Bottom	1	96.4	97.4	97.5	96.0
	2	96.8	97.2	97.0	96.0
	3	98.5	96.0	95.4	98.0

for upper and lower leaf surface. The cards used to collect the spray droplets were sensitive to the water and each spray droplet marked a spot without spreading on the cards. After collecting the cards, the droplet was measured by a binocular eye piece divided into millimeters. The eye piece was calibrated before the measurements.

The Field Test

The field tests were conducted in a farm planted with citrus trees with 6 m row spacing and the same distance between the trees within the row.

The layout for field tests with aerial spraying is shown in **Fig. 1**. The flying height was introduced as a factor and was 1, 2, and 3 m above the trees.

To measure the penetration efficiency inside the trees, three samples were placed at three horizontal distances in the trees as it is shown in **Fig. 2**.

Results and Discussion

The results from the field tests were divided into three groups:

A. Aerial spraying.
B. Spraying uniformity.
C. Drift

A. Aerial Spraying

Tables 1 and **2** show the cumulative percentage of the droplet size with and without Nalco-Trol with three different spraying heights. **Table 2** shows the upper leaf surface while **Table 3** shows the lower leaf surface. The graphical presentation is given in **Figs. 3** and **4** for upper and lower leaf surfaces, respectively. It is clear that the distribution of the droplets shifted upward when Nalco-Trol viscosity modifier was added to the spraying solution. The effect of this material extended to the three spraying heights, either to the upper or lower leaf surfaces. The driftable size (at 200 microns) was reduced from 25 % to 7 % for upper surface and from 17 to 4 % for lower surface when the Nalco-Trol was added. This reduction in the driftable size was due to higher viscosity in the solution that gave higher droplet size.

The effect of the spraying height on the droplet size was very pronounced. The increase in the droplet size was about 8 % when the spraying height decreased one meter. So, it was recommended to spray at one meter height with Nalco-Trol as the viscosity modifier. However, this height was a limiting factor if the area of spraying was surrounded with wind breaks or electricity towers.

Fig. 5 shows the value of volume medium diameter (at 50 %) for the three samples located at three levels of the trees (top, medium, and bottom). With Nalco-Trol, VMD values were usually more than that of spraying without. However, the difference was very small. The effect of the sample level had a smaller effect on the drop diameter where it was a little higher on the top sample than the bottom samples. The same trend was obtained with the upper and lower leaf surfaces.

Fig. 6 shows the droplet penetration in the middle of the citrus tree at different spraying heights: 1, 2, 3 m, respectively. The penetration improved at lower spraying heights, especially on the upper leaf surface. Adding the viscosity modifier to the solution reduced the penetra-

Fig. 3 Droplet size distribution of upper leaf surface with aerial spray

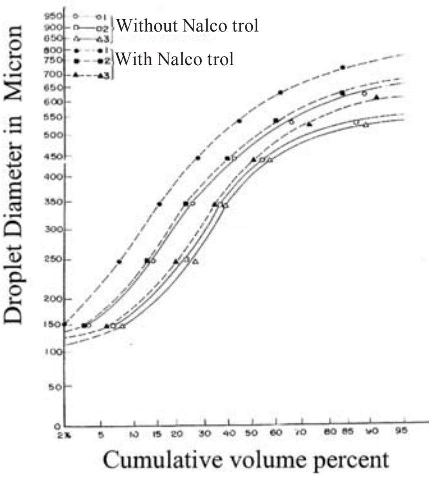
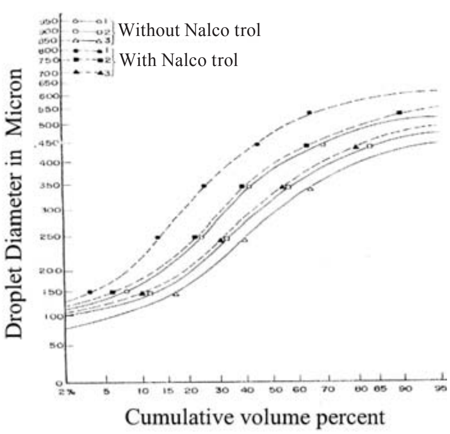


Fig. 4 Droplet size distribution of Lower leaf surface with aerial spray



tion slightly. The effect of spraying height on the lower leaf surface was greater than on the upper leaf. At one meter height there was a better penetration, even with Nalco-Trol, than at three meters between 12 and 16, while it reached 9 to 19 at three meters height. It was recommended to spray at one meter height; the viscosity modifier had less effect on the penetration.

B. Spraying Uniformity

The uniformity equation was:

$$u = \left[1 - \left(\frac{\sum |x_1 - \bar{x}|}{n\,\bar{x}}\right)\right] \times 100$$

Where:

U = Uniformity Percentage

$\sum |x_i - \bar{x}|$

= The Sum of the absolute deviaton of individual observations (x_i) from the average of the observation $\bar{X}$

n = The number of observation.

Table 7 shows the uniformity percentage for aerial application. The uniformity reached to 95.0 to 99.3 for aerial application. The uniformity improved by aerial application due to the spraying turbulence generated by aeroplane.

C. Drift

Fig. 7 shows the number of drops that fell in the sample area at different distances from the spraying line; tests were conducted with and without Nalco-Trol for aerial spraying at different spraying heights. It was clear that the effect of Nalco-Trol on the drift was very high since it reduced the number of drops to about 75 %, 87 % , 92 % , at 3, 2 and 1 m heights, respectively, This reduction was done with respect to the line of drift without Nalco-Trol at 3 m height. These reductions were due to larger droplets introduced with the thickner material, which was added to the spraying solution.

Conclusion

Better spraying uniformity, penetration and drift with the viscosity modifier were achieved. Aerial spraying was recommended to use for pest control, especially in orchard fields.

Fig.7 Drops number Vs Drift distance

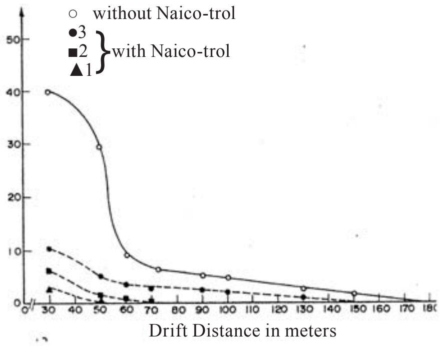


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Fig.5 Droplet size diameter with different helicopter height with aerieal Spraying

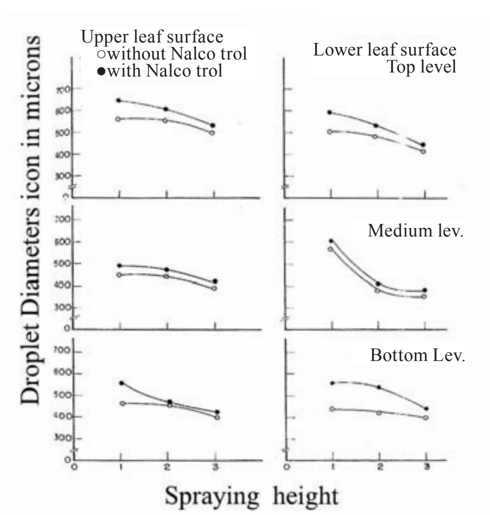
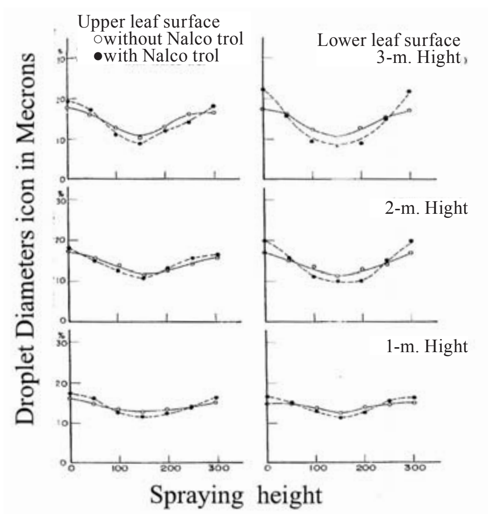


Fig.6 Droplet size Penetration on the tree with aerial spraying



Air Assisted Sleeve Boom Sprayer

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Abstract

A tractor mounted air assisted sleeve boom sprayer was designed and developed. The sprayer required about 127-152 L/ha chemical solution to spray through hollow cone nozzles at 0.4-0.6 L/min. The fine droplets produced were directed toward the crop canopy by an air stream that was emitted through 29 holes in the air sleeve fitted behind the spray boom. The axial fan fitted in the sprayer delivered air at 608 m^3/hr/m boom with an air speed of 11 m/sec from each hole. The boom width was 10.7 m with 20 nozzles fitted on the boom at 510 mm spacing.

The sprayer was tested in a cotton field. The field capacity of the sprayer was 2 ha/hr with an operational cost of US $3.38/ha. The sprayer gave higher chemical deposits on both sides of the cotton plant leaves as compared to the conventional sprayer. The air assisted sprayer gave approximately 5-7 % drift loss whereas the conventional sprayer loss was about 20-25 %.

Introduction

Pakistan is the fourth largest country of the world in production of cotton and the third largest exporter of raw cotton. Cotton contributes approximately 10 percent of the agriculture GDP and is a source of 80 % of the foreign exchange earning. The value addition through cotton is 8.2 % in agriculture and 2 % in the GDP. The area under cotton crop gradually decreased after 2003 due to shortage of water, late sowing and higher cost of inputs. The most important and cost effective input is the chemical spraying that accounts to 50 % of the total expenditure and indicates how sensibly and effectively it needs to be applied. The farmers in Pakistan use different types of high volume spray machines to spray their crops including hand operated knapsack sprayers, power operated knapsack sprayers, tractor mounted mist blowers and tractor mounted boom sprayers.

Hand operated knapsack sprayers have a field capacity of 0.8-1.2 ha per day and are used if the area to be sprayed is small. Power operated knapsack mist blowers have been used for a long time but are not suitable for field crops due to non-uniformity of spray, drift loss and less field coverage. Tractor mounted boom sprayers are the most popular sprayers among the farmers having relatively large areas. These are high volume sprayers and require 254 L/ha chemical solution. They normally apply pesticides on the top side of leaves and upper portion of the plant canopy. As a result the pests can find shelter under the leaves to escape. Himel (1974) reported that with high volume sprayers about 33 % of the total pesticide may be wasted through drift due to wind or air movement. Loss of pesticide also occurs if the rate of evaporation and rate of application are increased. These factors necessitate the use of pesticides in such a manner that minimum wastage occurs.

Most pesticides are applied to crops in the form of spray by using spray machines. The role and efficiency of the spray machines is perhaps the key factory to ensure pesticide deposit on the target. Pesticide treatment efficacy must be considered in conjunction with risks to the environment, i.e., drift, runoff, and off-target deposits (Van de Zande *et al*., 2002). When the target site is a thin vertical stem or an under-leaf surface located low down in a dense crop canopy, the use of small droplets is appropriate (Matthews, 2000). The use of small droplets, often associated with lower application volumes, leads to increased retention on targets, waste reduction and increased efficacy (Taylor and Anderson, 1997), and considerably increases the risk of drift. Where spray drift is a concern low-drift nozzles producing coarser sprays can be used as a drift control tool (Derksen *et al*., 1997).

The use of bi-fluid nozzles where a low volume of pressurized air is used to assist liquid atomization and even control spray quality offered some drift control (Lund, 2000). However, the air assistance is of little help in forcing the spray within the canopy (Matthews, 2000). The system using an axial fan and inflatable sleeves to distribute high volumes of air along the boom is efficient in crop canopies and airflow assists the transport of spray droplets from the nozzle to the target sites (Hislop and Western, 1993). This can be an effective drift control tool (Hadar, 1991 & Piche' *et al*., 2000). As a result, it offers greater flexibility in timing of applications in relation to weather conditions and pest life cycle. Matthews (2000) and Jorgensen and Witt (2000) conducted tests with the air assisted Twin Hardi sprayer on potato cultivation. They reported that air assistance reduced drift by 8-10 % for a distance of 1.5 to 2.0 meters from the boom, and around 0.2 % for 5.0 to 6.0 meters. The total deposit on leaves at the top of the crop canopy was reduced by 22 % compared to the conventional application when sprayed on potatoes with a Hardi Twin sleeve boom sprayer (Leonard *et al*., 2000). A larger fraction of the total deposit was found in the bottom section of the canopy when air assistance was used; i.e. 21 % compared to 13 %. Over the full height of the crop, 29 % of the deposit was found on the lower leaf surface with air assistance as compared to only 16 % without air assistance (Panneton & Piche, 2004).

Robinson (1960) reported that the use of air assistance technology was started in 1980 and, at the start of the 1990s, air assistance was effectively adopted in sleeve boom sprayers. Koach (1997) reported that this technology was introduced by Hardi in Europe and, in Germany during 1996, seven manufacturers exhibited equipment with air assistance at the Agricultural Trade Show. At that time, the Brazilian industry also incorporated this technology to the tractor driven trailing sleeve boom sprayers. Sartori (1997) reported that, for applying phyto-sanitary products on low stem cultivation, the sleeve boom sprayers equipped with air assistance appeared as the ideal tool to improve the application quality, increase productivity and reduce drift.

Raetano & Baner (2004) evaluated deposits and losses from spraying broth in bean cultivation with air assistance on sleeve boom sprayers with volumes of 60 and 100 L/ha. They reported that the higher volume resulted in greater deposits, but high losses to the soil above 60 %. Taylor *et al*. (1989) reported that the use of air angulations in favour of the displacement with fine droplets could increase the spraying deposit levels on vertical targets substantially. The use of higher water volumes, bigger droplets spray, high speeds of the tractor, unleveled field conditions and inappropriate environmental conditions increased the spray drift and worsened deposition patterns.

The review of literature dictated that a sprayer should be developed and introduced to eliminate the spray drift, improve coverage, enhance application efficacy and increase crop productivity.

Equipment Design

A tractor mounted air assisted sleeve boom sprayer was designed and developed at the Agricultural Mechanization Research Institute (AMRI), Multan, during 2004 for spraying cotton and other field crops (**Fig. 1**). The sprayer used 127-152 L/ha chemical solution to spray through hollow cone nozzles at 0.4-0.6 L/min. The liquid chemical sprayed through hollow cone nozzles in the form of fine droplets was directed towards the crop canopy by an air stream. The air stream, produced by an axial flow fan driven by a hydraulic motor, was emitted through an air sleeve fitted behind the boom. The description of the sprayer components follows below.

Pump

A diaphragm pump was placed in the sprayer for the application of chemicals. The basic part of the diaphragm pump was a chamber that was completely sealed at one end by a diaphragm. The other end had

Fig. 1 Tractor mounted air assisted sleeve boom sprayer

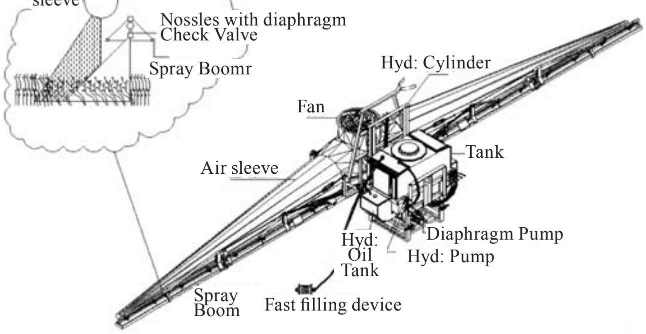
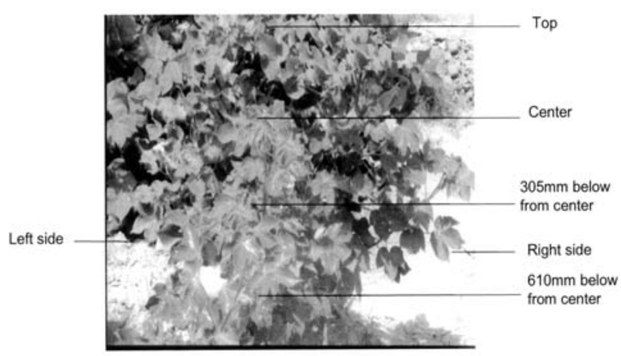


Fig. 2 Cards locations in cotton plant canopy to measure spray deposit



an inlet and outlet valves. Liquid was drawn through the inlet valve by movement of the diaphragm and, on the return of the diaphragm, was forced out through the outlet valve. The pump was located at the rear of the sprayer frame for easy service and maintenance and delivered 80 L/min of chemical at a pressure of 40 bars.

Tank

The tank was made of chemical resistant fiber glass with a wall thickness of 4.2 mm and a storage capacity of 450 liters. The tank had a large opening of about 465 mm diameter so that the inside could be cleaned and scrubbed. Hydraulic agitation was provided in the tank. Water was sucked by water pressure pipe through a control valve with a pump of discharge 15-20 L/min at a pressure of 30 bars that enabled the device to fill the tank. The tank had a drainage hole of 90 mm diameter at its lowest point for removing the residue during cleaning.

Axial Fan/Blower

An axial fan, 650 mm diameter, with eight aluminum blades was the main part of the air assisted sprayer. An axial fan was selected due to the large volume of air at low pressure. The fan delivered 608 m^3/h per meter boom with an air speed of 11 meter/sec from 29 holes of the air sleeve made of canvas.

Spray Boom

The boom frame, mounted on the main frame behind the spray tank, was made of M.S. square pipes 25.4 × 25.4 mm and M.S. rectangular pipes 20.3 × 42 mm with 13.5 mm inside diameter PVC pipe fitted inside the frame. The boom was made in five sections with a total width of 10.7 m and 20 nozzles with 510 mm spacing and two outer sections on both sides that were foldable. The boom height and its folding/unfolding were controlled through hydraulic cylinders operated through a hydraulic pump.

Air Sleeve Pipe

The air sleeve pipe was made of canvass and was behind the spray boom. It was 10.25 m long and 480 mm diameter at the centre (at the fan) and reduced to 140 mm diameter at the ends. The diameter reduction was to achieve uniform air velocity throughout the sleeve pipe. The sleeve had twenty nine 33 mm diameter holes 360 mm apart for exit of air in the form of a cone.

Hydraulic Pump and Motor

The hydraulic pump was behind the diaphragm pump, on the same shaft, and driven by the tractor PTO. It was controlled by the operator with levers. The pump had a discharge of 60 L/min at a pressure of 60 bars. A 1,500 rpm hydraulic motor driven by the hydraulic pump drove the axial fan.

Materials and Methods

The tractor mounted air assisted sleeve boom sprayer was designed at AMRI workshop in 2004. The design specifications and dimensions were based upon local farm and field conditions. The prototype of the air assisted boom sprayer was fabricated at the same workshop using locally available materials, fabrication techniques and facilities. The critical components and parts such as the diaphragm pump, hydraulic pump, tank, control assembly and nozzles were manufactured by local manufacturers having expertise in production of these parts based upon the specifications developed in AMRI. The sprayer was tested in the laboratory and field. Necessary modifications were incorporated in the various systems of the sprayer based upon laboratory and field tests. The modified prototype was tested in the field to assess its performance and obtained comments of the farmers. The improved version of the air assisted boom sprayer was fabricated taking into consideration the field results and farmers comments. The improved version was tested in the field of a cotton crop and data were recorded. Chemical deposit cards were used to catch droplets and check spray coverage, droplets deposition and drift. The cards were placed at various locations of the plant canopy as shown in the **Fig. 2**. The locations were plant canopy top, middle, 305 mm below middle, 610 mm below middle, and the right and left side of the plant canopy. The droplets collected on the cards were counted and the data analyzed for deposition, coverage and drift loss.

Fig. 3 Testing of air assisted sleeve boom sprayer in cotton field

Fig. 4 Side folding of sleeve boom due to obstruction in the field

Results and Discussion

The air assisted boom sprayer was tested in the cotton field to check its performance (**Figs. 3** and **4**). The average field capacity of the air assisted sprayer at a tractor speed of 6 km/hr was 2 ha/hr. The data collected for various parameters are discussed below.

Spray Distribution

The relative distribution in percentage of chemical spray with the air assisted and conventional sprayers is given in the **Fig. 5**. The conventional sprayer gave a narrow band of concentrated deposit immediately under the nozzle, which means a small spraying surface. The air assisted sprayer gave two and half times more spraying surface and showed a more even result. The larger spraying surface improved the bad results caused by an unsteady boom movement. Thus, the spraying effect was considerably improved with the air assisted boom sprayer.

Spray Coverage and Quality

The spray coverage of the air assisted sleeve boom sprayer was better at the middle of the plant canopy and even 610 mm below the middle. The top of the plant canopy was fully covered. The cards in **Fig. 6** demonstrated the spray coverage and quality. The 100-150 micron droplet size was an optimum size, which gave optimum droplet density for better coverage and pest control on the cotton crop.

Chemical Deposit

The air flow emitted from the air assisted sleeve boom sprayer interacted with the plant leaves and enhanced penetration into the canopy and gave better deposition of droplets on hidden surfaces of the plant leaves down into the canopy. **Fig. 7** demonstrates the chemical droplet deposit of the sprayers at various location of plant canopy. The spray droplets emitted from the air assisted sleeve boom sprayer and deposited at top, middle, 305 mm and 610 mm below the middle on plant leaves were 136, 183, 120 and 46 droplets/cm^2, respectively (**Table 1**). The spray droplets emitted from the conventional sprayer and deposited at top, middle and 305 mm below middle on plant leaves were 165, 88 and 5 droplets/cm^2, respectively. No droplets were found 610 mm below the middle of the plant canopy. The total deposit on plant leaves over a full season with the use of the air assisted sleeve boom sprayer was significantly higher (about 48.6 %) compared to that of the conventional sprayer (about 42.7 %).

The results showed higher chemical deposits on leaves in the plant canopy with the air assisted sleeve boom sprayer as compared to that of the conventional sprayer. The air assisted sprayer gave better deposits on the top and lower side of leaves as compared to that of the conventional sprayer.

Drift Loss

The cards were placed on left and right side of the plant perpendicular to the row direction to record chemical droplets in order to observe drift losses. The droplets deposition recorded on the left and right side of the plant canopy for both the sprayers are demonstrated in the **Fig. 7**. The average value of droplets were

Table 1 Chemical deposition on cotton plant leaves at various locations in the plant canopy

Sprayer	Card location in Plant Canopy	Observation 1 (Droplets/cm^2)	Observation 2 (Droplets/cm^2)	Average value (Droplets/cm^2)
Air assisted sleeve boom sprayer	Top	122	151	136
	Middle	175	190	183
	305 mm below middle	110	130	120
	610 m below middle	37	55	46
	Left side of plant	10	8	9
	Right side of plant	15	17	16
Conventional tractor mounted boom sprayer	Top	195	165	165
	Middle	78	98	88
	305 mm below middle	5	-	5
	610mm below middle	-	-	-
	Left side of plant	82	68	75
	Right side of plant	55	70	62

Fig. 5 Spray distribution curves for conventional and air assisted sprayers

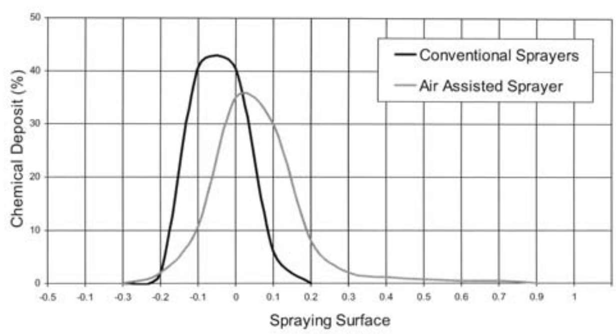


Fig. 6 Spray coverage on cotton plant canopy with air assisted sleeve boom sprayer and conventional boom sprayer

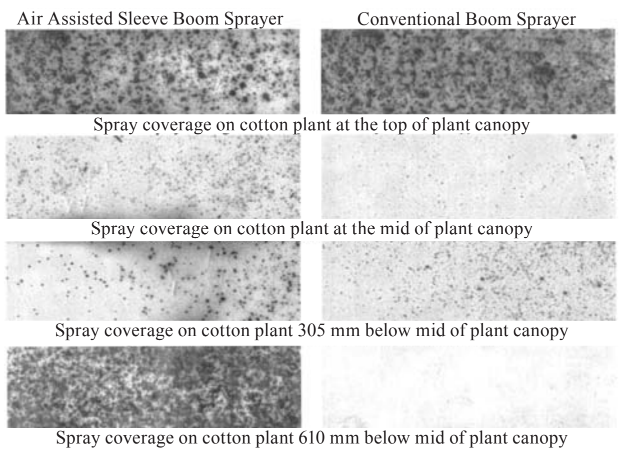


Table 2 Operational costs of the air assisted sleeve boom and conventional boom sprayers

Description	Air assisted sleeve boom sprayer	Conventional boom sprayer
Capital cost (P) (US$)	2,941	882
Annual use (AU) (hr)	400	400
Life in year (L in Year)	10	10
Salvage value (S) at 10 % of P (US$)	294	88
Depreciation (P − S) /L (US$/hr)	0.66	0.20
Interest at 10 % (P + S) /2 × 0.l/AU (US$/hr)	0.40	0.12
Insurance, shelter & taxes at 2 % of (P + S) /2 × 0.02/AU (US$/hr)	0.08	0.02
R & M at 15 % of P/L (US$/hr)	0.11	0.03
Operation cost of sprayer (US$/hr)	1.25	0.37
Operation cost of Tractor MF 375 (US$/hr)	5.52	5.52
Operational cost of tractor plus sprayer (US$/hr)	6.77	5.89
Operational cost tractor plus sprayer (US $ / ha)	3.38	2.94

at 1 US$ = 85 Pak Rupees

9 and 16 droplets/cm^2 on left and right side of the plant, respectively, for the air assisted sleeve boom sprayer (**Table 1**). The conventional boom sprayer sprayed 75 and 62 droplets/cm^2 on left and right side of the plant, respectively. There was approximately 5-7 % drift loss for the air assisted sleeve boom sprayer whereas in the conventional boom sprayer was about 25-30 % (**Fig. 8**). The air sleeve fitted in the boom sprayer reduced spray drift substantially irrespective of the nozzle type and pressure due to the energy of the air curtain, which forces the spray droplets down on to the target surfaces.

Operational Cost

The operational cost of the air assisted sleeve boom sprayer was US $3.38/ha (**Table 2**), and was slightly higher compared to the conventional boom sprayer, which was US $2.94/ha. The relatively higher operational cost (14.9 %) permitted the advantages relating to drift control and spray deposit on the target. The higher operational cost of the air assisted sleeve boom sprayer was due to higher initial purchase cost as compared to that of the conventional boom sprayer. The number of sprayings performed with the air assisted sleeve boom sprayer was less compared to the conventional boom sprayer. This was due to better chemical deposition on plant leaves and penetration of spray into the plant canopy. The use of the air assisted sleeve boom sprayer saved one spray costing US $11.6/ha for chemical and US $3.38/ha for tractor operational cost. Thus, a total benefit of US $14.98/ha was seen as compared to that of the conventional boom sprayer.

Summary

The tractor mounted air assisted sleeve boom sprayer was designed and developed at AMRI, Multan, during 2004. The spray boom width was 10.7 m and the height was adjustable up to 2.45 m by hydraulic cylinders. The sprayer was fitted with a diaphragm pump with a discharge of 80 L/min with maximum pressure of 40 bars. The air assisted sprayer help reduced drift loss with improved coverage for effective pest control. The chemical sprayed through a nozzle in the form of fine droplets was directed toward the crop canopy by an air stream emitted through the air sleeve pipe fitted behind the boom. The sprayer gave higher chemical deposits on both sides of the leaves as compared to that of the conventional sprayer. The air assisted sprayer gave approximately 5-7 % drift losses whereas the conventional sprayer gave about 20-25 %. The average field capacity was 2 ha/hr at a tractor forward speed of 6 km/hr and the operational cost was US $3.38/ha. The air assistance in the sprayer gave better spray penetration and distribution inside the canopy and increased deposition on the under surfaces of leaves. The air assisted sprayer atomized the chemicals and used the

Fig. 7 Chemical droplets deposit of conventional and air assisted boom sprayers at various location of the plant canopy

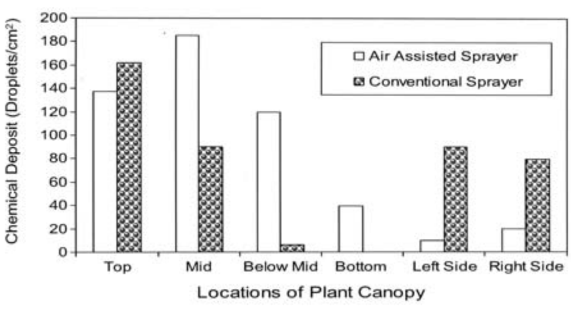
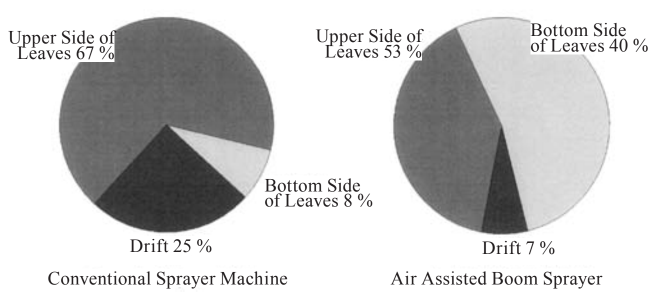


Fig. 8 Chemical deposit on cotton plant leaves & drift losses with conventional and air assisted boom sprayers



air effect to separate the leaves of plants so that the atomized chemicals could be deposited on both upper and under sides of the leaves.

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■■

NEWS

Rice breeding brings billions to SE Asia

Southeast Asian rice farmers are harvesting an extra US$1.46 billion worth of rice a year as a result of rice breeding.

The International Rice Research Institute (IRRI) indicates, according to a new Australian report.

The Australian Centre for International Agricultural Research (ACIAR) assessed the impact of IRRI’s research on improving rice varietal yield between 1985 and 2009 and found a boost in rice yield by up to 13%.

This means farmers are now harvesting more rice per hectare, raising up the land productivity.

They are also contributing to reduce poverty and increase regional stability.

There are some other benefits such as the growth of eating quality and resistance to pests and diseases.

Australia is supporting IRRI’s research, and recently gave AUS$15.4 million to facility upgrades.

IRRI's high levels of return on investment was appraised by many Australians.

from IRRI rice news

Performance Evaluation of Ncam-Modified Kerosene-Fired Batch Dryer

by
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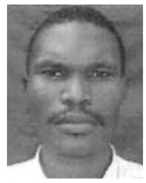

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Abstract

Performance evaluation of the NCAM modified, kerosene-fired batch dryer was made at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria, using two different crop products: paddy rice and cassava. Parameters measured were moisture content, drying rate, fuel consumption, and drying time. Test results revealed kerosene consumption rates of 0.057 l/kgh, 0.064 l/kgh and 0.046 l/kgh during drying of paddy rice, irregularly shaped cassava chips and threadlike shaped cassava chips, respectively. It took the dryer a total of 60, 114 and 120 minutes to dry 35 kg of parboiled paddy rice, 60 kg of threadlike shaped cassava chips and 43 kg of irregularly shaped cassava chips to a final moisture content of 14 %, 12 % and 22 % wb, respectively. The NCAM-modified kerosene-fired batch dryer was economical for drying of threadlike shape cassava chips. Because of the residue observed on the dried cassava chips, there would be the need to further modify the batch dryer in order to make it suitable for the drying of cassava chips by incorporating a heat exchanger to reduce or eliminate fumes on the chips.

Introduction

Rice is a health staple and one of the most important food crops, being consumed by about 80 percent of the world population (Yadollahinia *et al*., 2008). Rice production occurs in all agro-ecological zones of Nigeria (Wudiri, 1990). Rice is consumed in almost all households in Nigeria. It is a meal that cuts across all tribes. The average Nigerian eats 24.8 kg of rice per year, representing 90 percent of annual calorie intake (Ogunlade *et al*., 2010). The demand for rice is increasing at a much faster rate than domestic production in Nigeria; more than any other African country since the mid-1970s (Ogunlade *et al*., 2010).

Cassava, on the other hand, is a root crop which is one of the most important sources of energy in the human diet in the tropics. Nigeria ranks as the highest producer of cassava in Africa (FAO, 2000). Jeon and Halos (1992) stated that cassava accounted for 60 % of root crop consumption in Africa.

Thin-layer drying is the process of removal of water from a porous media by evaporation, in which excess drying air is passed through a thin layer of the material until the equilibrium moisture content (EMC) is reached. Moisture removal from an agricultural product depends on the drying temperature, velocity and air relative humidity, variety and maturity. Hence, various isolated and combined parameters are involved in moisture removal from a grain (Couto, 2002). The simplest situation is when the drying resistance (isothermal process) lies on the grain surface for which the decay of moisture with time follows approximately an exponential law (Yadollahinia *et al*., 2008).

Drying processes play an important role in the preservation of agricultural products. They are defined as a process of moisture removal due to simultaneous heat and mass transfer (Ertekin and Yaldiz, 2004). The most important reasons for the popularity of dried products are longer shelf-life, product diversity and the substantial volume reduction. This could be expanded further with improvements in product quality and process applications. Drying is essential for normal preservation of perishable foods and some crops. Drying can be enhanced by processing into more stable products. Cassava roots stored at 13 ºC and 85- 90 % RH can last for a maximum of 2 months and can last between 5 to 6 months when stored at 0-2 ºC and 85-90 % RH (NRI, 1994).

Rough rice is generally stored at between 12.5 and 14 % moisture content (wet basis). According to the equilibrium moisture data, rice at moisture content above 14 % (wb) will be exposed to drying conditions when relative humidity is less than 64 % at 400 F or less than 75 % at 800 F. If 14 % moisture content (wb) rice is exposed to humidity above these conditions, it will gain moisture (RQW, 2003)

When heated air is used as a drying medium, the primary factor influencing the rate of drying is the drying temperature (Yunfei and Morey, 1987). A study conducted by Sun and Woods (1994), revealed that drying is independent of air velocity in the range of 0.15 to 0.81 m/s, but depended sharply on the drying temperature of the air, from 21.1 to 76.7 ºC.

In cassava processing, the most common processing method is the prolonged direct sun drying of peeled root into a storable product (Mlingi, 1995). However, quick drying using mechanical dryers is advantageous in the sense that risk of the contamination and mould growth are minimized.

FAO (1987) reported that moisture content was the most important factor in preventing deterioration. Hence, use of drying to prevent deterioration is a very important process in post harvest operation. In a study by Pathak *et al*. (1991), the effect of drying temperature on thin layer drying of crops was high. Other factors that govern drying rate are moisture content, air velocity and relative humidity.

In order to improve the poor storage method of preserving food in Nigeria, the evaluation of the NCAM-modified kerosene-fired batch dryer is necessary to provide an alternative means for drying for the preservation of farm produce after harvest.

Objectives of the Study

The basic objective of this research was to carry out performance tests on the NCAM-modified kerosene-fired batch dryer. The specific objectives were to: -

1. determine the dryer suitability for drying cassava chips and paddy rice using thin layer drying;
2. determine the rate of moisture removal from cassava chips and paddy rice; and
3. determine uniform distribution of heated air within the batch dryer system both at the plenum and above the drying tray.

The Batch Dryer

Description of the Batch Dryer

A batch dryer was modified by NCAM to make it suitable for the purpose. It consisted of an axial fan blower unit, a 4.5 kW diesel engine, belt-pulley transmission system, kerosene burner incorporated with a metering device, a plenum and drying tray. The drying tray was made of a 2 mm diameter stainless screen. The batch dryer had an overall length of 2,501 mm, width of 1,165 mm and height of 810 mm. The dryer was mainly constructed with 1.5 mm galvanized sheet and 50 mm by 50 mm angle iron. **Fig. 1** shows the pictorial view of the modified batch dryer.

Working Principle of the Batch Dryer

For the purpose of this experiment the working principle of the modified batch dryer was as follows:

1. The burner was lit after turning on the kerosene supply knob to wet the wick in the burner;
2. The diesel engine was started to set the axial flow fan. The fan sucked the heated air across the burner, thereby transferring the

Fig. 1 The NCAM-modified kerosene-fired batch dryer

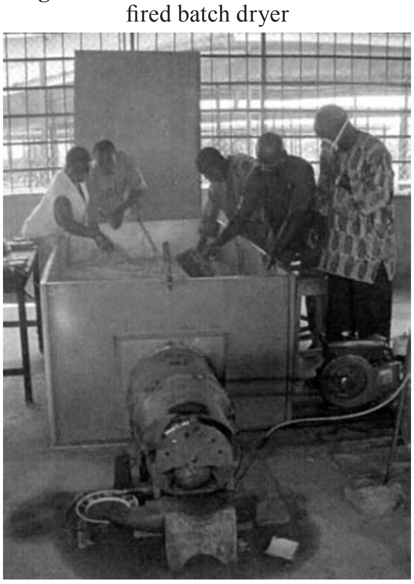
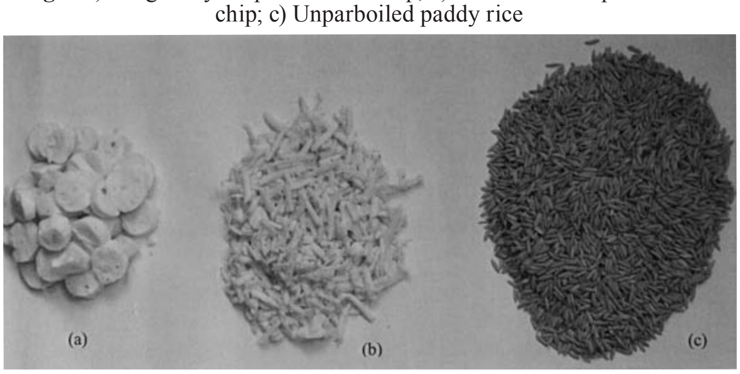


Fig.2 a) Irregularly shaped cassava chip; b) Threadlike shaped cassava chip; c) Unparboiled paddy rice



heated air to the plenum of the dryer for the drying operation to begin.

Materials and Methods

Materials: ***Cassava Chips***

Freshly harvested cassava roots (Manihot spp) were obtained from the Farm Management Unit (FMU) of the National Centre for Agricultural Mechanization (NCAM). They were peeled, washed and chipped. For this experiment, two different types of cassava chips were used, namely: irregularly shaped cassava chips and threadlike shaped cassava chips. These two types of cassava chips were obtained using two different types of NCAM-developed chipping machines. One of these cassava chipping machines was designed to produce irregular shaped cassava chips with an average thickness of 0.92 cm and a length varying between 30 and 50 mm depending on the size of the cassava root. The other type of NCAM-developed cassava chipping machine produced cassava chips having threadlike shape. The different shapes of cassava chips obtained were as a result of the two different types of chipping discs incorporated into the cassava chipping machines.

During this experiment, the initial weight used for conducting the experiment for irregularly and threadlike shaped cassava chips were 43 kg and 60 kg, respectively.

Paddy Rice

Paddy rice used for this evaluation was Faro 56 purchased from the National Cereals Research Institute, Baddegi, Nigeria. The paddy was parboiled using the NCAM farm level paddy parboiler. The average moisture content of the parboiled paddy before drying was 27 % w.b. 35 kg of parboiled paddy rice was used for the drying experiment with the NCAM batch dryer while five kg of parboiled paddy rice was used for the sun-drying method.

Fig. 2 shows the pictorial view of the three samples of agricultural materials used in their fresh state before drying.

Methods: ***Instrumentation of the Modified Batch Dryer for Temperature Monitoring***

In order to monitor the temperature of the drying air at the point of entering the drying tray through the plenum and the temperature of the moist air immediately after drying the agricultural materials, 4 K-type thermocouples were placed above the drying trays marked T_1, T_2, T_3 and T_4 for monitoring the moist air and a K-type thermocouples was placed at each dryer plenum marked T_5 and T_6 for monitoring the drying air. Each of the thermocouples was connected to a separate ALDA model AVD890G digital multimeter operating in the temperature mode. **Figs. 3** and **4** show the arrangement of the K-type thermocouples above and below the drying trays, respectively.

Drying Procedure

Before starting the drying experiment, the burner was fired, with the suction blower (axial flow fan) powered by a 4.5 kW diesel engine (Viking prime mover) and allowing it to run for a period of 30 minutes to stabilize the heated air in the dryer. Temperature was taken at six different points as identified above. The relative humidity and the ambient air temperature were recorded with the hygrometers and digital thermometer, respectively, while the speeds of the prime mover and blower were obtained with an analog tachometer. The measured parameters that included moist air temperature, drying air temperature and moisture content were recorded at specified time intervals. **Fig. 5** shows the pictorial view when the records were taken for the temperature reading.

The time required for all the operations was recorded using an analogue stop watch. Moisture contents were determined at intervals using an analogue quick moisture analyzer and confirmed by using the oven drying method. Weights of samples were determined using a sensitive electronic weighing balance. The fuel consumption for the kerosene

Fig. 3 Arramgement of thermocouples for sensing moist air temperature just above the agricultural materials

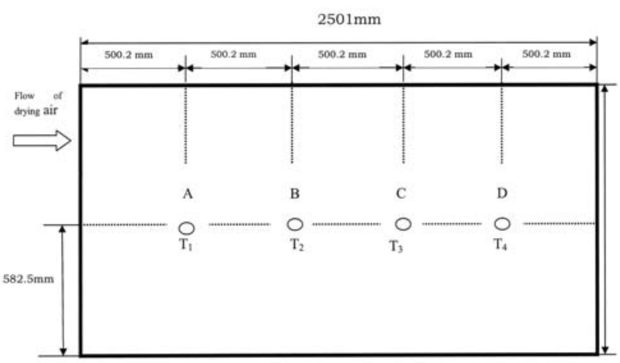


Fig. 4 Arramgement of thermocouples for sensing drying air temperature just below the agricultural materials

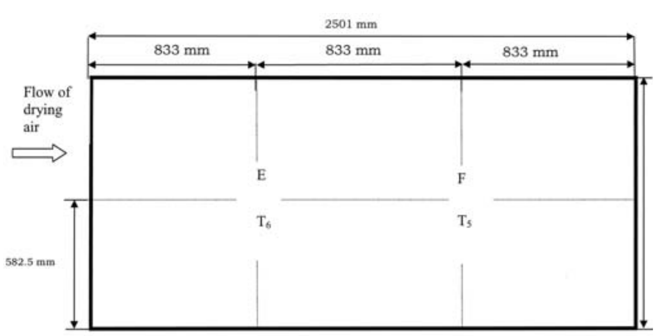


Table 1 Readings of Ambient Temperature and Relative Humidity before drying

Agricultural material dried	Measured parameters	
	Ambient Temperature (ºC)	Relative Humidity (%)
Paddy rice	28	35.9
cassava chips	33	12.4

Table 2 Temperature distribution at six different locations of NCAM batch dryer during paddy rice drying

Time, t (Minutes)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)	T_5 (ºC)	T_6 (ºC)	T_a (ºC)	T_b (ºC)
0	25	29	27	22	27	25	25.75	26.00
10	21	24	32	21	42	40	24.50	41.00
20	22	25	36	21	46	39	26.00	42.50
30	26	25	31	29	54	48	27.75	51.00
40	36	34	37	37	85	78	36.00	81.50
50	37	43	36	35	100	89	37.75	94.50
60	40	46	42	34	80	72	40.50	76.00
70	32	35	37	40	56	47	36.00	51.50

Legend:
T_1: temperature at point 1 on the top layer of the dryer
T_2: temperature at point 2 on the top layer of the dryer
T_3: temperature at point 3 on the top layer of the dryer
T_4: temperature at point 4 on the top layer of the dryer
T_5: temperature at point 5 under the dryer
T_6: temperature at point 6 under the dryer
T_a: average moist air temperature: $(T_1 + T_2 + T_3 + T_4) /4$
T_b: average drying air temperature: $(T_5 + T_6) /2$

burner was measured using a graduated cylinder.

Test Parameters

Kajuna *et al*. (2001) gave the equations below for obtaining the amount of bone dry matter based on the initial moisture content of the sample:

$MC_{db} = 100 (\% MC_{wb}) / 100 - (\% MC_{wb})$ .... (1)

But, $MC_{db} = M_w / M_{dm} \times 100 \%$ (2)

$M_w = MC_{db} \times M_{dm} / 100$ ....(3)

$M_{dm} = M_s - M_w$ ....(4)

where,

MC_{wb} = moisture content wet basis, %

MC_{db} = moisture content dry basis, %

M_s = mass of sample, kg

M_w = mass of water, kg

M_{dm} = mass of bone dry matter, kg

Eqn. 4 was found useful for obtaining the amount of moisture removed, moisture present in the sample, average moisture content dry basis (db) and the drying rate. All these parameters were related using the mathematical expression given below to calculate the drying rate.

$R = Mw / To [(Mbd) / 100]$ ....(5)

where,

R = drying rate in gm of water per minute per 100 gm of bone dry material.

M_w = Amount of moisture removed, %

Mbd = Total bone dry weight of sample, gm

To = Time taken to dry, mins

Results and Discussion

The initial relative humidity and ambient temperature of the environment obtained during the drying process of the agricultural materials is presented in **Table 1**.

Drying of Paddy Rice

Temperature readings taken at six different locations of the dryer for paddy rice drying using the NCAM-modified kerosene-fired batch dryer are presented in **Table 2**. The average temperature readings of the moist air and drying air were used in plotting the graph presented in **Fig. 6**. **Fig. 6** shows the graph of average temperature versus drying time for paddy rice. The temperature of the drying air increased steadily from 26 ºC to a maximum of 94.5 ºC within the first 50 minutes of drying. It took the drying air temperature an additional 20 minutes to move from 94.5 ºC to 51.5 ºC which is considered to be within the

Fig. 5 Pictorial view showing how temperature readings were taken

Fig. 6 Average temperature versus drying time for paddy rice

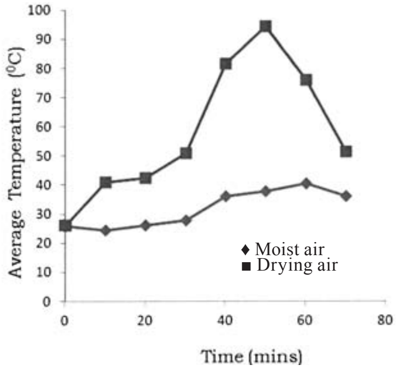


Fig. 7 Moisture content versus drying time for paddy rice

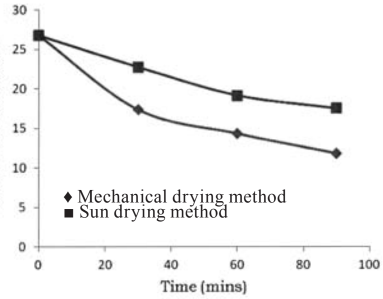


Table 3 Moisture content readings obtained during drying of paddy rice

Drying Method in Use	Moisture Content value (% w.b)			
	Initial	Time, t (minutes)		
		30	60	90
Mechanical drying using NCAM Batch dryer	26.8	17.37	14.33	11.8
Sun-drying	26.8	22.77	19.15	17.5

Table 4 Drying characteristics of the paddy in the batch dryer

Drying time, min	Moisture removed, kg	Moisture present in the sample, kg	Moisture content, % d.b	Average moisture content, % d.b	Drying rate, R, g of water/ min 100 g of bone dry materials
0	0.00	9.38	36.61		
30	3.99	5.39	21.02	28.815	0.519
60	5.09	4.29	16.73	18.875	0.331
90	6.21	3.17	12.36	14.545	0.269

Table 5 Drying characteristics of the paddy during sun drying

Drying time, min	Moisture removed, kg	Moisture present in the sample, kg	Moisture content, % d.b	Average moisture content, % d.b	Drying rate, R, g of water/ min 100 g of bone dry materials
0	0.00	1.34	36.61		
30	0.26	1.08	29.48	33.045	0.237
60	0.47	0.87	23.69	26.585	0.214
90	0.56	0.78	21.21	22.45	0.17

Table 6 Temperature distribution at six different locations of NCAM batch dryer during cassava chip drying

Time, t (minutes)	T_1 (ºC)	T_2 (ºC)	T_3 (ºC)	T_4 (ºC)	T_5 (ºC)	T_6 (ºC)	T_a (ºC)	T_b (ºC)
0	26	26	25	26	26	26	25.75	26.00
10	28	36	30	39	61	69	33.25	65.00
20	27	35	29	37	50	55	32.00	52.50
30	30	33	34	43	56	63	35.00	59.50
40	40	35	39	47	55	62	40.25	58.50
50	27	29	31	37	41	45	31.00	43.00
60	52	37	43	53	66	79	46.25	72.50
70	31	40	45	49	48	59	41.25	53.50
80	33	50	60	65	70	88	52.00	79.00
90	35	52	69	74	74	95	57.50	84.50
100	34	49	64	69	59	80	54.00	69.50
110	34	46	63	70	65	84	53.25	74.50
120	33	46	62	69	33	80	52.50	56.50
130	33	44	59	69	33	76	51.25	54.50

Legend:
T_1: temperature at point 1 on the top layer of the dryer
T_2: temperature at point 2 on the top layer of the dryer
T_3: temperature at point 3 on the top layer of the dryer
T_4: temperature at point 4 on the top layer of the dryer
T_5: temperature at point 5 under the dryer
T_6: temperature at point 6 under the dryer
T_a: average moist air temperature: $(T_1 + T_2 + T_3 + T_4)/4$
T_b: average drying air temperature: $(T_5 + T_6)/2$

range of safe drying air temperature for paddy rice.

The moisture content at different time intervals for paddy rice drying with the NCAM modified batch dryer and sun-drying method are presented in **Table 3** and plotted in **Fig. 7**. The rate of moisture removal was high within the first 30 minutes of drying using the NCAM-modified batch dryer. This might be attributed to the high initial drying air temperature that drove out moisture from the surface of the grains at this initial time. The moisture removed gradually increased over a period of time. As drying continued, the paddy rice attained a safe storage/milling moisture content of 14.3 % within 60 minutes. After 90 minutes of drying using the NCAM-modified batch dryer, 6.21 kg of moisture was removed corresponding to 0.269 kg of water/minute (**Table 4**). For the sun drying method, only 0.56 kg of moisture was removed after 90 minutes of drying, which corresponded to 0.17 kg of water/minute (**Table 5**). Thus, the drying rate was faster with the NCAM-modified batch dryer compared with the sun drying for drying of paddy rice.

Drying of Cassava Chips

Readings taken at six different locations of the dryer for cassava chip drying are presented in **Table 6**. The average temperature versus drying time for the moist air and drying air are shown in **Fig. 8**.

Fig. 8 Average temperature versus drying time for cassava chips

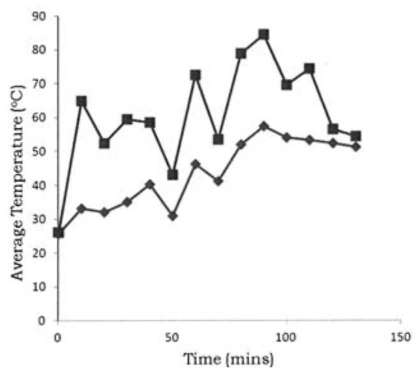


Table 7 Moisture content readings obtained during drying of threadlike shaped cassava chip

Moisture Content (% w.b)				
Initial	Time, t (minutes)			
	30	60	90	120
73.2	58.5	53.8	52.8	21.8

Table 8 Moisture content readings obtained during drying of irregularly shaped cassava chips

Moisture Content (% w.b)				
Initial	Time, t (minutes)			
	24	54	84	114
65.92	47.93	40.6	38.95	11.73

Table 9 Fuel consumed during drying operation

Agricultural material dried	Quantity of material dried, kg	Time taken to dry the agricultural material, mins	Amount of fuel used (l)	Fuel consumption rate, l/kg.h
Paddy rice	35	60	2.00	0.057
Irregular shaped cassava chips	43	120	5.53	0.064
Threadlike shaped cassava chips	60	114	5.23	0.046

The temperature of the drying air increased steadily from 27 ºC to a maximum of 84.5 ºC within the first 90 minutes, while the moist air temperature was at a maximum of 57.5 ºC within 90 minutes of drying. This might be attributed to the high moisture content nature of the cassava chip.

Results obtained for the moisture content readings taken at different time intervals for drying both threadlike and irregularly shaped cassava chip are presented in **Tables 7** and **8**, respectively, and are plotted in **Fig. 9**. The moisture content of the thread like cassava chips decreased from the initial moisture content of 66 % wb to 12 % wb within 114 minutes, while the round shaped cassava chips reduced from an initial moisture content of 73 % wb to 22 % wb within 120 minutes. This showed that the thicker cassava chips took longer to dry. Within the first 60 minutes of drying, the outer layer of the chips looked drier than the inner part. Further drying of the cassava chips for 40 minutes at a lower temperature allowed for migration of moisture from the region of higher moisture concentrations (inner part) to the region of lower concentration (the outer part). Thus, it can be deduced that fast drying using higher temperature resulted in faster removal of moisture from the outer surface of the chips. However, to reduce the drying time, it was advised to start drying with high drying air temperature within the first one hour because of the fast rate at which moisture was removed.

Fuel Consumption

The amount of kerosene used by the kerosene burner is presented in **Table 9**. **Fig. 10** presents a bar chart showing the amount of kerosene consumed per kilogram per unit time of agricultural material dried. Drying of the threadlike shaped cassava chips gave the least fuel consumption rate of 0.046 l/kg.h. This was followed by paddy rice drying which gave a fuel consumption rate of 0.057 l/kg.h, and drying of irregular shaped cassava chips with the highest fuel consumption rate of 0.064 l/kg.h. This implied that the NCAM modified batch dryer was economical in drying the threadlike cassava chips as compared to the other two agricultural materials.

PRD = Paddy Rice Drying; ISCCD = Irregular Shaped Cassava Chips Drying;
TSCCD = Threadlike Shaped Cassava Chips Drying

Fig. 9 Moisture content versus drying time

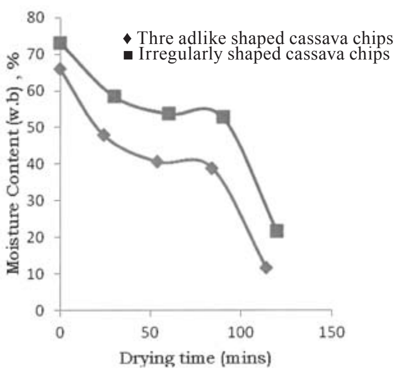
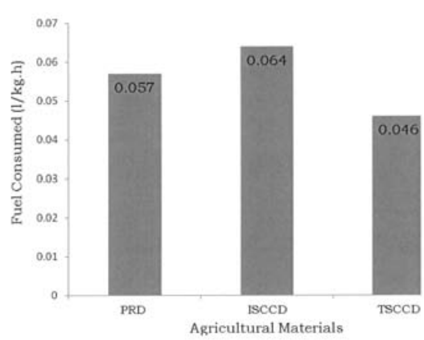


Fig. 10 Fuel consumed per kilogram per unit time of agricultural material



Conclusions

Performance evaluation was made on the NCAM-modified kerosene-fired batch dryer and the following conclusions were made:

1. The NCAM-modified kerosene-fired batch dryer was most economical for the drying of threadlike shape cassava chips.
2. The maximum average drying air temperature attained within the dryer was 94.5 ºC.
3. Flow of heated air within the batch dryer system, both at the plenum and above the drying tray, was not uniformly distributed.
4. The drying rate at which the

NCAM-modified kerosene-fired batch dryer dried agricultural materials was much faster when compared with the sun drying method.

5. The NCAM-modified kerosene-fired batch dryer was able to dry irregularly shaped cassava chips from an average thickness of 0.92 cm with initial moisture content of 73 % wb to a thickness of 0.62 cm with final moisture content of 22.0 % wb within 120 minutes using a total amount of 5.53 litres of kerosene.
6. The NCAM-modified kerosene-fired batch dryer was able to dry threadlike shaped cassava chips from an initial moisture content of 66 % wb to 12.0 % wb within a drying time of 114 minutes using a total amount of 5.23 litres of kerosene.
7. The NCAM-modified kerosene-fired batch dryer conveniently dried cassava chips. However, it was observed that the dried cassava chips were contaminated by soot/fumes from the burner. As a result, there was a need to incorporate a heat exchanger to eliminate fumes from the chips.
8. With the incorporation of the proposed heat exchanger into the batch dryer system, it was safe to conclude that the dryer was suitable for drying all types of agricultural materials grown in the world.

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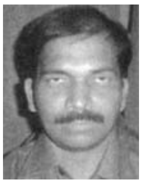
Manual and Motor Operated Paddy Thresher for the Kashmir Valley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INDIA

Abstract

A pedal operated and motorized paddy thresher equipped with an adjustable seat was designed and developed at the Division of Agricultural Engineering (SKUAST-K), Kashmir. The performance of the thresher was evaluated at 19.8, 20.2 and 22.1 % moisture content and 90.25, 105.25, 111.35 and 125.00 cm stalk length for conventional (drum beating), pedal operated and motorized threshers. The best threshing performance (threshing capacity and energy requirement) of the motorized paddy thresher was obtained at 19.8 % moisture content and 111.35 cm stalk length. Threshing efficiency obtained using drum beating (conventionally used in Kashmir valley) was 98.08 %; very close to the threshing efficiency obtained through the pedal operated (97.04 %) and the motorized thresher (96.44 %) but the threshing capacity of the motorized thresher was better than the pedal thresher. The conventional method showed lower capacity and higher energy requirement.

Introduction

In the Kashmir valley of J & K state (India), paddy (Oryza sativa L.) is grown in over 151,000 ha having a yield of 10.3 quintals per hectare (Raina, 2002). In this region, about 60-70 % of the area is rainfed and totally depends on rainfall. Due to the uncertain and erratic nature of rainfall, most farmers are able to grow one crop, i.e. paddy, in an area. The average size of an operated land holding in the valley is less than 0.53 ha, which is one third of the average operated holding size in India (Anonymous, 2008). About 10 % of the grain losses for cereal, pulses and oil seeds and up to 40 % for fruits and vegetables occur at the country level every year due to lack of storage and post harvest facilities. Therefore, raising agricultural and horticultural crops always necessitates improved post harvest processing facilities to reduce post harvest losses so that the improvement in production can be realized and, in turn, increase the net return to the grower (Dixit *et al*. 2006). Threshing is one of the important operations followed after harvesting where paddy is separated from the straw. Threshing represents the final field operation in rice production. Although tractor/power operated threshers are used in limited areas in the valley, generally, threshing of paddy is done manually. In view of the prevailing socio-economic conditions of the farmers in the Kashmir valley, the large capacity threshers are inappropriate and small size but more sophisticated harvesting equipment is difficult to be adopted (Quick, 1998). Conventional methods of threshing are time and labour consuming with lot of drudgery to the labourer (Sharma *et al*., 1984). In hilly the region, the threshing of paddy is conventionally done either by beating with sticks or by rubbing out under the human feet, which involves more time and labour. Paddy grains get threshed from the straw easily just by beating the bundles 2-3 times against a log/drum or hard surface. This requires 20-30 man-days per hectare depending on the condition of the rice fields. These methods of threshing lead to a higher percentage of grain loss. Pinar (1987) reported that the selection of improper threshing method causes grain loss in the range of 2.88 to 4.5 percent.

Das and Das (1989) developed and studied a manual paddy thresher and observed that higher capacity and optimum threshing efficiency could be achieved by threshing the paddy crop at 16.5 % moisture content at a peripheral velocity of 10.4 m/s. Due to higher weight and electric power requirements, this paddy thresher was not suitable in the North-Western Himalayan Region. Another axial paddy thresher was developed at IRRI that had the capacity of 100 kg/ha (Khan, 1971). This thresher was used extensively in some pockets of the North Eastern region of Bengal and Orissa. However, due to difficult terrain and low production, the farmers of the hills were reluctant to procure a heavy paddy thresher.

Fig. 1 Conventional method of paddy threshing

Keeping in view the above mentioned facts a need was felt to develop a thresher suitable for the Kashmir valley. Therefore, a study was initiated to develop and evaluate a pedal and motor operated paddy thresher for the Kashmir valley in order to increase the capacity and efficiency.

Materials and Methods

In the study, a pedal operated thresher (**Fig. 2**) and motor operated thresher (**Fig. 3**) were fabricated in the Division of Agricultural Engineering (SKUAST-K), Kashmir for testing and evaluation in the farmer's field. Both threshers consisted of a rotating drum mounted on a shaft that had a crate wire sprocket drive. Manual operation was by a pedal action similar to that of pedals on a bicycle. Power operation was by an electric motor with pulleys.

The pedal thresher was ergonomically designed such that the operator could operate the thresher in a sitting posture. The machine could be manually operated by single man. Back and hand rests of the thresher were designed so that the operator's spinal chord was 900 ± 5º from vertical, the leg opening was 85º-120º and arms (angle between upper and lower arm 135º) remained in a comfortable position during operation. The height of the hand rest could be adjusted by the operator (male or female) by providing an adjustable hand fold and back rest according to the height of the operator. Power was transmitted from pedal to threshing cylinder through a chain and sprocket system having a speed ratio of 1:7. The threshing drum diameter at the tip of wire loops was 0.50 m (**Fig. 2**).

A person could hold the paddy bundle on separate segments of the rotating drums and once the grain bearing portion was brought in contact with rotating spikes, the grain was easily separated from the bundle. This eliminated the drudgery of the conventional method of threshing, which was the laborious beating of bundles against a log or drum (**Fig. 1**). For the pedal operated thresher, threshing could be done at a comfortable speed of 150?200 rpm and for the motor operated thresher, threshing was done at a speed of 500 rpm. The speed of both the threshers was determined from results of preliminary experimentation. Three persons could operate the pedal operated thresher with one man pedaling and other two holding the bundles in their hands for threshing. The motor operated thresher could be easily operated by 1 hp electric motor with three persons holding the bundles in their hands for threshing (**Fig. 3**).

The total man-hr and power required were recorded for threshing under different moisture contents and different stalk lengths of the bundles. The human-hr and electricity requirement were converted into

Fig. 2 Pedal operated paddy thresher

Fig. 3 Motor operated paddy thresher

energy equivalents (Lidhoo, 2003) by using the following relationship:

1 Man-hr = 1.96 MJ

1 hp = 746 Watts

A comparative analysis between the conventional method of threshing and the developed threshers was done with respect to the threshing capacity, threshing efficiency and energy requirement under different moisture contents and stalk length.

Results and Discussion

Optimization Of Moisture Content and Stalk Length for Different Threshing

The threshers (manual, pedal operated and motorized) were evaluated for three levels of moisture content (19.8, 20.2, 22.1 % (db)) and four levels of stalk length (90.25, 105.25, 111.35, 125.0 cm) for conventional, paddy operated and motorized threshers in three replications. All three machines were tested for their threshing capacity, efficiency and energy requirement.

Two variables, moisture content (M) and stalk length (L), were used for investigation. To determine the sensitivity of these parameters, multiple regression analysis was carried out for threshing capacity, efficiency and energy requirement. After finding the relevancy of these parameters, the results (mean values) were analyzed statistically in SPSS (V-10).

Threshing Capacity

It is evident from **Tables 1** and **2** that the threshing capacity of the motorized thresher with different moisture contents and stalk lengths was higher as compared to the conventional and pedal operated threshers. Threshing capacity for the conventional method and pedal thresher was significantly higher at 19.8 % moisture content and 105.25 cm stalk length compared to others at the 5 % level of significance. Threshing capacity for the motorized thresher was significantly higher at 19.8 % moisture content and 111.35 cm stalk length. Threshing capacity for conventional, pedal operated and motorized thresher was linearly correlated with moisture content and nonlinearly with stalk length.

Threshing Efficiency

Threshing efficiency for the conventional method was comparatively higher followed by the pedal operated and motorized threshers (**Tables 1** and **2**). For the conventional and pedal operated thresher, the efficiency was non-significantly higher at 20.2 % moisture and significantly higher at 111.35 cm stalk length. At 19.8 % moisture content and 111.35 cm stalk length; the motorized thresher had significantly higher efficiency at the 5 % level of significance. Threshing efficiency for all three threshing methods was linearly correlated with moisture content and non-linearly correlated with stalk length.

Energy Requirement

As compared to the pedal operated and motorized thresher, the conventional method had higher energy consumption. Minimum energy was required as 1.37 MJ/q for the motorized thresher that saved 78 % and 40 % energy as compared to the conventional method and pedal operated threshers, respectively (**Tables 1** and **2**). For the motorized thresher, the energy was significantly less at 19.8 % moisture content and 111.35 cm stalk length at the 5 % level of significance. The energy requirement was linearly correlated with moisture content and non-linearly

Table 1 Effect of threshing methods on capacity, efficiency and energy requirement at different moisture contents

Threshing parameters	Type of thresher	Moisture contents, %		
		19.8	20.2	22.1
Thresher Capacity, Kg/hr	Conventional	100.00^{bc}	95.00^{b}	85.30^{a}
	Pedal operated	266.33^{abc}	259.10^{ab}	250.25^{a}
	motorized	635.73^{bc}	629.73^{ab}	620.33^{a}
Threshing efficiency, %	Conventional	98.40^{abc}	98.50^{ab}	97.90^{a}
	Pedal operated	97.30^{bc}	97.50^{b}	96.30^{a}
	motorized	97.30^{c}	96.20^{b}	95.30^{a}
Energy requirement, MJ/q	Conventional	5.90^{bc}	6.19^{b}	6.89^{a}
	Pedal operated	2.21^{abc}	2.27^{ab}	2.35^{a}
	motorized	1.35^{bc}	1.36^{b}	1.38^{a}

All data represent mean of triplicate. Means within a row with different superscripts are significantly different ($p < 0.05$).

Table 2 Effect of threshing methods on capacity, efficiency and energy requirement at different stalk lengths

Threshing parameters	Type of thresher	Stalk length, cm			
		90.25	105.25	111.35	125.00
Thresher Capacity, Kg/hr	Conventional	87.13^{a}	102.00^{b}	97.10^{bc}	94.970^{cd}
	Pedal operated	245.00^{a}	272.00^{b}	269.00^{bc}	248.13^{ad}
	motorized	611.73^{a}	622.30^{b}	632.70^{c}	619.40^{bd}
Threshing efficiency, %	Conventional	97.90^{a}	98.50^{abc}	98.90^{ac}	96.43^{d}
	Pedal operated	96.30^{a}	97.47^{b}	98.20^{c}	96.20^{ad}
	motorized	94.37^{a}	96.70^{b}	97.83^{c}	97.37^{bcd}
Energy requirement, MJ/q	Conventional	6.78^{a}	5.77^{b}	6.05^{bc}	6.22^{cd}
	Pedal operated	2.40^{a}	2.16^{b}	2.18^{bc}	2.37^{ad}
	motorized	1.39^{a}	1.37^{ab}	1.35^{c}	1.38^{abd}

All data represent mean of triplicate. Means within a row with different superscripts are significantly different ($p < 0.05$).

correlated with stalk length.

Conclusions

The motor operated paddy thresher recorded maximum threshing capacity of 634.23 q/hr at 19.8 % moisture content and stalk length of 111.35 cm. The lowest energy requirement of 1.34 MJ/q at moisture content of 19.8 %. and stalk length of 111.35 cm was observed for the motor operated paddy thresher. The threshing capacity of the motorized thresher was slightly less than the pedal operated and conventional method.

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NEWS

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Development of Electronic Weight Grader for Sapota

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Abstract

The investigation was carried out to develop a weight grader for sapota (Manilkara achras (Mill). fosberg). The weight grader, fitted with a singulation unit, was found to be more precise than any other. Since the singulation unit fed the fruits individually into the electronic balance, single fruit grading could be achieved. The singulation unit fed the fruits to the load cell individually where they were weighed and carried to the grading unit, which actually consisted of two gates that were operated electronically using the signal generated by the load cell that depended on fruit weight. The overall separation efficiency of the grader was 93.8%. Separation efficiency of W3 grade (> 120g) was best. The speed was optimized for 20 rpm, which gave best overall efficiency. The cost of grading for cricket ball was found to be low, i.e., Rs. 0.06 / kg, compared to manual grading (Rs. 0.4/kg).

Introduction

Sapota (Manilkara achras (Mill). fosberg) is a native of tropical America, having originated in Mexico of Central America. It is a delicious fruit, also known as chikoo and zapota. Sapota belongs to the family of Sapotaceae. Sapota is a good source of digestible sugar, protein, fat, fibre, calcium, phosphorus, iron and other minerals. India is the largest producer of sapota with 30 to 40 thousand hectares. The average yield per tree is 2,500 to 3,500 fruits weighing around 150 to 300 g under Bangalore conditions. Vyas and Shah (2004) developed an on the farm sapota grader. The grader was capable of fruit grading to 3 sizes. The overall grading efficiency was maximum at 14 rpm, which was about 90%. Advantages of mechanical grading are: systematic grading can be achieved; a continuous mechanical fruit grader can be integrated with any other processing operation like fruit packaging and peeling; it saves time and energy to process the individual produce; it reduces produce handling time; and reduces post harvest losses. The objectives of the work were to determine the physical parameters of sapota (Cricket ball-variety), to develop a singulation unit for the fruit grader, to evaluate the performance of a prototype weight grading machine and to evaluate the economics.

Material and Methods

Mature sapota (Cricket ball-variety) was purchased from the market. The sapota fruits were separated manually by weighing into three groups according to their weight. Fruits were chosen from each group for the determination of physical parameters using procedures suggested by Mohsenin (1996). Size was determined by digital vernier calipers, to find the major, minor and intermediate diameter of the sapota fruit. Shape was evaluated by following the chart given by Mohsenin (1996). The grader was evaluated at four different speeds (10, 15, 20, 25 rpm) and separation efficiency was calculated by the following formula (Bachah, 1982):

where,
Overall separation efficiency, %
Total weight of the sample, g
Weight of undersize in particular sample, g
Weight of oversize in particular sample, g

The feed hopper was fabricated from 18 gauge MS sheet, fitted at a slope of 10 degrees to the horizontal. The bottom front end was provided with an opening of 100 mm width to accommodate the conveyor belt with the carrier comb of the singulation unit (**Fig. 1**). The bottom end was fitted with a comb in a zigzag fashion. The sapota singulation unit had a frame, fruit conveyor, singulating channel, and a belt and roller with a shaft. The grading unit was fitted at an angle of 15º to ensure free flow of the fruit. Two gates 300 mm long and 140 mm high were fitted at a distance of 400 mm to divert the over sized and under sized fruits. Two outlets were provided on the opposite side of the gate when the gate was operated by the standard door opening and closing mechanism (Yi Zhang *et al*., 1995). The pushing of the vertical member was effected by the pulling type solenoid switches. Two pulling type solenoids with a pulling capacity of 1 kg and stroke length of 30 mm were used in the grading unit. The solenoid switches were connected to a 24 volt DC eliminator through a relay switch on the load cell that completed the circuit between the 24 volt DC eliminator and solenoid switch as shown in **Fig. 2**. The closing of this circuit resulted in pulling the vertical member of the door opening and closing mechanism which operated the gate fitted in the grading unit.

Results and Discussion

The results indicated that, for the size of the fruit, the major diameter of sapota (cricket ball variety) in various weights was in the range of 4.85 cm to 8.35 cm. Similarly, the intermediate diameters were 4.59 to 7.71 cm and minor diameters 3.91 to 8.48 cm according to the standard for fruits and vegetables (Mohensin, 1996). The shape of cricket ball was round. This property was used in designing the singulation unit for sapota. The sphericity value of sapota fruit ranged from 0.91 to 0.98 with an average of 0.95. This value being close to one, it was inferred that the fruit could be considered as spherical. This explained why the fruit rolled on the grader. The average weight of cricket ball variety was 155.9 g. The fruit weight varied from 42.1 g to 290.5 g. The variation in the weight was in agreement with Laxminarayana (1980). This property was used in setting up limits in the load cell. True density ranged from 0.97 to 1.05 g/cc. Volume of the fruits in the representative size group of cricket ball fruit ranged from 43 to 275 cm^3. This property helped in design of containers for bulk handling of the fruit.

Surface area of sapota ranged from 45-290 cm^2. The angle of repose of sapota fruit in their natural heaped position was 24 degrees. This property was useful in finalizing the angle for the singulation unit, since the singulation unit was mounted at an angle of 40 degrees to horizontal and there was no rollback of fruits during carrying. The moisture content on wet basis for sapota fruit was 77.7 %. This property ensured free flow of fruit over the grader, which could affect capacity and efficiency of the machine. Firmness of fruit at harvest differed among various weight groups. The firmness was in the range of 5.75 to 7.0 kg/cm^2. This property also explained ease of rolling of fruit on the grader (**Table 1**).

The grader was evaluated at four different speeds. The overall separation efficiency of the grader for 20 rpm was 93.8 % (**Fig. 6**, **Table 2**). The feed rate was 430 kg/hr and separation efficiency of W_3 grade (> 120g) at this speed was best as 95.8% (**Fig. 5**). Capacity of the grader for cricket ball variety was 0.43 ton/hr.

Table 1 Physical properties of sapota (variety-cricketball)

Grade	Weight, g	Major dia., cm	Minor dia., cm	Inter-Mediate dia., cm	Sphericity	Volume, cm^3	True density, g/cm^3	Surface area, cm^2
W_1 < 60 g	42.1	4.85	3.91	4.59	0.91	43	0.97	45.50
W_2 61-120 g	105.6	6.35	6.46	5.92	0.98	130	1.03	140.00
W_3 > 120 g	290.5	8.34	8.48	7.71	0.98	275	1.05	290.75

* W=Weighed range of fruit

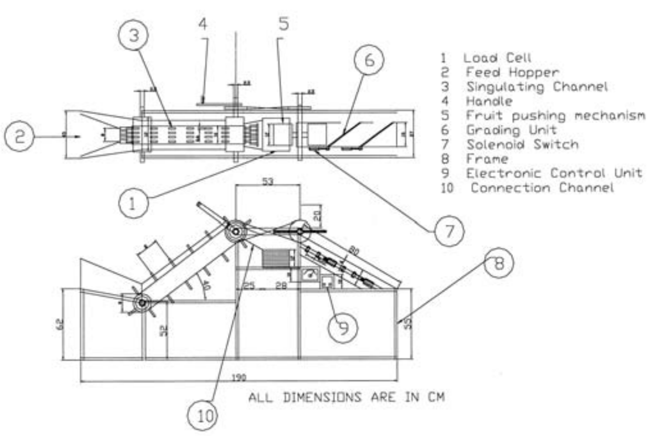

Fig. 1 Schematic diagram of electronic weight grader for sapota

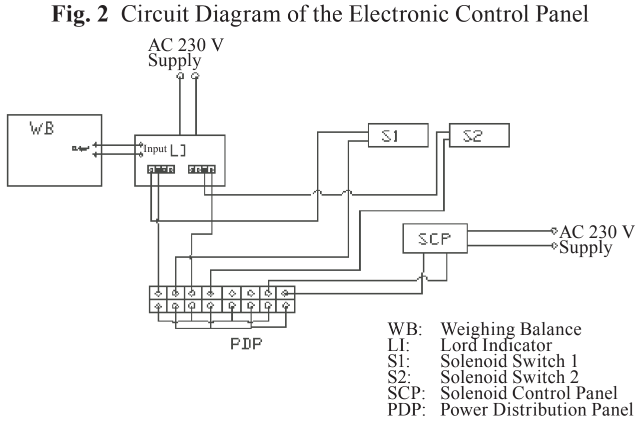

Fig. 2 Circuit Diagram of the Electronic Control Panel

Table 2 Performance of grader at 20 rpm

Grade	Wt. (Total wt of sample)	Wu (Under wt, g)	Wo (Over wt, g)	Efficiency, %	Wc (Correctly Graded wt, g)
W_1 < 60 g	2,140.3	0	144.7	93.2	1,995.6
W_2 61-120 g	2,608.6	53.2	146.8	92.3	2,408.6
W_3 > 120 g	2,489.2	103.2	0	95.8	2,386.0
Total	7,238.1				6,790.2
Overall Separation Efficiency, %			93.8		
No. of Fruits			56		

Conclusion

Grading of sapota in India is still done manually, either by hand picking or through sieves. Efficient grading operation on the basis of physical dimensions of sapota can be made with the help of a mechanical sapota grader. Some fruit have consistent shape so that they can be conveniently weighed and sorted. The result is a product that is consistent in volume and shape and packs easily. The developed weight grader should operate at the optimum speed of 20 rpm for sapota of cricket ball variety to achieve the best combination of speed and overall separation efficiency, i.e., 93.8 percent. The cost of grading is also economical, which is about 0.0611/kg. This is about one sixth of cost of manual grading through scarce labour.

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Fig.3 Effect of speed on separation efficiency for W_1 (> 60 gm)

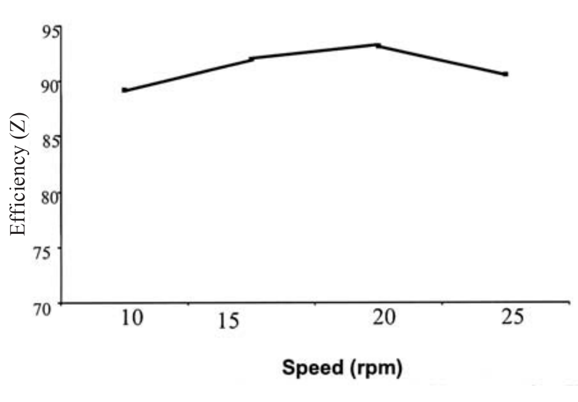


Fig.4 Effect of speed on separation efficiency for W_2 (61-120 gm)

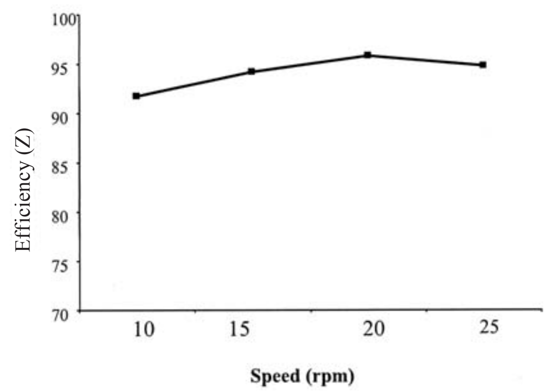


Fig.5 Effect of speed on separation efficiency for W_3 (> 120 gm)

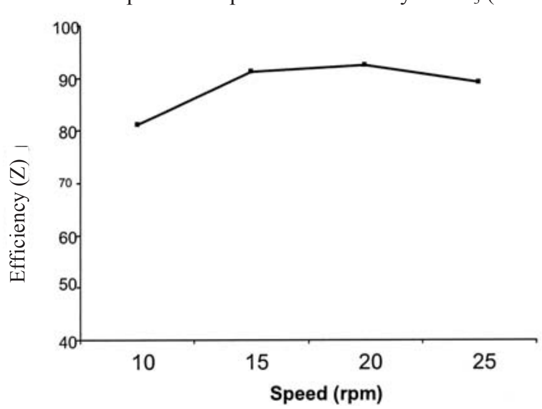
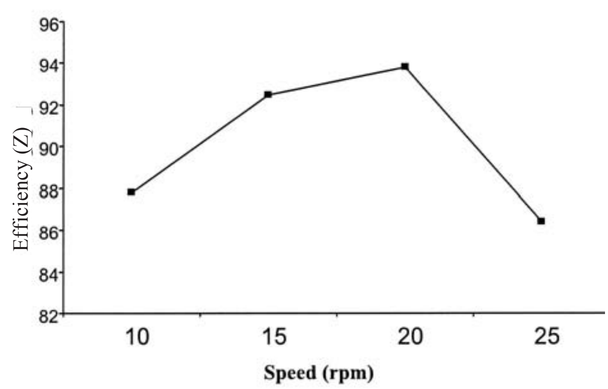


Fig.5 Effect of speed on overall separation efficiency



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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.

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Field Evaluation of Center Pivot Sprinkler Irrigation Systems Using a Simulation Model, River Nile State, SUDAN: **Hassan Elhaj Hamed H. Alsayim**, Assistant Professor, Dept. of Agril. Engg. Faculty of Agric., Nile Valley Univ. P.O. Box 346 Atbara, SUDAN Alsayim101@yahoo.com; **Amir Bakheit Saeed**, Associate Professor, same, University of Khartoum P.O. Box 32 Shambat, same.

Field evaluations were made during seasons (2007/2008) on two center pivot sprinkler irrigation systems operating in different two sites: Ras Elwadi and Jordanian Bashair agricultural projects located at the River Nile State, Sudan. Alfalfa and onions were used as the indicator crops to verify a center pivot simulation model designated (CPM) for designing, evaluating and managing the center pivot systems. The results covered total available water, crop evapotranspiration, irrigation intervals and system water application depth. For Ras Elwadi they were found to be 49 mm, 8.9 mm day^{-1}, 6 days and 70 mm, while for the Jordanian Bashair they were 49 mm, 9.3 mm day^{-1}, 6 days and 70 mm, respectively. The systems' discharges were 318.8 m^3 hr^{-1} for Ras Elwadi and 227.2 m^3 hr^{-1} for the Jordanian Bashair. The coefficient of uniformity (CU) and distribution uniformity (DU) for Ras Elwadi were 82.8 % and 48.3 % and for the Jordaian Bashair were 77.3 % and 69.6 % respectively.

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Some Physical Properties of Aonla Fruits and Seeds Relevant to the Design of Processing Equipments: **Thangavel, K**, Professor, Dept. of Food and Agril. Process Engg., AEC & RI, TNAU, Coimbatore-641003, Tamil Nadu, INDIA. kulandaithangam@yahoo.com; Ambrish Ganachari, Post graduate student, same; **V. Eyarkai Nambi**, same; **R. Viswanathan**, Professor, same.

Selected physical properties of three cultivars of aonla fruit were determined. Chakaiya, Kanchan and NA-7 cultivars were selected for the study. The properties like size, shape, roundness, sphericity, angle of repose, density, pulp to seed ratio, surface area, mass of 1,000 fruits and cutting force were studied for the fruits. It was found that the geometric mean diameter of the fruit was maximum for the variety Chakaiya (40.7mm), closely followed by Kanchan (39.5mm) and NA-7 (36.5mm) respectively. Based on the values of roundness and sphericity, the fruit shape was observed to range from round to oblate. The angle of repose was 20.7^0 for NA-7 followed by 19.7 and 19.10 for Chakaiya and kanchan respectively. The Chakaiya fruit was more spheroid (97.22 %) as compared to Kanchan (96.98 %) and NA-7 (93.79 %). Kanchan was found to be more compact with a density of 1.16 g/cm^3, where as the bulk density was found to be similar for all the three varieties. The mass of 1000 fruits was found to be maximum for the Kanchan, 32.25 kg and for NA-7, Chakaiya were 30.41 and 30.1 kg respectively. The cutting force was observed to be maximum when cut from the stem end side and NA-7 got higher value because of the presence of more fibers. The seed diameter for the three cultivars varied between 12.1 to 17 mm.

Main Production of Agricultural Machinery Manufactures in Japan

by
Shin-Norinsha Co., Ltd.
1-12-3, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101-0054 JAPAN

Introduced here are the main products of agri cultural machinery manufactures in Japan with a number of photographs. The products are developed and improved for both foreign and domestic makers. For further information please refer to the manufacturers listed in the directory.

ALPS KEIKI
Battery Tester ***"SP1250BT"***
Applying "Kinetic Inward Resistance System" (patent), which estimates the ohmic value by looking at the displacement of current and tension in the battery while charging and discharging. ■L145×W280×H70mm ● 800g

CANYCOM
Bush Cutter ***"F1 Masao"***
Outstanding ability to turn in a small radius (minimum radius of 1.8m). 75 degrees of front wheel steering angle. ▲22hp □Running speed: 14km/h when moving, 8km/h when working. □Cutting height adjusting lever with 21 levels. □Working Width: 975mm

ISEKI
Tractor ***"TJV95"***
High output and torque engine of 95ps equipped. Common rail type electronic fuel injection system applied. This tractor computerizes the fuel injection, and the user is able to choose from two types of engine output patterns “Output Priority Mode” and “Fuel Consumption Priority Mode”.

ARIMITSU
Knapsack Power Mist Dusters
"SG-6020D"
It can carry out fetilizer spreading and herbicide spraying from ridge between rice fields and it can spread/spray uniformly in a short time. ■L363×W520×H740mm ●10.1kg ▲49.4cc □Chemical tank: 20L.

ISEKI
Sub-Compact Tractor ***"TXG237"***
Easy to jack up by applying full-open bonnet. A full flat floor with expanded floor space. HST with two pedals. Perfect lever alignment for efficient operation. ▲23ps

ISEKI
Rice Transplanter ***"PZ60-HGRTE18"***
The transplanting part can automatically rise, and rotate with no brake. “Rotating Seedling Case” and “Big Deck” are equipped, and it can handle winding plants seen in many Chinese markets. ▲16hp □Row: 6

■: Dimensions ●: Weight ▲: Engine

KAAZ

Backpack Brush Cutter

"VRS400(S)-TU43"

KAAZ has manufactured brush cutters over 40 years. Our concept is "Made in Japan". ■Shaft: 26mm, Length of main pipe section: 1500mm ●10.6kg ▲2-stroke ▲ 42.7cc □Fuel tank: 0.9L

KOSHIN

"Hidels Pumps SEV-80X"

PUMP □Connection: 80mm □Total Head: 25m □Delivery Volume: 1050L/min □Max. Suction Head: 8m ENGINE ▲3.1kW/3600rpm, 179cc ●7.7kg

KUBOTA

Tractor ***"M9540"***

M9540 is a high performanced M-series tractor which can be operated in dry field including land preparation with high mobility and low fuel consumption. ▲95ps

KARUI

Chipper ***"DraCom KDC-131B"***

Grind the branches in parks, bamboo woods, and fruit farms into useful woodchips and decrease the volume at the same time. ■L1800×W770×H1250 mm ●415kg ▲9.6kW □Max. branch: ø120mm □Processing Capacity: 800-1300kg/h

KOWA

Chipper ***"Green Shredder P-550"***

Best for saving the environment. Spiral blade enables efficient cutting with less sound. ■L1080×W695×H1050mm ●98kg ▲4.9PS/2000rpm □Max. branch: ø40mm □Processing Capacity: $4m^3/h$

KUBOTA

Combine ***"DC-68G"***

Compact body & High-performance fulfills rigid professional demands. DC-68G Combine offers superb performance, outstanding durability, and ease of servicing.

KAWABE

Trencher for Multi-Crops ***"NF-843"***

By forward movement you can plow to replace surface soil with subsoil. ■L2150×W800×H1090mm ●297kg ▲Water-cooled Diesel 8ps □Tire: 4.00×8AG □4 wheel driving vehicle with same Dia. tires. □Self propelled

KUBOTA

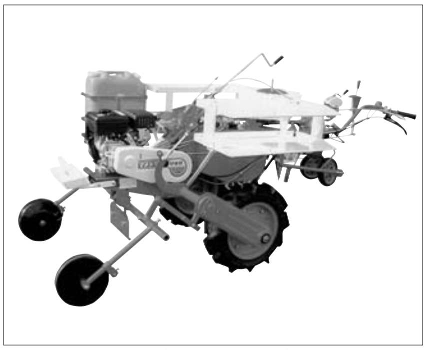
Tractor ***"L4708"***

L4708, is a high perforamnced L-series tractor which can be operated in both paddy and dry field with high horse power and column shuttle specification. ▲47ps

KUCHOFUKU

"Air Conditioning Clothing"

Out-of-door work clothing with air conditioning fan inside. The two fans set on both sides of the waist gets fresh air into the clothing. By evaporating the sweat, vaporization heat would cool down the body and makes agricultural work a comfort one.



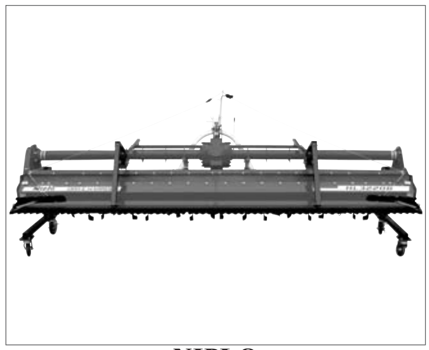
MAMETORA
Vegetable Transplanter ***"TP-4"***
This machine is available both pot and soil block in seeding transplanting. ■L217×W122×H106-130cm ●170kg ▲4.4ps/2000rpm, 126cc □Speed: 0.2-0.4m/s □Efficiency: 10a/1.5-2.0h □Rows: 1

MITSUBISHI
Tractor ***"GCR1350"***
■L4260×W2100×H2640mm ●5300kg ▲4-cycle, Water-cooled diesel 92.8kW/2200rpm, 4398cc □Crawler: W550×L2390mm □HST □PTO: 559, 793, 1040rpm

NEW DELTA
Blower ***"NDBL 6500V"***
High-power engine blower. The original blow-integrated fan case is supported by various users. ■ L355×W457×H457mm ●10.8kg ▲64.7cc □Fuel Tank: 2L □Rotating Speed: 6500rpm □Air Volume: 15.0m^3/min

MARUNAKA
Brush Cutter ***"V282W/TJ45E"***
■L1860×W690×H525mm ▲45.4cc □Driveshaft Housing: ø28mm □Driveshaft: ø8mm □Ergonomic Double Handle □2 stroke □OutPut: 1.4kW

MITSUBISHI
Tractor ***"MT36"***
Cover all aspects of Ground and Lawn care ■W1400×L3190×H2410mm ●1205kg ▲4-cycle, Water-cooled diesel 27ps/2600 rpm, 1662cc □Gear □Speed change: 8F-8R □Rear PTO rpm: 540/1000 □Tires: F7-16 R12.4-24 □Wheelbase: 1750mm □Ground clearance: 330mm



NIPLO
Rotary Harrow ***"HL4020B"***
High durability guaranteed by the double frame structure. Large spring-brake ploughs in the straws and residual stems beautifully. ■ L850×W4150×H1395mm ●575kg ▲70-100ps □Working Width: 391cm □Side drive

MARUYAMA
Boom Sprayer ***"BSA650LDE"***
For crop management in rice paddy and field cultivation. ■L3940×W2150×H2400 /800mm (effective ground height) ●1145kg ▲15.4kW, 1123cc □Discharge Rate: 100L/min □Working Width: 9.9-15.9m

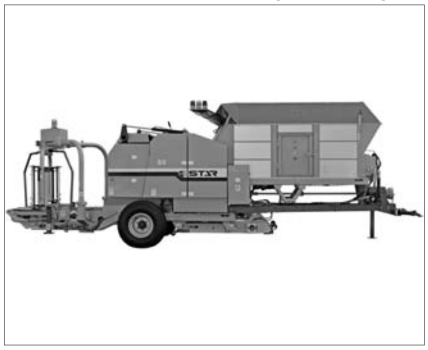
MITSUBISHI
Rice Trans-Planter ***"LV63"***
■L3255×W2000×H1930mm □Ground height: 435mm ●696kg ▲Water cooled 4-cycle, OHC gasoline. 16.0ps/2800 rpm □HST □Rotary type □Rows: 6 □Width of stub: 11/12/14/16/18/21cm

OCHIAI
Riding Type Tea Picking Machine
"OHC-6A"
Full working width cutter bar. Stepless speed control. ▲Water-cooled Diesel engine 28.4ps.

■: Dimensions ●: Weight ▲: Engine

OREC
Dehedral Levee Bush Cutter
"Wing Mower WM624A"
■L1785×W830×H940mm ●61kg ▲4.3 hp □Handle load: 9kg □Speed change: F2, R1 □Driving wheels: F □Working Width: 600×H10-70mm (left roter adjustable in 4 levels) □4 bar knives

SHIBAURA
*Green Mower **"G-EXE"***
The perfect finish for a variety of greens. ■L1100×W970/1055×H1050mm ●78/83kg ▲3.2kW/4,000rpm, 2700cc □Working Width: 557/643.5mm □Mowing speed: 4.3/5.5 □Cut frequency stages: 3.5/4.5/5.1/6.5mm □Off-set moving system (5 settings from 4-12mm)



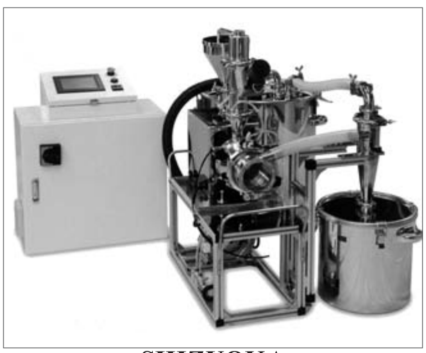
STAR
Storability of Round Baler/Wrapper
"TSW2020"
Combined machine of chopping role baler and bale wrapper, co-developed by BRAIN and Star. ■L870×W235×H270mm ●3920kg □Hopper: 4.5m³ □Wrapping Size: 100×100cm □Suitable Tractors: 37-73.5kW

SANEI
*Poteto Harvester **"MINI·SS-11"***
Works remarkably on slope lands and small plantations!! ■L3800×W2250×H2280mm ●1200kg □Half mounted type □Adaptable Tractors: over 22.5kW (over 30PS) □Discharge Height: 855-2285mm

SHIBAURA
*Reel Mower **"SR525A-S"***
Lightweight Quintupulex. One of the best-in-class lightweight and full fledged, compact and underslung machine. ■L2700×W2900×H2040mm ●1320kg ▲27.9kW/2850rpm, 1662cc □HST □Working Width: 2500mm

SUKIGARA
*ABLE Potato Planter **"TAP-110M"***
Planting, ridging, ground cover laying in one operation.

SATAKE
*Mill **"SRG30A"***
Rice Powder Food Responded Flouring Machine. Able to flour from small amount. ■W1950×D1000×H2896mm □Processing Ability: 30kg/h □Required power: 3-phase 200V 8.55kW



SHIZUOKA
*Mill **"SM150"***
Rice Powder Responded Flouring Machine. Finishes up in a fine powder form by swirling airflow crush system. ■L1010×W830×H700mm ●140kg □Processing Ability: 1-15 kg □Crushing Grain Size: 10-100μm

SUKIGARA
Three-Tine Light Cultivator
■Length: 51cm ●8.5kg □Cultivator width: 18-30cm

■: Dimensions ●: Weight ▲: Engine

SUZUTEC

Seeder for Box Nursery ***"THK2008"***

Full automatic seeding. You can just dial and control the seeding amount by the gram weights. Aluminium rails used to attain lighter bodies.

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Torque Wrench ***"QL"***

The first click-type torque wrench made in Japan, 1956. A global standard structure of tightening a bolt. An alarm tells you the finish of tightening when it reaches the torque you've configured.

YAMAMOTO

Vertical Rice Milling Machine

The rice milled by of the vertical rice milling machine evolves further.
XP-4000 ■W1315×L2282×H2282mm ●2000kg □Required power: 58.2kW □Max capacity: 4.0t/h

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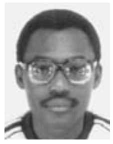
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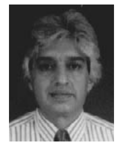
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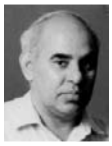
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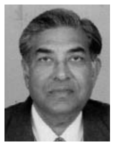
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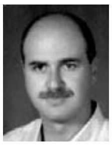
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CHINA WELL-KNOWN BRAND

DFAM

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Changzhou Dongfeng Agricultural Machinery Group Co., Ltd. (DFAM) is among the Top 3 of the tractor manufacturers in China.

Under the brand name of DONGFENG (DF), DFAM produces and sells around 50,000 sets of the Four-wheel Tractor ranging from 20-125 HP and over 100,000 sets of the Walking Tractor/Power Tiller ranging from 6-18 HP. Besides, DFAM also produce the farm implements under the Band Name of TOWNSUNNY. The annual sales is up to USD 310 million in 2010.

Since 1952, with excellent quality and competitive price, DFAM products enjoy very good reputation in the overseas markets and are widely accepted by the farmers of 105 countries and regions all over the world.

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