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EDITORIAL

Last year, Japan has recorded a drastic decline of the country's population by nearly 240 thousand. This is the largest number of decrease in population in a year ever recorded in Japan. What is worse, more than 30 % of the population are elderly people aging more than 60 years.

Today, Japan imports almost all of the feeds for animals, and many other agricultural products. Regarding forestry, since the liberation of forest products trade in 1960's, tons of low cost wooden materials came from abroad, as a result Japanese forest industry suffered a severe damage. Tragically, the average age of laborers to support the Japanese forestry today is over the age of 76 years.

About half of the mountain forests in Japan areartificial and left untouched. More than 80 % of them need to be thinned, but left to become worthless in near future. The root of trees won't grow well due to the high plantation density, therefore after any disasters such as Typhoon strikes, landslide will occur. Even if there are forests on the mountains, their roots are too weak to hold the earth and cannot prevent it from moving.

Japan tried to integrate agriculture and forestry to make a sustainable new industry. As a result, mountainous area agriculture has been established and sustained for a long time. Sadly, as the forest industry collapsed, mountain villages started to disappear and in a matter of course, mountain agriculture is being abandoned.

To meet the demand of 120 million people in Japan, more than 60 % of food in calorie base is imported from abroad. This is causing hunger in many regions outside of Japan. What's more, by looking at a global picture, population is growing vigorously, while the farmlands are decreasing in size. There is a critical issue as to how we can manage to produce enough food for this increasing population around the world.

To save the earth from food crisis, agricultural mechanization is in a definite need, especially in developing countries. As the population continues to grow, we need to work more on precision agriculture.

Milk and grains are sold at a much cheaper price than water; as a result young people are not motivated toward agricultural work. The aging of farmers is a problem which can occur in any country. The authorities should rethink their agricultural policies and creating a balance approach in trading between agricultural products and industrial products.

Human beings today are living their lives by exploiting forest and earth, and the limit is coming just around the corner.

The developments of agricultural mechanization and communication do raise the land productivity, but there is also a new technology to lend a helping hand. It is information technology (IT).

We need improved technological knowledge to work for agricultural sector, but today, many of us can easily get the highly technological information through internet. Every farmer who has a personal computer or a smart phone can access the latest available technology related to their interest. IT is one of the key factor for the bright future of agriculture. Agricultural robots or an automation technology in agriculture shall be called informatization. It is our task how to utilize the development of IT for agricultural mechanization. We should be more active to promote global activities concerning agricultural mechanization and IT.

Yoshisuke Kishida
Chief Editor

April, 2013

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Mechanized System for in-Field Oil Palm Fresh Fruit Bunches Collection-Transportation

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Abstract

A new machine system was developed to overcome the limitations for the in-field collection-transportation of oil palm fresh fruit bunches (FFB) with the commonly used mini tractor-trailer with grabber in the oil palm plantations in Malaysia. This single chassis 50.5 kW universal prime mover was operated at 2,600 rpm and had a 4 wheel dirve and a collection-transportation attachment with a 1,500 kg payload storage bin. The machine system had an output of 2.526 ton/h or 20.213 ton/day on sloping terrain and 2.620 ton/h or 20.965 ton/day on gently undulating terrain. Operating cost reductions were in the range of 10.26 % to 14.44 % per ton or operating cost savings in the range of USD 0.27/ton to USD 0.38/ton over that of the mini tractor-trailer with grabber. Generally, this new machine system offered a good technological solution for in-field collection-transportation of FFB for the oil palm plantation industry in Malaysia.

Introduction

Prompt, careful and efficient evacuation of the oil palm fresh fruit bunches (FFB) from the plantation field to the near mill are extremely important since it determines the quality of the extracted crude palm oil (CPO) from the harvested bunches. All harvested FFB must be evacuated from the plantation field to the near by processing mill in an undamaged condition within 24 hours. Any delay reduces the quality of harvested FFB due to the increase in the free fatty acid (FFA) content in the oil within the bunch (Rankine and Fairhurst, 1998). Consequently, both in-field collection-transportation of the harvested FFB and mill transportation of the evacuated FFB are highly recommended to be mechanized to minimize the delay in processing of harvested FFB and at the same time solve the acute labour problem of the Malaysian oil palm plantation industry.

A number of prototype machines have been developed and tested by various organizations in the effort to promote mechanization for the in-field FFB collection-transportation operation in the oil palm plantation. Currently, the mini tractor-trailer with grabber by PORIM (1992) is the most commonly used machine in the oil palm plantations for the in-field collection-transportation of the cut FFB. Nevertheless, being a two-unit configuration machine system, the maneuverability of the mini tractor-trailer with grabber is very much restricted on less accessible and hilly terrains which are commonly found in most oil palm plantations. Prior to in-field collection-operation operation, the fresh cut fruit bunches are manually picked and thrown close to the machine path by the harvester so that these bunches are within the picking distance of the grabber arm of the mini tractor-trailer in the later operation. Since the grabber unit is located behind the operator seat of the machine system, much discomforting body movements by the operator are required in directing the grabber arm for picking the cut FFB, lifting and directing the grabber arm with the picked FFB to the mini trailer at the rear, placing the picked FBB into the mini trailer, and directing back the grabber arm for the next picking attempt.

Many attempts have been made to develop a single chassis machine in the efforts to overcome the said design limitations of the tractor-trailer with grabber. Jahis and Hitam (1999) developed a single chassis machine "Crabbie" for the purpose of performing in-field FFB collection and transportation operation on the areas planted with short palms. The machine system had two arm units with grapples at both sides for collecting and loading the cut FFB into its storage bin while moving straight and continuously within the machine path. Unfortunately, this machine had difficulty collecting the cut FFB that were not properly prearranged in-line at the machine path since the movements and picking distance of its grapples was limited. Mutasim and Yahya (2001) introduced a single chassis machine with a front picking facility and a scissor lift fruit storage bin for collecting-transporting of the FFB on inland and coastal areas. There was no requirement for prior prearrangement of the cut FFB at the machine path by the harvester in this system. The operator ran the machine to collect the available cut FFB within the machine path and around the palm circle where the cut FFB fell on the ground from the earlier harvesting operation. With the current machine design, visibility in positioning the clamping unit for picking the cut FFB was a problem since the position of the front picking mechanism was not located at the front center of the machine. Furthermore, the clamping unit was not able to grasp the cut FBB if it was lying in the ditch or when the cut FFB was not lying on a flat plantation surface. Based on these reviews of literature, there was not much success in the effort to improve the mechanization for in-field FFB collection-transportation operation.

Ultimately, there was a need to design and develop a new and workable machine system for in-field FFB collection-transportation operation in Malaysian oil palm plantations. The new concepts of the proposed machine system were (1) a single chassis with good operator visibility for picking cut FFB; (2) capability of moving in a random manner within the machine path to collect the cut FFB at the location where they fell; (3) ability to pick cut FFB with varying terrain surface conditions; and (4) direct tipping of the collected FFB into the awaiting lorry at the mainline collection point.

This paper describes a newly developed machine system for in-field FFB collection-transportation operation in Malaysian oil palm plantations. Comparisons on economic analysis of the machine system against the commonly used machine for this operation is also presented.

Material and Methods

Machine System Configuration

The machine system (**Figs. 1** and **2**) consisted of a 4WD universal prime mover running on a 50.5 kW Kubota V-3300 diesel engine with a rated speed of 2,600 rpm. It was equipped with an in-field FFB collection-transportation attachment with a storage bin with a total payload capacity of 1,500 kg. The engine of the prime mover was directly coupled to a Sauer Danfoss Series 40 main pump with a displacement of 46 cm^3/rev- at a continuous pressure of 210 bar. This main pump ran two other units of Eaton Char-Lynn Series 2000 hydraulic motors with displacement of 245 cm^3/rev at continuous pressure of 205 bar in a closed loop system to enable the prime mover to either propel in series or parallel drive modes. An additional open loop hydraulic system was provided to run the respective hydraulic cylinders and motors in the steering system of the prime mover and its machine attachment. The main chassis was equipped with front and rear oscillating axles having a combination of spring and absorber suspension unit on either side to support the 12-16.5 drive tires size.

The configuration of the proposed in-field FFB collection transportation attachment consisted of the clamping jaws, lifting arm, open-

Fig. 1 Design concept of the new machine system for in-field FFB collection-transportation operation

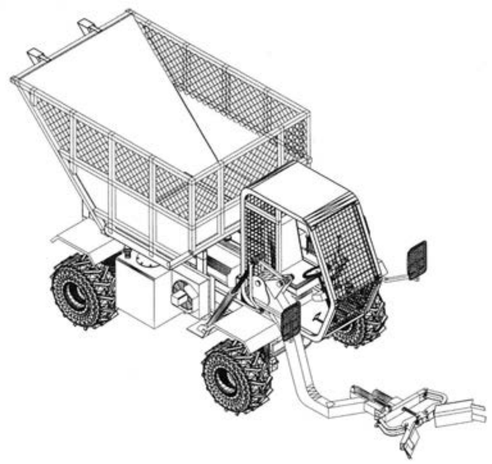


Fig. 2 The developed prototype of new machine system for in-field FFB collection-transportation operation

ing-tilting mechanism unit, storage bin, pivot frame, and associated hydraulic system. The lifting arm, clamping jaws and opening-tilting mechanism unit constituted the picking assembly while the storage bin and its pivot frame constituted the collection assembly (**Fig. 3**). The available hydraulic cylinders on the opening-tilting mechanism permitted the clamping jaws to be wide open at 180 degrees and fully tilted at 45 degrees below the horizon. The collection assembly was made-up of the storage bin and the pivot frame. The bin was trapezoidal in shape with the longest length of 2,560 mm, shortest length of 1,880 mm, width of 1,680 mm and height of 1,735 mm, and capable of accommodating a total capacity of 1,500 kg of cut FFB. The bin was designed with a 45 degree inclined floor at its rear to facilitate easy flowing of the FFB into the collection bin of the mainline transporter during dumping. A special pivot frame made-up of two 45 degree inclined beams with mounting plates and support beams and a pin bracket was located behind the rear inclined floor of the storage bin. The frame was used to provide the mounting support for the storage bin on the prime mover chassis and the fulcrum point for rear tipping of the storage bin. This fulcrum point on the pivot frame was set to be at 2.80 m height from ground level and was mounted on the chassis of the prime mover. It was designed so that, during full tipping position, the rear end of inclined storage bin bottom was slightly above the collection bin of a 6 ton lorry, which was commonly used as the mainline transporter in the oil palm plantations in Malaysia. With the current collection assembly design, all available FFB that were collected in the storage bin could fall directly into the collection bin of the mainline transporter with a single tipping attempt. Tipping action of the storage bin was made possible with the use of a pair of hydraulic cylinders that were mounted underneath the storage bin floor within the pivot frame.

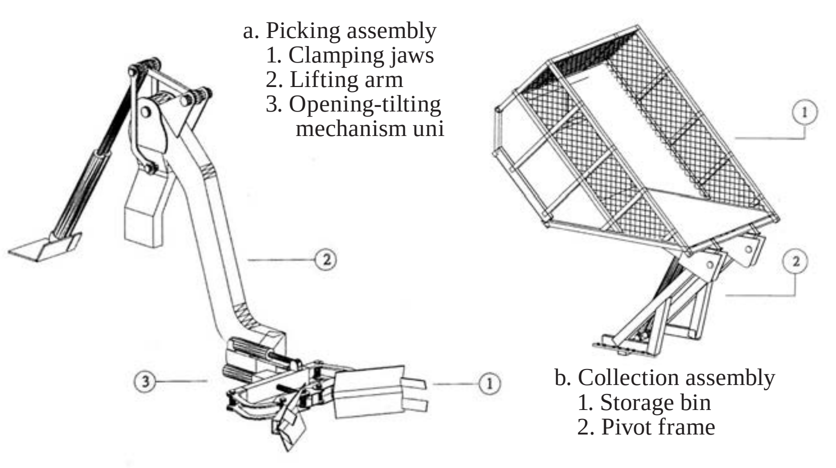
Machine Operation

The whole collection transportation operation involves one operator who acts both as the driver for the prime mover and the operator for the in-field FFB collection-transportation attachment on the prime mover. The driver maneuvers the machine system along the machine path and stops the machine at the various locations of the cut FFB on either side of the plant rows. Upon reaching the cut FFB, he operates the control lever to lower the lifting arm so that the clamping jaws height are within the position of the laying cut FFB on the ground. If the cut FFB happens to be in the ditch or at the location below ground level, he operates the relevant control lever to tilt the clamping jaws to the best clamping position. He operates the other control lever to close the clamping jaws and gently clamp the FFB. He operates the earlier used control lever to raise the lifting arm with clamping jaws on the FFB. With the lifting raised to the top most position, he operates the other earlier used control lever to cause the clamping jaws to be wide-open to release and gravity drop the FFB from behind into the storage bin of the machine system. He then drives the machine system forward to the next cut FFB location and repeats the picking and loading of the cut FFB on to its storage bin. Cornering is made at the headlands before he drives the machine system to enter the next machine path to continue with the in-field collection-transportation operation. When the storage bin has reached its payload capacity, he drives the machine to the road side to dump the storage bin into the available collection bin at the mainline collection point. Finally, with the storage bin empty, he drives back into position to continue the collection operation. He repeats these activities until the collection operation for the whole assigned areas are completed.

Field Performances Evaluation of the Machine System

Field evaluation on the performance of the prime mover with in-field FFB collection-transportation attachment were conducted to determine the average time for the in-field FFB collection transportation operation, machine fuel consumption, machine field capacity, machine total cost and to evaluate

Fig. 3 Design concept of the picking and collection assemblies of the new machine system



the human expenditure and mean increase in heart rate of the operator.

Field evaluations were in June 2008 to July 2009 at the New Labu Oil Palm Estate, Negeri Sembilan. The field evaluations were made on sloping and gently undulating terrain types that were heavily covered by undergrowth. The machine path on both terrain types showed scattered patches of bare surfaces due to the formation of gullies. The headland areas for turnings were narrow with closed to steep slopes. Ant hills were found on several points on the ground surface around the palm trunks. The test area was fully covered with matured palms with a planting density of 127 palms per hectare with planting rows that ranged from 12 to 15 palms per row. The variety of oil palms was Dura × Pisifera with an age that ranged from16 to 23 years on the sloping areas and 11 years on the gently undulating areas.

A detailed time and motion study on the in-field FFB collection-transportation using the new machine system was conducted for 3 days duration under the earlier mentioned terrain types having the test day as the replications. Duncan's Multiple Range Test (Duncan, 1955) was conducted to compare the significant differences on the breakdown of average time for the in-field FFB collection-transportation operation.

The measured parameters in the in-field FFB collection-transportation operations included time for picking the cut FFB, traveling between the cut FFB locations, turning at headlands, traveling from the collection bin at the mainline collection point to the location of the first cut FFB, transporting the collected FFB from the last cut FFB location to the collection bin at the mainline collection point, and dumping the collected FFB into the collection bin at the mainline collection point.

The total time for the in-field FFB collection-transportation operation was calculated as the sum of time spent for picking the available cut FFB along the two planting rows, traveling between cut FFB locations along the two planting rows, cornering at headlands, traveling from the collection bin at the mainline collection point to the location of the first cut FFB, transporting the collected FFB from the last cut FFB location to the collection bin at the mainline collection point, and dumping the collected FFB into the collection bin at the mainline collection point. These tasks were repeated until the in-field collection-transportation operation for whole assigned area was completed.

Measurement of fuel consumption was taken after completion of the in-field FFB collection-transportation operation for each day of operation. The fuel tank of the machine system was filled to its full capacity before the operation commenced. The tank was refilled back to its full capacity after completion of the operation for the day. The volume of fuel being added in liters represented the volume of fuel consumed for the operation. The average fuel consumption of the machine system in unit of liters per hour was computed by dividing the recorded volume of fuel consumed for each day operation with the recorded time operation duration for each day.

The heart rates and total energy expenditure of the operator while performing the in-field FFB collection-transportation operation was recorded using a Polar S810M Heart Rate Monitor (Polar Electro, Oulu, Finland). The machine output of the machine system in terms of ton/h was obtained by multiplying the total number of collected FFB with its average fruit bunch weight and dividing the obtained value by the collection time. The effective field

Table 1 The parameters used in cost analysis of the machine system

Parameters	Prime mover with in-field FFB collection and transportation attachment	Mini tractor- trailer with grabber
Estimated initial cost	USD 18,353.71	USD 18,571.42*
Estimated economic life1	7 years	7 years
Salvage value, Kepner (1982)	10 % of initial purchase	10 % of initial purchase
Tax, shelter and insurance (ASABE, 2006)	2 %	2 %
Interests of investment , Kepner (1982)	10 %	10 %
Factor for repair and maintenance cost (ASABE, 2006)	RF^1 = 0.003 and RF^2 = 2.0	RF^1 = 0.003 and RF^2 = 2.0
Current local diesel market price	USD 0.51/l	USD 0.51/l
Fuel consumptions	3.23 l/ h (sloping) 3.14 l/ h (gently undulating)	3.65 l/ h**
Lubricants cost, Kepner (1982)	15 % of fuel cost	15 % of fuel cost
Estimated total operating hours in a year	2460 hours***	2192 hours***

* Based on the quoted sales price by a local manufacturer
** Based on the published fuel consumption data by Mutasim and Yahya (2001)
*** Based on an average plantation size of 1005 ha and annual total working days of 312 days.

capacity of the machine system, in terms of in ha/day, was obtained by multiplying the earlier obtained machine output with the committed working hours per day and dividing the obtained value by the number of workers involved in the operation.

Economic Analyisis

Analysis was conducted to compare the total costs of the prime mover with in-field FFB collection-transportation attachment against the mini tractor-trailer with grabber for in-field FFB collection and transportation. The mini tractor was normally equipped with a 21 kW engine and operated at 2,200 rpm with a trailer payload of 1 ton for in-field FFB. The following parameters were used in cost analysis of the machine systems as shown in **Table 1**. The effective machine field capacity of 11.92 ha/day that was equivalent to 2.50 ton/h for the mini tractor-trailer with grabber was based on data published by PORIM (1992). In 2008, the market price of USD 18,571.42 for the mini tractor-trailer with grabber was derived from the sum of USD 10,571.42 for the mini tractor, USD 3,714.28 for the grabber unit and USD 4,285.71 for the 1 ton trailer unit.

Results and Discussion

The average machine output for eight committed working hours per day for the in-field FFB collection-transportation operation with the machine system on gently undulating terrain was 2.620 ton/h which was equal to 20.965 ton/day (**Table 2**). An average machine output increment was 3.58 % higher than that of the average machine output of 2.526 ton/h, or equal to 20.213 ton/day on sloping terrain.

There was a slight difference in the machine output with the two different types of terrain, i.e. sloping and slightly undulating, due to the differences in the size and mass of FFB that had to be handled in the two operations. The average mass of the FFB from the area with sloping terrain was 24.5 kg while that from the area with gently undulating terrain was 14 kg. The FFB from the palms planted in the area with gently undulating terrain were lighter since the palms were much younger than the palms on sloping terrain. Picking the small FFB consumed more time than the big FFB because the machine system had to handle more FFB to fill the storage bin to its maximum payload capacity. But the effort and time taken to complete a picking task on either small or big FFB were not much different. The total number of big FFB to the storage bin volume was, obviously, less than that of smaller FFB. Therefore, the accumulated total time taken for picking big FFB to fill the storage bin volume was less as compared to the small FFB.

The machine output for the prime mover with in-field FFB collection-transportation attachment in the operation increased with the days of operations since the machine operator had developed the skill to operate the machine system. The measured machine outputs were very much affected by the terrain conditions, crop yield, harvested FFB sizes, harvested FFB arrangements on the ground, and location of the mainline collection bin. Field with steep sloping terrains and terrains with obstacles such pits, ditches and ant hills slowed the machine operation. These situations caused the duration to complete the involved tasks within the in-field FFB collection-transportation operation to be longer. Harvesting during high yield season, also, increased the machine output since picking of the cut FFB along the machine paths could be straightforwardly done. The total time spent for picking smaller cut FFB was longer than picking bigger cut FFB. Greater bunch numbers must be added to fill the storage bin to its maximum payload when handling small cut FFB. Machine output could be increased with good arrangement of the harvested FFB on ground. Indirectly, with good arrangement, less time would be taken for the machine system to move between the harvested FFB locations along the machine paths. Having good accessibility and spacious area at the collection bin location could help to improve the machine output of the machine system. Under such situations, the time spent for dumping the collected FFB could be reduced since the machine operator could easily maneuver the machine system to the collection bin for dumping task.

There were no significant differences in the mean time of picking the cut FFB, turning at headlands and traveling between FFB loca-

Table 2 Effective machine field capacity of the prime mover with in-field FFB collection transportation attachment

Days operation	Sloping		Gently undulating		Differences of machine output on gentle undulating over slope (%)
	Effective field machine capacity (ton/h)	Effective field machine capacity (ton/day)	Effective field machine capacity (ton/h)	Effective field machine capacity (ton/day)	
1	2.456	19.648	2.599	20.792	
2	2.546	20.368	2.628	21.024	
3	2.578	20.624	2.635	21.080	
Average	2.526	20.213	2.620	20.965	3.72

tions on sloping terrain. Again, there were, also, no significant differences in the mean time of traveling from the collection bin at the mainline collection to the location of the first cut FFB and traveling between the cut FFB locations on gently undulating terrain (**Table 3**). Dumping the collected FFB into the collection bin was the most time consuming task within the in-field FFB collection-transportation operation with the machine system under both terrain conditions. The mean time for dumping the collected FFB into the collection bin at the mainline collection point on gently undulating terrain was about 1.49 times lower than on sloping terrain.

Picking the cut FFB, turning at the headland and traveling between the cut FFB locations were the least time consuming tasks within the in-field FFB collection-transportation operation with the machine system on sloping terrain. Traveling from the collection bin at the mainline collection point to the location of the first cut FFB and traveling between cut FFB locations were the least time consuming tasks within the in-field FFB collection-transportation operation with the machine system on gently undulating terrain.

Mean time for transporting the collected FFB from the last cut FFB to the collection bin at the mainline collection point on gently undulating was about 4.04 times lower than the mean time on sloping terrain. Time for transporting the collected FFB was very much influenced by the location in the field at the instant when the machine system reached its maximum payload capacity. On gently undulating terrain, the machine system at the instant when it had reached its maximum payload capacity was normally located close to the mainline collection point. Such situation occurred since the area on gently undulating terrain had high crop yield which made the machine system do less total traveling distance to fill its storage bin.

Mean time for traveling from the collection bin to the location of the first cut FFB on gently undulating terrain was about 3.02 times lower than the mean time on sloping terrain. Similarly, the time spent for traveling from the collection bin to the location of the first cut FFB was affected by the location of the collection bin and the location of the first cut FFB. The time spent traveling from collection bin to the first cut FFB on gently undulating terrain was faster than the time spent on sloping terrain since the machine system was normally closer to the location of the first cut FFB whenever it commenced a new collection operation due to high crop yield.

Mean time for picking the cut FFB on gently undulating terrain was about 1.33 times greater than the mean time on sloping terrain. The machine operator required extra skill in picking the small FFB on gently undulating terrain. This was because of the tendency to slip from the clamping jaws of the picking assembly with small FFB. When slipping occurred, the operator had to repeat the picking task on the same bunch and this added to the time.

Mean time for turning at the headland on gently undulating terrain was 2.43 times greater than the mean time on slopping terrain. Time spent for turning was very much affected by the terrain conditions in the headland. Turning at the headland on gently undulating terrain consumed longer time since the headland of the area with gently undulating terrain had limited area for the turning. Sometimes, the operator had to reverse the machine system after completing the collection operation for the machine in order to get enough clearance to make the turn within the area between the palms just before the headland.

Mean time for traveling between cut FFB locations on gently undulating terrain was 1.75 times lower that the mean time on sloping terrain. The time spent for traveling between cut FFB locations was very

Table 3 Breakdown of average time in the in-field FFB collection-transportation operation

Task	Sloping	Gently undulating	Sloping[1]		Gently undulating[1]	
	Time range, s	Time range, s	Mean time, s	Propor-tion, %	Mean time, s	Propor-tion, %
Dumping the collected fruit bunches into the collection bin at the mainline collection point	89 to 180	57 to 133	112[a]	88.89[a]	75[a]	49.59[a]
Transporting the collected fresh fruit bunches from the last cut fresh fruit bunch location to the collection bin at the mainline collection point	5 to 300	5 to 62	97[b]	33.68[b]	24[b]	16.18[b]
Traveling from the collection bin at the mainline collection point to the location of the first cut fresh fruit bunch	5 to 120	3 to 23	29[c]	10.07[c]	9[d]	5.59[d]
Picking the cut fresh fruit bunch	9 to 89	9 to 62	15[d]	6.94[d]	20[c]	12.82[c]
Cornering at headlands	9 to 22	7 to 46	16[d]	5.55[d]	20[c]	12.82[c]
Traveling between cut fresh fruit bunch locations	3 to 74	3 to 30	14[d]	4.86[d]	8[d]	5.10[d]

[1]Means in a given column having suffices with the same letters are treated not significantly different at 0.05 probability level

much influenced by the crop yield and the harvested FFB arrangements on the ground. Higher crop yield and better arrangement of the cut FFB on area with gently undulating terrain explained the shorter time spent traveling between cut FFB locations.

The fuel consumption of the machine system operating on slopping terrain was 2.78 % higher than on gently undulating terrain (**Table 4**). **Table 3** shows that the total mean time for the machine system to complete the in-field operation on sloping terrain was 1.83 times greater than on gently undulating terrain. The fuel consumption on slopping terrain was higher because the engine of machine system had to run at higher throttle setting and it took a longer time to complete the operation.

The total cost for in-field FFB collection-transportation operation by the machine system was USD 5.95/h on sloping terrain and USD 5.90/h on gently undulating terrain (**Table 5**). With a known average machine output of 2.526 ton/h on sloping and 2.620 ton/h on gently undulating terrains, the total cost for in-field FFB collection-transportation operation on both the terrains were USD 2.27 ton/h and USD 2.33 ton/h, respectively. Fuel consumption cost showed the highest percentage cost breakdown with a value of 27.88 % on sloping and 27.35 % on gently undulating terrains of the total operation cost. Tax, shelter and insurance cost showed the lowest percentage cost with a value of 2.50 % for sloping and 2.52 % for gently undulating terrains.

An operating cost reduction of 10.26 % to 14.44 % per ton or cost savings in the range of USD 0.27/ton to USD 0.38/ton were obtained for the in-field FFB collection-transportation operation with the prime mover over the mini tractor-trailer with grabber (**Table 6**). The mini tractor was normally equipped with a 21 kW engine with a rated speed of 2,200 rpm and trailer payload of 1 ton. Slightly higher average machine output of 1.03 % to 4.58 % and slightly lower initial cost of 1.17 % for the prime mover with in-field FFB collection-transportation attachment over that of the mini tractor-trailer with grabber explained the lower operating cost and greater cost savings.

There were no significant differences in the mean increase in heart rate and human energy expenditure of the machine operator, and the field capacity of the in-field FFB collection-transportation operations on the two tested terrains (**Table 7**). According to Christensen (1953), any work on the basis of the measured human energy expenditure could be categorized as unduly heavy operation (greater than 12.5 kcal/min/man), very heavy operation (10.0 to 12.5 kcal/min/man), heavy operation (7.5 to 10.0 kcal/min/man), moderate operation (5.0 to 7.5 kcal/min/man), light operation (0.5 to 5 kcal/min/man), and very light operation (less than 0.5 kcal/min/man), Thus, involved work

Table 4 Fuel consumptions of the machine system in the in-field FFB collection-transportation operation

Day	Fuel consumptions (l/h)	
	Sloping	Gently undulating
1	3.13	3.07
4	3.25	3.18
5	3.31	3.25
Average	3.23	3.14

Table 5 Costs breakdown for in-field FFB collection-transportation operation

Cost component	Sloping		Gently undulating		Rank based on the highest cost
	Cost	Percent. from total cost, %	Cost	Percent. from total cost, %	
Depreciation cost, USD/h	0.67	11.28	0.67	11.37	4
Interest on investment cost, USD/h	0.41	6.91	1.41	6.97	5
Tax, shelter and insurance cost, /h	0.15	2.50	0.15	2.52	7
Repair and maintenance cost, USD/h)	1.35	22.74	1.35	22.94	3
Fuel consumption cost, USD/h	1.66	27.88	1.61	27.35	1
Lubricants cost, USD/h	0.25	4.17	0.25	4.11	6
Operators cost, USD/h	1.46	24.52	1.46	24.73	2
Total, USD/h	5.95	100	5.90	100	

Table 6 Comparisons on cost and average machine output between the prime mover with in-field FFB collection-transportation attachment and mini tractor-trailer with grabber

Parameter	Prime mover with in-field FFB collection-transportation attachment		Mini tractor-trailer with grabber	Differences	
	Sloping	Gently undulating		I*	II**
Average machine output (ton/h)	2.526	2.620	2.50	1.01 times	1.05 times
Cost (USD/ton)	2.36	2.25	2.63	− 10.26 %	− 14.44 %

*Comparisons between prime mover with in-field FFB collection transportation attachment against the 21 kW mini tractor-trailer with grabber on sloping terrain
**Comparisons between prime mover with in-field FFB collection-transportation attachment against the mini tractor-trailer with grabber on gently undulating terrain

with this machine system could be categorized as moderate operation since the average human energy expenditure was only 5.64 kcal/min/man. From both the field observation and comments from the machine operator, the operator comfort in conduction the operation could be further improved if the present power steering system on the machine system could be modified using a bigger steering wheel diameter and the operator compartment could be insulated from the engine heat. With these suggested provisions to improve the operator comfort with the machine system, the human energy expenditure of the operator would expect to be further reduced from 5.64 kcal/min/man.

Conclusions

A new machine system for in-field FFB collection-transportation operation in the oil palm plantation in Malaysia has been successfully designed and evaluated. The average effective machine capacity of this mechanized system on sloping and gently undulating terrain was 0.78 times and 0.81 times higher over the mini tractor-trailer with grabber. An operating cost reduction in the range of 10.26 % to 14.44 % per ton or cost savings in the range of USD 0.27/ton to USD 0.38/ton were obtained with new system. This new mechanized system presents great promise to overcome the problems with the usage of tractor-trailer with grabber for the in-field FFB collection-transportation operation in the palm plantations in Malaysia. Overwhelmingly, the machine system had showed an enormous potential to be introduced to the oil palm plantation in the efforts to reduce the high dependency on workforce for the in-field FFB collection-transportation operation.

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■■

Table 7 Field capacity, mean increase in heart rate, human energy expenditure individual operation with the machine system

Field operation	Field capacity ha/h/man	Mean increase in heart rate, beat/min	Human energy expenditure, kcal/min/man
In-field FFB collection-transportation on sloping terrain	1.68[a]	18[a]	5.67[a]
In-field FFB collection-transportation on gently undulating terrain	1.77[a]	17[a]	5.61[a]

Means in a given column having suffices with the same letters are treated not significantly different at 0.05 probability level

Effects of Tillage on Soil Moisture Content, Okra (*Abelmosehus Esculentus*) Emergence and Yields

by
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Abstract

The effects of primary, secondary, conventional and ridge tillage operations on soil moisture, okra (Abelmosehus esculentus) emergence and yields were determined for sandy loam soil of Port Harcourt, Nigeria ecological zone, for a period of one growing season. Two depths, 0-150 and 150-300 mm were used in the experiment to test and analyze the effects of tillage on soil moisture content, okra emergence and yields. The data obtained were analyzed statistically using ANOVA and regression analysis. The moisture content in primary tillage was 9.62 % (w/w), secondary tillage 10.12 % (w/w), conventional tillage 8.96 % (w/w) and ridging 8.21 % (w/w) the least. The highest okra emergence rate of 6.88 was obtained with the conventional tillage, while 3.66, 4.66 and 2.11 emergence rates were obtained with ploughed, ploughed + harrowed and ridging practices, respectively. Okra percentage emergence obtained from the various tillage methods were 58.89 %, 75.55 %, 98.88 % and 92.44 % for ploughing, ploughing + harrowing, ploughing + harrowing + harrowing and ridging operations, respectively. The best tillage treatment for okra was achieved using conventional tillage which gave the highest okra yields of 9.45kg/ha. This research becomes important because it depicts the best tillage method for high profit making in okra production.

Introduction

Okra, (Abelmosehus esculentus) is an important vegetable crop grown by peasant farmers in Nigeria. According to Clemson (2006), okra is a warm season crop grown in home gardens. The immature leaves and fruits are rich sources of vitamins and minerals and are eaten in various forms.

Tillage aims to create a soil environment favorable to plant growth (Nail *et al*., 2007). They defined tillage as any physical loosening of the soil carried out in a range of cultivation operations, by manual or mechanized operations. Soil tillage is the mechanical manipulation of soil to develop a desirable soil structure for a seedbed and a specific surface configuration for planting, irrigation, drainage and harvesting operations (Nkakini *et al*., 2008, Aluko and Lasisi, 2009). Tillage influences crop growth and yields, changes soil structure and moisture removal patterns over the growing season. Tillage systems impacts soil moisture status because it influences infiltration, runoff, evaporation, and soil water storage. Tillage methods affect the sustainable use of soil resources through its influence on soil properties (Hammel, 1989). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes. Excessive and unnecessary tillage operations are often harmful to soil. (Lal, 1993). Rashidi and Keshavazpour (2007) stated that soil tillage is among the important factors affecting soil physical properties and crop yields. Among the crop production factors, tillage operations contribute up to 20 % (Khurshid *et al*., 2006). Conventional tillage practices modify soil structure by changing its physical properties, one of which is soil moisture content. This has some effects on soil physical properties and okra yield. Tillage is the fundamental practice in farming and plays an important role in crop production as it creates optimum soil environmental conditions for crop growth and yield (Nkakini, 2004).

Early land preparation is an important step in crop production. Soil turning creates a favourable condition for decomposition of crop residue before okra is planted. However, it also encourages weed growth which adversely affects crop production. The effects of different tillage methods on soil properties and crop yield is still a problem under consideration. Prior to this time a wide range of tillage methods were used in Nigeria without evaluating their effects on soil physical properties and crop yields.

Therefore, there is a need to study the specific problems of soil treatment and crop production by evaluating tillage effects on soil properties. Thus, attention needs to be paid to the specific crop, soil type, moisture content and climatic factors involved in tillage research. With these results, the specific tillage and soil type, moisture content, time and climactic conditions for okra cultivation becomes clearer. Application of appropriate tillage methods would improve okra performance and production and reduce economic waste. Okra would be a profitable crop when suitable recommended practices are followed.

The main objective of this research was to ascertain different tillage system effects on soil moisture content and okra yield and to recommend the most suitable tillage type of seedbed preparation for okra production.

Materials and Methods

Description of the Study Area

This research was conducted at the School Experimental Farm of the Rivers State University of Science and Technology Port Harcourt Nigeria, Lat. 0.50 01' N, Long. 0.60 57 E, Alt. 274 mm. The location has well drained soil classified as sandy loam using the textural triangle.

Experimental Field Design and Treatments Applications

The land area was 16 m by 22 m using a randomized complete block design (RCBD). The site was cleared manually, followed by stumping. The land was divided into 12 relative plots of 4 m by 4 m. A headland of 10 m served as the turning space as well as the implement hitching point. The plots were 2 m apart. Initial preparation of the plots had an average depth of 200 mm using disc plough and disc harrow.

The tillage treatments were designated as T_1 (ploughing), T_2 (ploughing + harrowing), T_3 (ploughing + harrowing + harrowing) and T_4 (ridging operation) in a randomized complete block design (RCBD) with three replications.

Planting Materials

Among the several varieties of okra: (Emerald, that has a round shape and matures in 57 days; Dwarf green long pod, that has a star shape and matures in 52 days; Annie Oakley (Hybrid), that has a star shape and matures in 57 days; U.G.A. red star, that has a star shape and matures in 58 days; Louisiana green, that has a round shape and matures in 58 days; Clemson spineless No. 80, that has a star shape and matures in 60 days; V-35, that has a round shape and matures in 35 days), V-35 was chosen for this work because of its early maturity and late planting requirement. Planting was done in May, 2008 during the wet season. The seeds were soaked in a container for 24 hrs before planting to decrease germination time. The okra seeds were planted at a spacing of 1,000 mm between rows and 500 mm within rows with 3 seeds per hole. Seeds that did not germinate and those that looked scotched after planting were replaced. Seeds were thinned to two plants per stand according to recommended agronomic practices. Weeding was done one week and also three weeks after planting. Cultivation and an organic mulch layer of 54 mm to 77 mm were used to control weeds, conserve soil moisture and prevent damage to roots of the crop. These processes were done manually.

Measurement of Soil Moisture Content

Soil samples were taken randomly from each of the plots at various locations. The data collected from the samples were analyzed using conventional laboratory methods. A shovel was used to collect samples at depths of 0-150 mm and 150-300 mm and were put in polythene bags and taken to the laboratory for soil moisture analysis. The soil samples were collected in one day for accuracy in their results.

Plant Parameters

Seed emergence rates were taken on each of the plots, in randomized blocks with three replications, five days after planting, starting from June 1 to 5, 2008. This was done by counting the number of plants in the areas of the plots after seedling. The total number of okra seeds planted per treatment plot was 90 stands of V-35. Two weeks after complete emergence (on June 21, 2008) the height of the plants and the number of leaves were taken. And after another two weeks (on of July 5, 2008) plant height and number of leaves were taken again. The number of flowers per plot was monitored with plant flowering beginning on July 25, 2008 and the final flowering on August 30, 2008. Yields were measured in three replications.

Data Analysis

Moisture content

The moisture content of soil was obtained using **Eqn. 1**.

$M_C = M_w / M_T \times 100\ \%$ .... (1)

where

M_w = moisture mass

M_T = total mass

M_c = moisture content

The average of all measured parameters were analyzed using analysis of variance (ANOVA) and simple mean statistical methods.

Percentage emergence rata of okra was obtained using **Eqn. 2**.

Percentage emergence = (*Average Emergence / No. of seed* *planted) × 100*......................(2)

Linear regression was obtained using **Eqn. 3**.

Linear regression analysis,

$Y = a + bx$................................(3)

Coefficient of correlation was obtained using **Eqn. 4**.

Coefficient of correlation,

$$r = \frac{xy}{\sqrt{\sum x^2 - \sum y^2}} \qquad (4)$$

Results and Discussion

In accordance with the result from the sieve analysis, the textural triangle reading showed that the soil in which this research was conducted was a sandy loam soil with composition of 71 % sand, 8.47 % silt and 17.94 % clay.

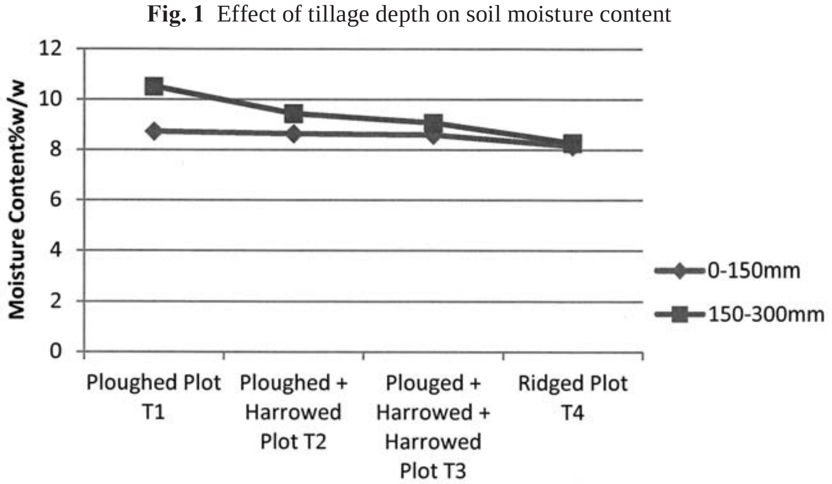
Soil Physical Properties

Moisture Content

The soil moisture content was significantly lower in ridged plots than in other tillage treatments. The values of moisture content were higher in ploughed + harrowed plots than ploughed plot and ploughed + harrowed + harrowed plots. Ploughed plots had the highest moisture content at 100-300 mm, while ridged plot had the least amount of moisture content at both depths. This agreed with the result of Nkakini *et al.* (2008) which showed that moisture content was higher in ploughed plot than in the no-tillage plot. The finding was a result of better infiltration rates and increased water holding capacity due to larger pore spaces in tilled plots. Rydberg (1990) stated that no-tillage reduced the rate of evaporation, mainly by reducing slaking of the surface. Ojeniyi and Dexter (1979) observed that during tillage operations mean soil particle size was reduced as a result of fragmentation and sorted soil particles. However, since sorting also created an evaporation control layer to the depth of tillage, moisture content below tillage depth could be higher than no-till treatment. The trend of soil moisture content to various tillage operations and its mean values for the four tillage treatments at different tillage depths (0-150, 150-300 mm) are shown in **Fig. 1**.

In **Fig. 1**, ploughed plots recorded a relatively high level of soil moisture of 8.73 % (w/w) and 10.51 % (w/w) at depths of 0-150 mm and 150-300 mm, respectively. This was followed by the ploughed + harrowed plots, which had soil moisture contents of 8.64 % (w/w) and 9.44 % (w/w) at the same depths. Ploughed + harrowed + harrowed plots recorded soil moisture contents of 8.59 % (w/w) and 9.07 % (w/w) at depths of 0-150 mm and 150-300 mm, respectively. The ridged plots had the lowest level of soil moisture contents of 8.14 % (w/w) and 8.27 % (w/w), also at the same respective depths. This was similar to the findings of Maze and Atkins (1992), which stated that, at a tillage depth of 102 mm, soil moisture content was more than on plots tilled to a depth of zero or 51 mm. A relationship between soil moisture and tillage depth appeared to exist. The deeper the tillage, the greater the moisture content. They further stated that the plots that were not tilled gained soil moisture, while those tilled to depths of 51 mm and 102 mm lost 0.2 and 1.0 percent moisture content, respectively. These results indicated tilled plots lost more moisture than plots which were not tilled following the fact that no till plots appeared to retain more moisture than tilled plots. According to the findings of Nwagu and Oluka (2006), conventional tillage systems emphasized very fine tilt resulting in loss of moisture content in soil. Similar to the results of Nkakini *et al.* (2008) moisture content for no-tillage, ploughed, and ploughed + harrow tillage operations were higher at the tillage depth of 100-150 mm than those at 0-50 mm and 50-100 mm depths. Oparanadi (1993) observed that the total moisture retention, saturated and unsaturated hydraulic conductivity and the maximum water storage capacity increased under no-tillage with mulch. Various tillage systems affected soil moisture content status because tillage influenced infiltration, run-off, evaporation and soil water storage (Unger and Cassel, 1991; Unger and Fulton, 1989). In addition to soil moisture changes, tillage may affect other soil physical and chemical properties.

Fig. 1 Effect of tillage depth on soil moisture content



With tillage practices, weeds that compete with crops for moisture are mechanically removed. They could also promote drought stress through low residue cover, increased runoff, and reduced water infiltration.

Table 1 shows analysis of variance effect of moisture content at different tillage depths. The

Table 1 ANOVA effect of moisture content (% w/w) at different tillage depths (0-150 mm, 150-300 mm)

Sources of variance (S.V)	d_f n^{-1}	SS	$M_{S\ (ss/df)}$	F_{calF}	Table F Ftab (0.05)
Total variation (n^{-1}) 8	7	6.64	0.95	1.53	
Total treatment 4	3	4.12	1.37	2.21	6.94 NS
Depth 2	1	9.16	6.53	9.15	6.94 SS
Block 3	2	0.03	0.03	0.05	6.94 NS
Error (total variance-treatment + depth) d_f	3	2.49	0.62	1.00	

NS: Not significant ($p \leq 0.05$) SS: Significant difference ($p \leq 0.05$)

Table 2 Mean emergence, emergence rate and percentage in various tillage treatments

Tillage operations	Days and number of seeds emergence							
	1st 01/06/08	2nd 02/06/08	3rd 03/06/08	4th 04/06/08	5th 05/06/08	Mean Emergence	Emergence rate	% Emergence
Ploughed plot	47	62	76	80	80	53	3.66	58.89
Ploughed + Harrowed plot	42	61	71	82	84	68	4.66	75.55
Ploughed + Harrowed + Harrowed plot	52	75	98	106	114	89	6.88	98.88
Ridging plot	71	80	86	89	90	83	2.11	92.44

analysis showed that there were no significant differences at ($p \leq 0.05$) in moisture content among the treatment plots, but a significant difference at ($p \leq 0.05$) in various plots depths. This agreed with the findings of Chaplin *et al.* (1986), Ojeniyi and Dexter (1979b) and Nkakini *et al.* (2008) who reported significant differences on soil moisture content of tillage systems. The results agree with that of Kanwar (1989) who reported that tillage systems affected soil-water tensions in the surface layer of soil in the second year of a two-year study. However, there were no significant differences at the 5 % level in the first year of the study. Again, similar to this result was that of Changa and Lindwall (1990) who found that soil physical properties at a depth of 0-30 mm and 90-120 mm (below the tillage zone) were not significantly different among tillage and crop rotation treatment. Kanwar (1989) confirmed this when he stated that most experiments on tillage relations to soil moisture were neither consistent nor show significant differences among different tillage practices. Further in his findings, he reported that a no-till system of tillage tended to show more soil-water storage in the soil profile but no significant statistical difference between the tillage systems on the basis of two years of his field data.

Table 2 shows that the emergence rate obtained was 3.66 in ploughed, 4.66 in ploughed + harrowed, 6.88 in ploughed + harrowed + harrowed and 2.11 in ridged plot. The percentage emergence of 58.89, 75.55, 98.88 and 92.44 was for ploughed, ploughed + harrowed, ploughed + harrowed + harrowed and ridging operations, respectively. This is represented graphically in **Fig. 2**.

Fig. 2 shows that conventional tillage (ploughed + harrowed + harrowed) resulted in the highest percentage seeding emergence of 98.88

Fig. 2 Average emmergence rate of okra at different tillage operations

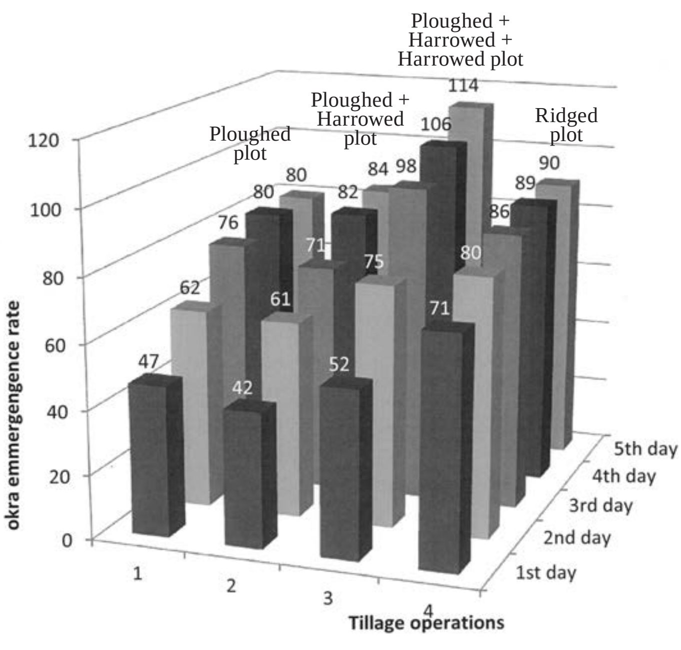


Table 3 Response of okra plant height at different tillage treatment plots (mm)

Period of collection (two weeks interval)	Ploughed plot	Ploughed + Harrowed plot	Ploughed + Harrowed + Harrowed plot	Ridged plot
21/06/08	51.3	41.3	41.7	40.7
5/07/08	70.0	66.7	51.7	53.0
19/07/08	126.7	150.0	106.7	63.3

Table 4 ANOVA effect of plant height

Sources of variance(s.v)	d_f $^{n-1}$ (n^{-1})	SS	M_S (ss / d_f)	Cal_f	$Table_f$
Total variance 12	11	144.30	13.12	4.13	
Total treatment 4	3	21.73	7.24	2.28	6.94NS
Depth 2	1	100.31	100.31	31.54	6.94Ss
Block 3	2	0.03	0.03	0.05	6.94NS
Error total variance −(treatment −depth) (df)	7	22.26	3.18	1.00	

NS: Not significant difference ($p \leq 0.05$) SS: Significant difference ($p \leq 0.05$)

Table 5 Okra plant leaf count at different periods of growth

Period of collection (two weeks interval)	Ploughed Plot	Ploughed + Harrowed plot	Ploughed + Harrowed + Harrowed plot	Ridged plot	Block total
	4.00	4.00	4.00	5.00	
21/06/08	4.00	3.00	3.00	3.00	
	5.00	6.00	5.00	5.00	
Mean	4.33	4.33	4.00	4.44	16.99
	4.00	5.00	8.00	5.00	
5/07/08	7.00	6.00	5.00	6.00	
	5.00	6.00	5.00	5.00	
Mean	5.33	5.67	6.00	5.33	22.33
	5.00	6.00	8.00	8.00	
19/07/08	7.00	6.00	5.00	9.00	
	6.00	6.00	5.00	6.00	
Mean	6.00	6.00	6.00	7.67	25.67
Mean total	5.00	5.00	5.00	6.00	21.66

Table 6 ANOVA effect of okra plant leaf count

Sources of variance (S.V)	d_f n^{-1}	SS	$M_{S\,(ss/df)}$	F_{calF}	Table F Ftab (0.05)
Total variance 12	11	12.07	1.10	3.93	
Total treatment 4	3	0.54	0.18	0.64	6.94NS
Depth 2	1	9.58	9.58	34.21	6.94Ss
Block 3	2	0.03	0.03	0.05	6.94NS
Error total variance-(treatment - depth) (df)	7	1.95	0.28	1.00	

NS: No significant difference ($p \leq 0.05$) SS: Significant difference ($p \geq 0.05$)

%, followed by the ridged (92.44 %), ploughed + harrowed (75.55 %) and ploughed plot that recorded the least emergence of 58.89 % after five days. Generally, the highest emergence was recorded in the conventional tillage treatments (ploughed + harrowed + harrowed) while the lowest emergence was recorded on the ploughed plot treatment after the same number of days. The result was similar to the finding of Nkakini *et al.* (2008), which was as a result of soil pulverization offering little or no structional impendence to seedling emergence. According to Nwagu and Oluka (2006) no-tillage, when compared to other types of tillage operations, had the potential of reducing the free flow of air and water into and within the soil profile. The same thing was applicable to the ploughed operation, which agreed with this research result. The result also agreed with the findings of Adamu *et al.* (2004), confirming conventional tillage resulting in the highest seedling emergence of 82.5 % in comparison with the lowest of 61.6 % recorded with no-tillage. When crop emergence was compared to experimental factors, no relationship was apparent. Precipitation on the plot was suspected to be the main factor influencing no significant difference in emergence as was also alluded to by Maze and Alkins (1992).

Table 3 shows okra growth measured as plant height was affected by different tillage treatments. Ridged plot had lower plant height than the ploughed + harrowed + harrowed plot. This might be due to the rate of infiltration and moisture retention in these tillage treatments.

Table 4 showed no significant difference in height of plant among the treatment plots but a significant difference in height of plant among the depth in the plots. The plant under ploughed plot, and ploughed + harrowed plot were not significantly different in their growth at ($p \leq 0.05$). According to Adamu *et al.* (2004) the result of the effect of tillage on plant height for soybean was significantly higher with no-tillage than disc ploughing and conventional treatments. This could be attributed to the beneficial effect of the plant residue left on the soil surface in the no-tillage treatment.

Table 5 shows that the highest leaf counts of 6 and was obtained from ridged plot, while 5, 5 and 5 from ploughed + harrowed and ploughed + harrowed + harrowed plots, respectively, indicating not

Table 7 Mean effect of different tillage treatments on okra yields

Treatments	Number of plant per plot	Number of fruits per plant	Fruit length, mm	Fruit diameter, mm	Fu Fruit weight, kg	Mean values, kg/ha
Ploughed plot, T_1	22.52	3.40	52.8	27.2	0.94	21.37
Ploughed + harrowed plot, T_2	27.24	4.35	61.7	30.0	1.05	24.86
Ploughed + harrowed + harrowed plot, T_3	30.26	5.27	68.2	31.5	1.76	27.39
Ridged plot, T_4	19.12	3.04	53.7	22.8	0.84	19.9

Table 8 Regression Analysis of various treatments on plant yields

Treatments	a	b	r	Y kg/ha
Ploughed plot, T_1	3.43	0.17	0.82	4.53
Ploughed + harrowed plot, T_2	4.88	0.04	0.87	7.50
Ploughed + harrowed + harrowed plot, T_3	5.97	0.23	0.96	17.69
Ridged plot, T_4	2.77	0.20	0.80	4.77

much difference.

Table 6 shows no significant difference in the number of leaves per plant among treatments and block plots but a significant difference in the number of leaves per plant among the depths. This significant effect in depth was due to moisture retention capacity that increased as depth increased.

Table 7 shows that the conventional treatment plot had the highest okra yield of 27.39 kg/ha in all ramifications as the best treatment for okra production. The ridged treatment plot had the lowest yield of 19.9 kg/ha. In ploughed plot and ploughed + harrowed plot, yields of 21.37 kg/ha and 24.86 kg/ha were obtained, respectively. These results were in agreement with those of Khan *et al.* (2001) and Rashidi and Keshavarzpour (2007) who concluded that conventional tillage method produced a favorable environment for crop growth, nutrient use and crop yield. Nkakini *et al.* (2008) concluded that emergence rate of okra was favoured by conventional tillage for profitable okra production in comparison with others. Rashidi and Keshavarzpour (2007) studied the effect of different tillage practices on the salient component of watermelon (citrullus vulgaris) yield, such as number of plants per hectare, number of fruits per plant, fruit weight, fruit length, fruit diameter, total soluble solids, root length, and dry matter and reported that the highest crop yield of 24.11 t/ha was obtained with the conventional treatment and lowest of 12.26 t/ha was in no-till treatment. According to Lindwall (1984) moisture was usually the limiting crop yield factor. The findings of Silvio *et al.* (2005) stated that the greatest maize yield of 7.78 mg ha^{-1} was achieved with conventional tillage and differences with other tillage operations were not significant. Borin and Sartori (1995) reported that among the tillage operations in maize growing the highest yield was obtained with the conventional tillage. Maurya (1988) also reported that lower maize grain yield was achieved with no-till treatment as compared to conventional tillage.

Table 8 shows a positive value of 0.17 for the coefficient (b) and 0.82 for the coefficient of correlation (r). This indicated a direct correlation between plant height and number of leaves per plant, meaning that height of plant increased with increase in the number of leaves per plant in T_1, ploughed treatment plot. The same was applicable in T_2, ploughed + harrowed treatment plot, T_3, ploughed + harrowed + harrowed treatment plot and T_4, ridged treatment plot; b having positive values of 0.04, 0.23, and 0.20 and coefficients correlations of (r) = 0.87, 0.96 and 0.80, respectively. All of these had direct correlation relationships between plant height and number of leaves per plant. This indicated that the increase in height of plant corresponded with an increase in the number of leaves per plant with time. The T_3, ploughed + harrowed + harrowed treatment plot had the highest yield of 17.69 kg/ha and T_1, ploughed treatment plot had the lowest yield of 4.53 kg/ha.

Conclusions

This research study evaluated the effect of ploughing, ploughing + harrowing, ploughing + harrowing + harrowing, and ridging treatments on soil moisture properties and yield performance of okra. Soil moisture content was studied to determine the effect of different tillage operations on soil moisture and okra performance. Soil moisture was, also, analyzed with respect to tillage depth (0-150 mm and 150-300 mm), which showed a loss of 0.2 and 0.1 percent moisture content, respectively. The different tillage treatments were significantly different with respect to soil moisture content. In addition to soil moisture changes, tillage affected other soil physical properties. Average emergence rate in various tillage treatments was in favour of ploughed + harrow + harrow treatment plot (conventional tillage). The lowest was the ploughed treatment plot.

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Conceptual Design of a Semi Automatic on-Farm Fruit and Vegetable Washer

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Abstract

Cleaning and grading of agricultural products at the farm level improve their marketability. Even simple washing to remove foreign materials and other adhering soil particles will make a significant impact in price. Generally farmers in developing countries tend to transport the product immediately after harvest from farm to market without any postharvest operation. A washer with optimum cost, minimum operational supervision, portability and suitability for a variety of products would be highly beneficial to the small and medium scale farmers in developing countries. The objective of this study was to design and develop an on farm fruit and vegetable washer. A semi-automatic fruit and vegetable washer was designed in Auto CAD and fabricated with three major units: washing, brushing and drying. The developed unit could be moved to any place near a water source on the farm. The clearance between the nylon bristle brushes, the drying temperature and time can be controlled based on the nature of product.

Introduction

In developing countries most of the farmers transport fruits and vegetables immediately to market without any postharvest operation. Traders/merchants procure the products from the farmers and conduct some primary cleaning and grading at their handling centers to add value to the products. In addition to field debris, soil and latex from the crop stick to some of the fruits and vegetables and cause unhealthy appearance. Cleaning the debris, soil and latex are very important for hygienic conditions, good health and better economic returns. It also eases the cleaning operation in a food processing plant before processing.

Various types of commercial washers are available for commodities such as apples, potatoes, carrots, leafy vegetables, root vegetables and corn. These include brush washers, reel washers, pressure washers, hydro air agitation wash tanks, immersion pipeline washers, and so on. Geyer (1999) stated that several washing machines with different principles are used for vegetable washing with varying sensitivities. Sapers (2001) conducted experiments on commercial type produce washing and sanitizing equipment to reduce bacterial populations on fresh and minimally processed fruits and vegetables. However, it was realized that conventional washing technology was developed primarily to remove soil from produce, not microorganisms. Le-Bohec (1993) and Moos *et al.* (2002) stated that conventional washing methods for carrots, consisting of rotary washing systems in which carrots were not immersed, tended to damage carrots, so improvements developed by industry included washing on a horizontal plane or washing by immersion in a rotary system. Mendenhall *et al.* (1988) and Moos *et al.* (2002) discussed several approaches to vegetable washing with concepts similar to the washing action of common commercial machines. However, for a horizontal, rotating drum in which the vegetables would be partially submerged, incomplete cleaning for nonspherical vegetables such as carrots was expected. Monroe and O' Brien (1983) stated that the design did not consider additional processes during washing such as disinfection via the addition of chemicals, hydro cooling, and treatments for ripening, appearance and preservation. Stark (2000) developed a new commercial cylindrical carrot washer. The diameter of the washer was 0.9 m with a length of 5 m. It had a full length spray bar, used four rollers with 600 kg capacity each, operated at 12 to 13 rpm, and required a 7.5 kW motor.

Even though, several models of fruit and vegetable washers are available in the market, a washer with optimum cost, minimum operational supervision, portability and suitability for a variety of products, would be highly beneficial to the small and medium scale farmers in developing countries. The objective of this study was to design and develop a semi-automatic on farm fruit and vegetable washer.

Materials and Methods

The factors to be considered for the design of a fruit and vegetable washer included all sample sizes, a low operating speed to prevent bruising and breakages, low water pressure and flow rates, retention of small pieces, ease of sample loading and unloading, time and cost savings compared with manual washing systems, and operator safety (Moos, 2002).

Conceptual Design

The conceptual design of the proposed fruit and vegetable washer was based on the following three principles:

Washing:

For a thorough cleaning, the fruits and vegetables must be dumped into a pool of water where they can be cleaned by a single worker. During this process the unhealthy and unsized fruits and vegetables can be discarded from the lot. This manual cleaning and grading helps to achieve a uniform product at the end of cleaning and immersion in water tends to clean the loosely bound debris from the surface.

Brushing:

To further wipe of the sticking latex or soil, other debris from the surface of the fruits and vegetables requires a rubbing action. A set of nylon bristle brushes may provide this rubbing action for effective cleaning. A jet of high pressure water may also enhance the cleaning of latex and soil from the surface. Experiments with spray jets for low —pressure cleaning have been carried out by Kaye *et al.* (1995), Rose (1997) and Sawamura and Kanazawa (2001).

Drying:

After thorough cleaning, the water sticking onto the fruits and vegetables must be dried off for safe storage or marketing. High temperature air will assist drying of the fruits or vegetables in the post cleaning process. In general, with only two workers, the proposed fruit and vegetable washers can effectively be used for thorough cleaning.

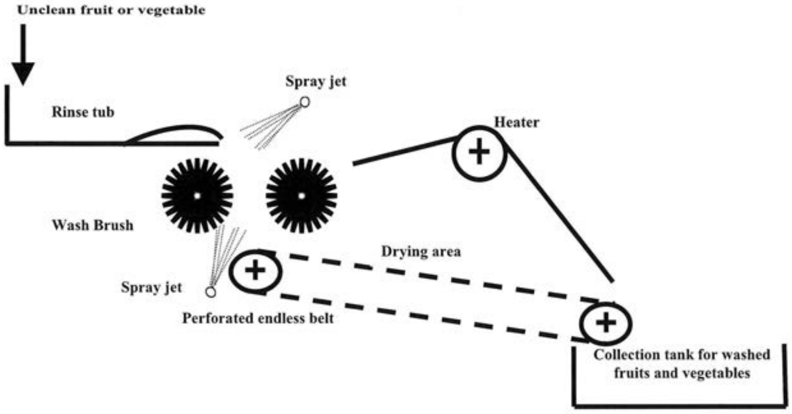
Pilot Model

A conceptual model was designed with Auto CAD (Auto CAD 2004). The design detail is given in **Fig. 1**. The pilot model has been fabricated based on the conceptual design and the components of the pilot model served the three major concepts explained. These components are explained below;

Washing unit:

It was planned to design a fruit and vegetable washer which could be used for washing small to large fruits and vegetables. A water tub was fabricated with a non-corrosive aluminum sheet. The height of the tub was 9 inches with a width was of 24 inches because the hand of a worker assisting in the floating and grading from one side of the tub can reach the other end of the tub. The length of the tub was 60 inches. It was assumed that the fruit introduced in one end of the tub would take 3 to 5 minutes to reach the other end without other assistance. The 3 to 5 minutes would be sufficiently long to clean the loosely bound debris from the products. The bottom of the tub was placed at the

Fig. 1 Schematic diagram of an on farm fruit and vegetable washer



height of 33 inches from the ground floor. The top of the tub, therefore, was at a height of 42 inches. This height was essential for the comfort of workers to watch, assist, clean and grade. The washing tub with developed washer setup is shown in **Fig. 2**.

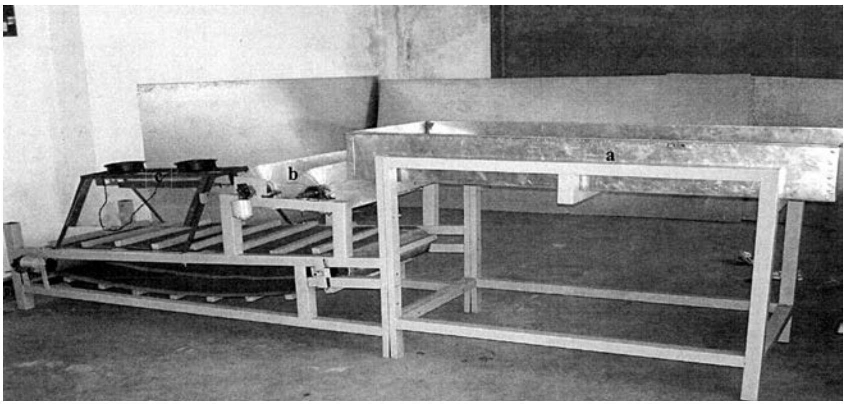
Brushing Unit

The bristles used for the nylon brush were 3 inches long and medium strong. The medium strong bristles were chosen because they offered sufficient rubbing action for an effective cleaning of soil and latex. Hard bristles may injure fruits and soft bristles may not offer the required rubbing action. They were densely positioned and were very closely held in position on a wooden shaft. The length of the bristles was 3 inches giving a shaft to shaft 6 inches when the bristles were kept touching each other tangentially. A shaft to shaft distance of 6 inches was essential for rubbing large fruit like mangoes. The distance between the shafts depends on product size and was adjustable by adjustable slots. The shaft rotation was adjusted in terms of rpm by the motor. Greater rubbing action was required for removing strongly sticking latex from the harder surface of produce. Spray jets were also used to spray the water with little pressure to remove latex and unwanted debris from the surface. Regulation of the pressure range of spray water could avoid damaging the produce. In addition, spray jets may possibly reduce or eliminate the usage of chemicals for cleaning, which is normally present in commercial washers. The brush assemblies with controls are shown in **Fig. 3**.

Drying Unit

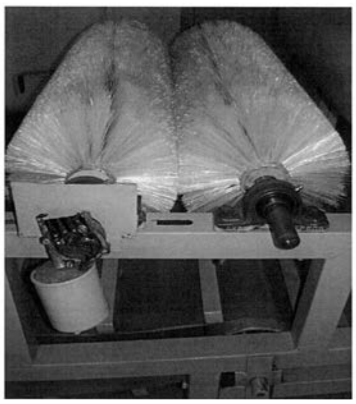
The drying unit consisted of a perforated stainless steel conveyor belt (2 feet wide × 6 feet long) with wooden rods to prevent the fruits and vegetables from rolling. Motors were used for the power source. The ideal pulley was used to prevent belt sagging. Heater assemblies were used for drying the surface water that consisted of two fans, a heating coil and a flow diverting frame. The washed produce fell on one end of this belt and conveyed to the other end. The speed of movement was adjustable. During this movement, the excess water sticking on its side would be drained. An air blower and heater assemble with an appropriate duct system was provided to assist in effective removal of surface water from the washed produce,. This system was mainly used to dry the surface of the produce. After drying, the commodity was processed

Fig. 2 Setup of a semi-automatic on-farm fruit and vegetable washer

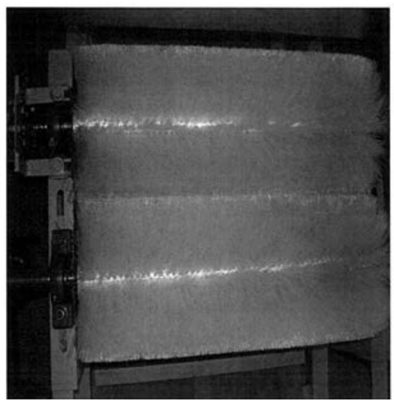


a).washing tub b).brushing assembly with controls c).drying unit with controls

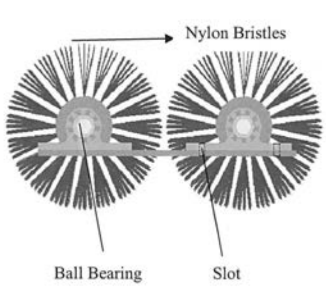
Fig. 3 Brush assembly with controls



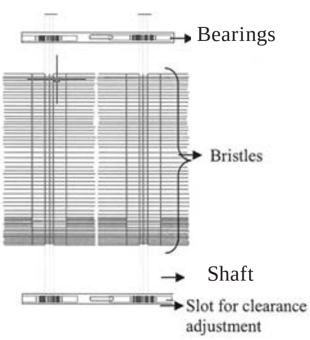
a. Motor connection



b. Top view of brush with bristles



c. Ball bearing connection with brush



d. Clearance adjustment slot view

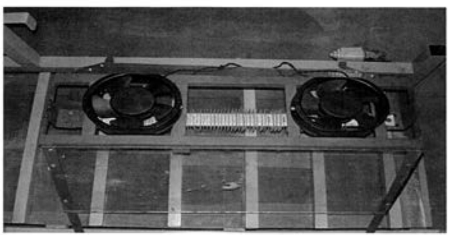
to packing and then marketing. The drying unit with controls is shown in **Fig. 4**.

Conclusion and Recommendations

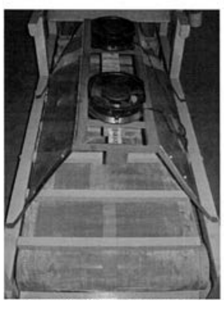
An on farm fruit and vegetable washer has been designed and fabricated for small and medium scale farmers in developing countries. It was suitable for all sizes and types of fruits and vegetables such as potatoes, carrots, mangoes, apples and guava with minor adjustments. The pilot model consisted of essential components of a commercial fruit and vegetable washer. This equipment was made of non-corrosive materials such as stainless steel and aluminum that could protect and increase the life of equipment. This equipment was easy to operate and maintain by unskilled workers. The pilot model in its current form reduces dependence on the worker for cleaning fruits and vegetables and can be operated with the supervision of only one worker. The worker can also comfortably stand and perform the cleaning, grading and the supervising job. This reduced the worker's physical fatigue and improved efficiency with operator safety. It held minimum moving parts and was easy to dismantle into two components such as washing unit and brushing unit along with drying unit. Farmers should handle the equipment safely.

The following recommendations are being suggested for improving the pilot model. The pilot model must be evaluated for its performance using field harvested fruits and vegetables. Wheels could be attached to the unit to move in the farm wherever the water source is available. Pre-brushing with smaller diameter shaft bristle brushes at the water tub will improve overall efficiency of the unit.

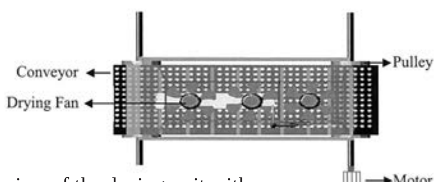
Fig. 4 Drying unit with controls



a. Top view of the drying unit with heating coil and fan



b. Front view of the drying unit with a perforated conveyor, and heating coil and fan



c. Top view of the drying unit with a perforated conveyor, heating coil and fan

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Custom Hiring and Scope of Entrepreneurship Development in Farm Machinery

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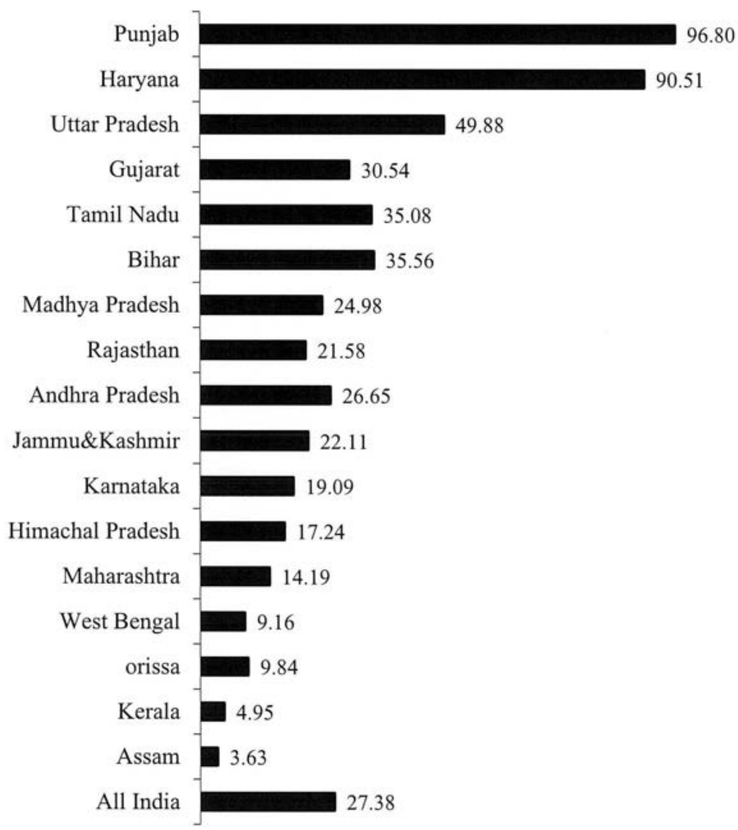
Abstract

The recent structural changes in economic environment, liberalization policy and the signing of a general agreement on tariff and trade (*Sharma et. al.*, 2010). has laid down new challenges in which, India has to compete in the international trade, including agricultural trade. The basic requirement of this competition is to reduce the unit cost of production and improve quality of agricultural produce so as to meet the international standards. The cost of production can be reduced only if the cost of every single factor contributing towards the total cost is minimized and resource productivity maximized. Increased productivity and production of food grain from limited land resources is required for feeding the ever-increasing population. This is possible through mechanization of agriculture by adoption of high capacity, improved agricultural machinery. High cost of these machines, with associated low annual utilization, bottlenecks their large-scale adoption on an ownership basis. Ensuring availability and use of these machines on a custom hire basis could help the rapid mechanization of agriculture. These services could be provided by governmental agencies as well as private entrepreneurs. A strong agro-service network is, in fact, a necessity to meet the technology and knowledge needs of Indian farmers.

Introduction

Mechanization in agriculture has enhanced production and productivity of agricultural commodities through timeliness of operations, better management of inputs, im-

Fig. 1 Tractor density/1,000ha



proved quality of work and reduction of post harvest losses. Increasing land and labour productivity with dignity are the mechanization requirements of developing a country like India. Due to agro-ecological diversities, high population density and socio-economic disparities, a diverse mechanization scenario exists in India. Tractor density in different states varies from 3.63 tractors/1,000 ha in Assam to 96.80 tractors/1,000 ha in Punjab with an all India average of only 27.38 tractors/1,000 ha (**Fig. 1**). The wheat growing northern region has higher concentration of tractors than other regions. Productivity of wheat in this region is also the highest. Small and marginal farmers in all the regions of the country experience constraints in the use of improved agricultural machinery due to limited capital resources. Small farm holders own about 60 % of the land and could play a major role in increased production and productivity of the crops. These farms could use improved agricultural machinery on a custom hire basis to achieve higher land productivity and could contribute in overall improved productivity of the crops at the national level.

Table 1 Progress of agricultural development in India

Pre-Green Revolution Era (before 1965)	Green Revolution Era (1965 - 1975)	Post Green Revolution Era (1975 onwards)
Farming by traditional methods	HYVs, fertilizer, irrigation, chemical inputs	Use of more scientific methods/machinery/ implements/precision
Farm power availability was about 0.27 kW/ha	Farm power availability was about 0.47 kW/ha	Present farm power availability is about 1.77 kW/ha
Share of animate power sources was 98%	Share of animate power sources decreased to 62 % in 1975	Share of animate power sources decreased to 11 %
Low productivity of food grain (0.58 t/ha)	Productivity of food grain increased (1.14 t/ha)	Present productivity of food grain is about 1.7 t/ ha
Enhanced production through increase in cultivated area	Enhanced production/ productivity through adoption of HYVs, fertilizer, irrigation and chemical inputs	Enhanced production/ productivity through adoption of improved farm machines / implements / precision in addition to adoption of other agricultural inputs

Table 2 Cropping intensity and power availability on Indian farms

Year	Cropping intensity, %	Food grain productivity, t/ha	Power available, kW/ha	Power per unit production, kW/t	Net sown area per tractor, ha
1975-76	120	0.944	0.48	0.51	487
1985-86	127	1.184	0.73	0.62	174
1995-96	131	1.50	1.05	0.70	84
2004-05	135	1.65	1.46	0.87	50
2007-08	137.2	1.860	1.60	0.86	41
2008-09	138.01	1.909	1.66	0.98	40
2009-10	139.22	1.798	1.71	1.03	37
2010-11	140.83	1.660	1.77	1.05	36

Progress of Agricultural Development and Constraints in Small Farm Mechanization

As a result of the green revolution in the sixties, the total food grain production increased from 50.8 million tones during 1950-51 to 230 million tones in 2009-10 and productivity increased from 522 kg/ha to 1,854 kg/ha. The increase in production of food grain was possible as a result of adoption of quality seeds, higher doses of fertilizer and plant protection chemicals coupled with assured irrigation. Progress of agricultural development in India is presented in **Table 1**. Enhanced food production in the country is required to feed an ever-increasing population in the country from the same or shrinking land resources. This demands increased land productivity through timely performance of farm operations, better management of inputs and natural resources and efficient management of crops. Mechanization of farm operations through adoption of efficient farm machines in this context could play a very important role.

India has 165 million hectares of cultivated land owned by more than 106 million farm holders with average land holding size of 1.57 ha, medium (4-10 ha) to large group of farm holders (> 10 ha) own about 44.4 % of total land. Medium and large farm holders could use improved agricultural machinery on ownership as well as on custom hire basis. Small farm holders, due to their limited resources, contribute to low productivity of land as they depend on traditional equipment and methods of crop cultivation. Because of the low productivity of their lands, they also use a low amount of crop inputs and do not adopt high yielding varieties of the seeds. Since small farm holders own about 60 % of land resources, they have an important role to play in higher agricultural production. Mechanization of agriculture of small farm holders could be promoted by extending the benefits of improved agricultural machines to them through custom hire services with governmental efforts and development of entrepreneurs for providing custom services at affordable rates.

Cropping Intensity, Food Grain Productivity and Power Availability Scenario on Indian Farms

It is apparent from **Table 2** that the cropping intensity increases with increase in per unit power availability. It was 120 percent with power availability of 0.48 kW/ha during 1975-76 that increased to about 141 percent with increase in power availability of 1.77 kW/ha in 2010-11. Net sown area per tractor shows the reverse trend during the same period, which was 487 ha/tractor in 1975-76 and reduced to 36 ha/tractor in 2010-11.

Farm Power Availability and Food Grain Productivity Relationship

Food grain productivity increased in India from 0.710 t/ha in 1960-61 to 1.856 t/ha in 2008-09 while farm power availability increased from 0.296 kW/ha to 1.600 kW/ha (*Singh et. al.*, 2011). Thus, food grain productivity was shown to be positively associated with unit power availability in Indian agriculture (**Fig. 2**). The relationship between food grain productivity and unit farm power availability for the period 1960-61 to 2008-09 was estimated by log linear function, with a highly significant value of coefficient of determination (R^2) as follows:

$$Y_{fgs} = 674.18Ln\,(x_{ps}) + 1480.8$$

$$R^2 = 0.989$$

where,

Y_{fgs} = food grain productivity of India, kg/ha, and

x_{ps} = power availability in India, kW/ha

This indicates that productivity and unit power availability is associated linearly. It is also evident that farm power input has to be increased further to achieve higher food grain production with the composition of farm power from different sources to be properly balanced to meet of its timely requirement for various farm operations.

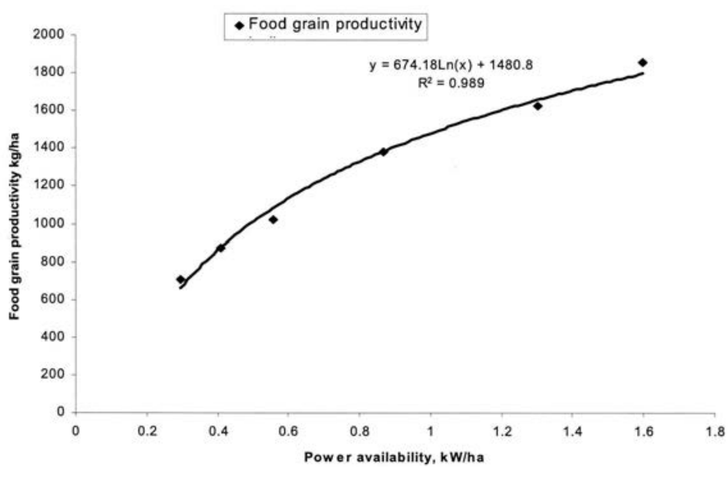
Promotion of Use of Improved Agricultural Machinery

The government of India, realizing the importance of the role of agricultural machinery in enhancing the productivity of crops, has put emphasis on promotion of improved agricultural machines through various programmes such as:

- Front Line Demonstration (FLD) on improved agricultural machinery through technology mission on oilseeds, pulses and cotton,
- Department of Agriculture and Cooperation (DOAC) sponsored FLD programmes on improved agricultural machinery for rice,
- DOAC sponsored FLD programmes on improved agricultural machinery through selected Krishi Vigyan Kendra's (KVKs),
- DOAC sponsored FLD programmes on improved agricultural machinery through centres of All India Coordinated Research Projects on Farm Implements and Machinery, Utilization of Animal Energy and Ergonomics and Safety in Agriculture, and
- DOAC sponsored subsidy programmes through State Department of Agriculture for improved agricultural machinery

These programmes have contributed to the creation of awareness among the farm holders about the advantages of improved agricultural machinery in timely completion of the farm operations and better management of various agricultural inputs and crops. Medium and large farm holders that make use of subsidies provided by the government along with the use of finances provided by the banks have gone for owning of tractors, irrigation equipment and selected farm machines. These farm holders, apart from using these machines on their farms, also provide custom hire services on a limited scale to small farm holders.

Fig. 2 Food grain productivity and power availability relationship in Indian agriculture



Why Custom Hiring?

The recent structural changes in economic environment and liberalization policy have laid down new challenges in which India has to compete in the international trade, including agricultural trade. The basic requirement of this competition is to reduce the unit cost of production, and improve quality of agricultural produce so as to meet the international standards. The cost of production can be reduced only if the cost of every single factor contributing towards the total cost is minimized and resource productivity maximized.

There has been a progressive shift

from draft animal power (DAP) to mechanical power in Indian Agriculture because DAP and manual labour are not adequate to cope with the work load of intensive agriculture. The use of mechanical power is becoming indispensable for making optimal use of inputs and in-time completion of various farm operations under intensive agriculture. Mechanization saves time in completing different operations, which gives the crop adequate time to mature; allows the farmer to be more flexible in his farming operations; and facilitates multi and relay cropping. The composition of Indian farms varies drastically. India has a large number of small farms with land holding of less than 2 hectares and a poor resource base. Single farm ownership and use of tractors and machinery on these small farms is not economically viable. But, through custom hiring of agricultural machinery, even small farmers have been able to get the benefit of agricultural mechanization. Punjab and Haryana have amply demonstrated it. Small farm mechanization could be promoted by extending the benefits of improved agricultural machines through custom hire services at affordable rates.

Custom Hiring of Improved Agricultural Machinery in Madhya Pradesh

Agricultural machinery is being adopted in the state of Madhya Pradesh as a result of promotion of custom hiring by the Department of Agriculture, Government of Madhya Pradesh, Central Institute of Agricultural Engineering and custom hire entrepreneurs cum farmers. The machinery includes tractors, diesel engines, electric motors, tractor operated mould board ploughs, tractor operated cultivators, rotavators, seed drills and seed cum fertilizer drills, inclined plate planters, self propelled and tractor operated reapers, self propelled combine harvesters, tractor operated multicrop threshers and tractor operated straw combines. Use of different farm power sources in selected districts from different agro climatic regions of Madhya Pradesh are presented in **Table 3**. The table shows that annual utilization of these power units is very low. The low annual use of power units is due to mechanization of only a few farm operations of the crop production systems. Further adoption of improved farm implements and equipment is very low (*Singh et. al.*, 2006). Major constraints in adoption of improved farm equipment are:

- High initial cost of the equipment
- Inadequate loan facilities
- Low annual use of the equipment
- Non-availability of spare parts at the rural level
- Inadequate repair and maintenance facilities in rural areas

Small farm holders in the state account for 60 % of the total holdings and 22 % of cultivated land. These farmers are resource poor and cannot use improved equipment and farm machinery on ownership basis. Mechanization of the agriculture of these holders has to be ensured through custom hiring of the machines.

Central Institute of Agricultural Engineering, keeping in view the acceptability of the machines as a result of its front line demonstration programmes, initiated custom hiring of selected equipment to ensure its adoption even by the smallholder farmers.

Table 3 Use of different farm power sources (hours/year)

Name of the district	Tractor				Electric motor			Diesel engine		
	Agricultural use			Non-agricultural use	Self	Hiring	Total	Self	Hiring	Total
	Self	Hiring	Total							
Datia	168	179	347	87	320	117	427	228	58	286
Sagar	68	110	178	49	237	84	321	246	46	292
Jabalpur	115	127	242	61	132	0	132	72	0	72
Hoshangabad	103	108	211	68	176	73	249	202	81	283
Ratlam	65	22	87	42	105	17	122	97	15	112
Betul	57	25	82	28	400	-	400	-	-	-
Dhar	197	11	208	41	446	52	498	15	-	15
Tikamgarh	180	24	204	37	187	50	237	42	-	42
Balaghat	84	156	240	97	311	121	423	21	-	21
Shahdol	40	52	92	116	138	54	192	44	11	55
Indore	216	36	252	82	736	67	803	35	15	40
Panna	170	123	293	213	289	36	325	81	0	81
Bhind	176	15	191	189	109	53	162	34	201	235
Overall	176	76	202	85	275	56	330	86	33	118

Custom hiring charges: Tractor with tillage/seeding implement = Rs. 300 − 350/h
Diesel engine = Rs. 60.75/h, Thresher = Rs. 400/h

Custom hiring rates for these machines were worked out with and without power units to help the farmers use the improved equipment as per their requirement and resources. The rates are presented at **Table 4**. Rates of these machines for entrepreneurs for providing custom hire services have also been worked out indicating the payback periods of the machines and the same are presented at **Table 5**.

Payback periods for these machines ranged from 1 to 3.9 years and this period could further get reduced by increased annual use of these machines. Custom hiring services used by the farmers for different machines is presented at **Table 6**. It can be seen from the table that use of a tractor-operated rotavator had the highest demand. Custom hiring of this machine was also promoted with the help of manufacturers of the machine. More than 200 machines in the state were purchased by the farmers under Rs. 30,000 per unit subsidy from the state government. These machines were also provided to smallholder farmers by 45 such custom providers on custom hiring for periods ranging from 50 h to 500 h for the total of 6,000 h during year 2007-2008.

Apart from this, tractor owner farmers also extend services of their machine namely; tractor with Duck-foot cultivator and seed drill and high capacity Hidamba thresher. Custom services for machines such as self-propelled combine harvester and high capacity thresher in different parts of the state during harvest seasons of Kharif and Rabi is also being extended by entrepreneurs from state of Punjab, Haryana and Rajasthan. Rates for custom hire services provided by entrepreneurs are presented at **Table 7**.

As a result of promotional custom service provided by the institute, demand for following improved equipment for use on custom hire is also growing:

- Animal and tractor operated puddlers
- Tractor cage wheels
- Self propelled rice transplanters
- Self propelled reapers
- Straw baler

Entrepreneurship Development for Custom Hiring

For development of sustained custom hire services for agricultural machinery it is desirable that efforts be made to develop entrepreneurs to extend this service. Entrepreneurship development programmes have been initiated by the Central Institute of Agricultural Engineer-

Table 4 Cost calculation of improved equipment for custom hiring services by the institute

Name of the equipment	Unit cost per hour (with power unit)			Unit cost per hour proposed (with power unit)			Unit cost per hour without power unit (proposed)
	Fixed cost	Operational cost	Total cost	Fixed cost	Operational cost	Total cost	
Tractor operated straw baler	151	305	456	75	305	380	75
Tractor operated straw combine	43	305	348	21	305	326	21
Kamco reaper	20	46	66	10	46	56	-
Vardan reaper	20	46	66	10	46	56	-
Tractor operated rotavator	50	305	355	25	305	330	25
Multicrop thresher	108	-	108	54	-	54	-
Tractor mounted vertical conveyor reaper	21	350	371	10	350	360	-
Self propelled 4 wheel paddy transplanter	190	100	290	95	100	195	-
Self propelled single wheel paddy transplanter	48	85	133	24	85	109	-
Tractor operated high capacity multicrop thresher	21	305	326	10	305	310	5
Tractor operated mole plough	10	305	315	5	305	310	5
Self propelled reaper (riding type)	125	171	296	62	171	233	-
Tractor operated MB plough	22	350	372	11	350	361	11
Tractor operated inclined plate planter	22	305	327	11	305	316	11
Tractor operated seed cum fertilizer drill	18	305	323	9	305	314	9
Tractor operated post hole digger	71	81	152	35	81	116	35
Engine operated post hole digger	10	70	80	5	70	75	-

ing through its technology transfer units, network of cooperating centres of All India Coordinated Research Projects and in collaboration with manufacturers of agricultural machines and financial institutions. The efforts are in the form of:

- Demonstration of model custom hire activities
- Help in development of feasibility reports for custom hire enterprises
- Training to entrepreneurs on operation and management of custom hire enterprise
- Help in getting finance for enterprise from financial institutions
- Procurement of quality equipment to run the enterprise

Bank finances for establishment of entrepreneurship are available up to Rs. 10 lacs to trained entrepreneurs. For extending the finance, banks require feasibility reports on the enterprise and guarantee. On these issues, entrepreneurship promotion institutions can play an important role. Further, rural youth can also take advantage of governmental subsidies available on power-operated equipment in purchase of the equipment. For promotion of entrepreneurship at rural level, availability of quality equipment at regional level, availability of critical spares for the equipment at the rural level and establishment of rural workshops for ensuring repair and maintenance of agricultural equipment at the rural level are desirable.

Conclusions

Increased agricultural productivity and profitability from limited

Table 7 Custom hire service being provided by machine owning farmers and entrepreneurs

Name of the equipment	Rates, Rs./h	Rates, Rs./ha
Tractor with Duckfoot cultivator	350	875
Tractor with tractor operated seed drills	350	875
Tractor operated rotavator	500	2,000
Tractor operated high capacity thresher	400	1,500
Self propelled combine harvester	800 (60/q)	2,500

Table 5 Cost of operation of implements under custom hiring through entrepreneurs

Equipment	Cost (Rs)	Annual use (h)	AFC (Rs./h)	AVC (Rs./h)	TC (Rs./h)	Custom rates	Annual Net Return	Pay back period (years)
Straw baler	500,000	525	160	183	342	428	128,625	3.9
Straw combine	85,000	420	40	183	223	279	40,320	2.1
Kamco reaper	70,000	525	20	46.25	66	83	192.94	3.6
Vardan reaper	70,000	525	20	46.25	66	83	1,929.4	3.6
Rotavator plus Tractor	520,000	430	105	183	288	360	70,880	1.0
Tractor	450,000	1,000	75	183	258	322	139,000	3.3
Multicrop thresher	55,000	400	20	45	65	81	14,400	3.8
Vertical conveyor reaper (riding type)	120,000	400	44	133	177	222	35,600	3.4
4 wheel paddy transplanter	600,000	400	202	100	302	377	110,800	5.4
Single wheel paddy transplanter	120,000	400	47	85	132	165	32,000	3.8
High capacity multicrop thresher plus tractor	550,000	600	105	213	318	400	112,200	2.2

(AFC=average fixed cost, AVC= average variable cost, TC=Total cost)

Table 6 Custom hire services for different farm equipment availed by the farmers

Name of equipment	Hours of use	No. of beneficiaries	Area covered, ha
Tractor operated MB plough	80	12	50
Tractor operated Rotavator	525	51	300
3.Tractor operated inclined plate planter	40	3	410
Walk behind type self propelled vertical conveyor reaper	30	4	10
Tractor operated high capacity multicrop thresher	50	1	-
Tractor operated straw combine	100	27	75
Engine operated post hole digger	53	2	-
Tractor operated post hole digger	50	1	

land resources in a globally competitive manner in India needs large scale mechanization. High cost of these machines with associated low annual utilization has been a bottleneck in their large-scale adoption on ownership basis. Ensuring availability and use of these machines on custom hire basis could help in rapid mechanization of agriculture in those situations where the land holdings are small and marginal and farmers are not in a position to own the machinery. These services could be provided by governmental agencies as well as private entrepreneurs. A strong agro-service network is in fact a necessity to meet the technology and knowledge needs of Indian farmers.

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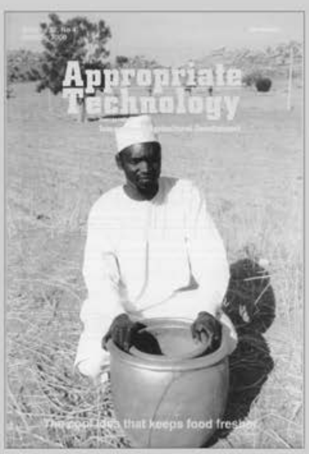

Comparative Performance Evaluation of Self Propelled Paddy Transplanters in Calcareous Soil


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Abstract

Field performance and planting accuracy of two different transplanters: 8-row riding (Model: 2ZT-238 -8) type transplanter, 4-row walking (Model: KUKJE-KP-450) type transplanter were compared with manual transplanting in actual paddy field conditions. The 8-row riding type Chinese transplanter had a field capacity of 0.182 ha/h with the field efficiency of 73.85 % when operated at 1.295 km/h forward speed while, for the 4-row walking type transplanter, the field capacity, field efficiency and forward speed were 0.145 ha/hr, 79.7 % and 1.416 km/h, respectively. Grain yield in both types of mechanical transplanting remained on par with manual transplanting.

Introduction

Rice is an important crop of India grown over an area of 43.814 million ha with a production of 96.43 million tones (Agricultural Statistics, 2008). In irrigation commands, rice is largely grown by manual transplanting of seedlings. Though manual transplanting gives a uniform crop stand, it is quite expensive and requires a lot of labour in addition to a lot of drudgery. Singh *et al.*, 1985 reported that transplanting takes about 250-300 man hours/ha which is roughly 25 percent of the total labour requirement of the crop. Further, due to rapid industrialization and migration to urban areas, the availability of labour became very scarce and with a hike in the labour wages, manual transplanting became costly leading to reduced profits to farmers. Under such circumstances a less expensive and labour saving method of rice transplanting without yield loss is the urgent need of the hour (Tripathi *et al.*, 2004). Mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Hence, in the present study, an eight row self propelled rice transplanter (Model 2ZT-238-8) was evaluated for its performance on a field scale.

Manual transplanting also fails to meet the agronomical requirements like plant population m-2 and uniform row and hill spacing, thereby limiting the use of agricultural implements and hand tools for intercultural operations. A rice transplanter works on puddled soil; it encounters a hard surface at the plow pan and a soft puddled soil at the top where it must also have sufficient bearing capacity to prevent sinkage of the float. At the same time the plow pan must not be too deep to provide necessary thrust to propel the transplanter. Both traction and bearing capacity are dependent upon shear strength of the soil (Knight and Freitag, 1962). Efficient working of a self-propelled rice transplanter requires a suitable puddled soil condition *vis-à-vis* optimum depth of puddling, degree of puddling and soil strength of puddled field (Goel *et al.*, 2008; Sharma and Dutta, 1985) Therefore, in order to identify ideal puddled soil conditions with respect to puddling equipment for satisfactory performance of rice transplanter as well as the rice crop, the present study was undertaken.

Material and Methods

Field Preparation and Transplanting

The study was undertaken at the Agricultural Research Farm, Rajendra Agricultural University, Pusa (Agro climatic zone –I, 25º85′16″ N latitude and 85º40′16″ E longitude and at a height of 46 m above MSL). Analysis of a composite soil sample showed that it was calcareous sandy loam in texture (sand: 28 %; silt:

Table 1 Field conditions of experimental plot

Particulars	
Soil texture	Sand: 28 %; Silt: 53.9 %; Clay: 18.1 %
Water depth, cm	4-5
Wet bulk density, kg/cm^3	496
Soil pH	8.6
Hydraulic conductivity, mm/h	0.22
Infiltration rate, mm per h	4
Resistance before puddling, MPa	1.34
Cone index	62.92
Puddling index, %	45.5

Table 2 Technical specifications of self propelled paddy transplanter

Specification	8 -row riding type	4 -row walking type
Model	2 ZT - 238 -8	KUKJE - KP -450
External dimension, L × W × H	2410 × 2131 × 1300	2700 × 1600 × 1000
Weight, kg	320	320
Power unit	4 hp, air cooled diesel engine	2.3 hp, air cooled petrol engine
Number of rows	8	4
Row Spacing, cm	23.8	30
Hill to hill spacing, cm	12-14	11-14
Operating speed, km h^{-1}	1-2	NA
Planting depth, cm	0-6 (Adjustable)	2-5 (Adjustable)
Width of seedling gate, cm	22	30
Price	1,15,000.00	1,87,425.00

53.9 %; clay: 18.1 %), slightly alkaline in soil reaction, rich in organic carbon, low in available nitrogen and rich in available phosphorous and potassium.

The experimental fields were prepared with tractor drawn rotavator in flooded condition. Planking was done with a wooden plank attached to the same tractor. Before the test, the soil properties affecting the performance of the transplanters were monitored (Eam-pas *et al*., 1988). Those properties were pH, hydraulic conductivity, puddling index, cone index value (CI) and wet bulk density (specific weight). The field conditions, such as water depth and infiltration rate were also recorded (**Table 1**).

The experiment consisted of evaluation of field performance of the mechanical transplanter in comparison with manual transplanting. For this, a Chinese made 8−row self−propelled rice transplanter (Model: 2 ZT-238-8) and Japanese made 4−row self− propelled rice transplanter (Model: KUKJE-KP-450) were used. An operational view of the 8-row rice transplanter is shown in **Fig. 1** and a view of the 4-row rice transplanter is shown in **Fig. 2**. A detailed technical specification of the rice transplanter is given in **Table 2**.

Mechanical transplanting requires a special method of raising seedlings called Dapog or mat type seedlings (**Table 3**). Rice variety ‘Prabhat’ was used for raising the nursery. Raised beds of 10 m length, 0.75 m width and 2.5 cm high were prepared. Soil was sieved and mixed with an equal quantity of barm yard manure and spread over a polythene sheet 50 micron thick to a depth of 2 cm. Sprouted seeds were spread uniformly on the polythene sheet and pressed gently. They were covered with paddy straw and watered through rose cans for four days. After the fourth day, paddy straw was removed and seedlings were grown normally by regular watering. To enhance the growth of seedlings, a two percent foliar spray of Nitrofoska (19: 19: 19 N: P: K) was given twice at 12 and 15 days after sowing. For tansplanting 1 ha of land with mat type seedlings, 70 m^2 mat area is required. When the seedlings were about 2-3 leaf stage, water was drained from the nursery and the seedling mat was cut to required size with a knife and rolled and fed to the mechanical transplanter. In case of manual transplanting, the paddy nursery was raised following the recommended package of practices. Transplanting was done with the mechanical transplanter by running length wise of the field on the puddle and leveled land with water level in the field at 2 cm only

Fig. 1 Operational view of paddy transplanter at research plot of RAU, Pusa farm

Fig. 2 A view of 4-row paddy transplanter

Table 3 Seedling conditions used in the experiment

Particulars	
Type of nursery	Dapog or Mat type
Mat size	10 × 0.75, m
Seeding rate, Kg/m^2	0.6
Age of seedling (day old)	21
Leaf stage per plant	3
Height of seedling, cm	15
Mat thickness, cm	2
Plant establishment in Mat, $/cm^2$	12

to avoid floating of seedlings. **Table 3** gives information about the field condition of the experimental plot.

Measurement of Different Parameters

Depth of Puddling

Depth of puddling was measured by a penetrometer as suggested by Taneja and Patnaik (1962).

Puddling Index

Soil water suspension samples were collected during last lap of puddling from different spots behind the puddling equipment with the a 1.25 cm diameter steel pipe. Samples were taken from each treatment by closing the upper end of the pipe with the thumb and collecting in a measuring cylinder till the volume reached 500 ml. The soil water suspension was allowed to settle for 48 hours and the volume of soil settled was recorded. Puddling index was determined by the following relationship (Bhole and Pandya, 1984).

Puddling index (PI) = Vs/V × 100 .... (1)

where,

Vs = Volume of soil, ml

V = Total volume of the sample, ml

Hydraulic Conductivity

Saturated hydraulic conductivity was determined using a falling head permeameter as suggested by Rane and Varade (1972). The instrument consisted of a glass tube of 75 cm length and 1.25 cm diameter. These were fixed to a depth of 10 cm from surface of the soil just after transplanting. The permeameters were filled with water up to a certain level, h_1, which was kept constant for all treatments. Evaporation loss from the permeameters was checked by adding 3-4 drops of lubricating oil. To prevent rain water from entering the permeameters, the top was covered with a polythene sheet. Observations were recorded at 24 hours interval and the height of water column, h_2, was noted. Saturated hydraulic conductivity was determined using the following formula:

$K = (aL/At)\ 2.302 \log (h_1/h_2)$ .... (2)

Where, K = Saturated hydraulic conductivity, mm h^{-1}

a = Cross-sectional area of the pipe, mm^2

L = Length of soil column, mm

A = Cross-sectional area of the soil column, mm^2

t = Time interval during which the head falls from h_1 to h_2, h

h_1 = Head of water column at the beginning, mm

h_2 = Head of water column after time ‘t’, mm

Cone Index

To determine cone index, a cone penetrometer (model BL, 250 EC, Baker Mercer type C10, LC = 0.002 mm), having a 2.618 cm diameter cone base with a cone angle of 20º, was used. The cone penetrometer was calibrated with known weights and the relationship between applied load and dial gauge deflection was established. Since puddled soil had low strength; the cone penetrometer tended to sink without showing any deflection. Hence, the weight of cone penetrometer (3,485 g) per unit area of cone base was also taken into account while determining the cone penetrometer resistance (Singh and Garg, 1979). The cone penetrometer resistance (CPR) per unit area (cm^2) was determined by the following relationship:

$CPR, = 0.648 + 0.025\ X,\ kg\ cm^{-2}$. .... (3)

where,

X = dial gauge deflection, small divisions

The average cone penetrometer resistance over a depth range (0-15 cm) has been termed as cone index. The calculated value of CPR and CI was multiplied by a constant factor 98.067 to get CPR and CI in kPa. Cone penetrometer readings at different depths were taken randomly from five different places in each treatment at an increment of 2.5 cm and converted into CPR by the above formula. Cone index values were determined by taking the average of CPR values at different depths (0-15 cm).

Buried and Floating Hills

Hills which are completely buried under soil after transplanting are called buried hills (Mori, 1975). Floating hills are those hills where all seedlings in a hill are either floating on the surface or just placed on the surface of the mud (Singh *et al.*, 1985). Buried hills and floating hills were counted in a square meter area after transplanting. Five observations were taken for each treatment. Floating and buried hills were calculated by the following formulae:

Buried hill, % = (BH/TNH) × 100 .... (4)

Floating hill, % = (FL/TNH) × 100 .... (5)

where,

BH = Number of buried hill m^2

FL = No. of floating hill/m^2

TNH = Total number of hill transplanted m^2

Hill Mortality

One square-meter area was marked after transplanting and the numbers of hills transplanted were counted. After 15th days of transplanting, the numbers of hills that survived were counted. Hill mortality was determined by the following formula (Garg *et al.*, 1997):

Hill mortality,% = [1 − (HS/TNH)] × 100 .... (6)

where,

HS = No. of hills survived 15 days after transplanting (DAT)/m^2

Observations were recorded on speed of operation, depth of placement of seedlings, number of seedlings per hill, number of missed

Table 4 Picking performance of transplanting

Particulars	8 -row riding type	4 -row walking type	Manual
Row −row spacing, cm	23.4	30	NA
Plant −Plant, cm	12.1	13	18-22
No of seedling per hill	4.66	4.37	7.61
Percent of missing hill	2.95	2.5	0
Percent of buried hill	2.95	2.2	0
Percent of floating hill	0.5	0.6	0
Percent of damaging hill	Nil	Nil	0
Planting depth, cm	4.80	4.46	4.45

Table 5 Field performance of the transplanter

Performance	8 -row riding type	4 -row walking type
Operational forward speed, km/h	1.295	1.416
Theoretical field capacity, ha/h	0.246	0.182
Actual field capacity, ha/h	0.182	0.145
Time taken to cover 1 ha, h	5.494	6.896
Field efficiency	73.85	79.7
Slippage, %	19.58	15.23
Fuel consumption, l/h	1.09	1.05
Cost of transplanting, Rs/ha	1,090.66	1,625.23

hills, time taken for turning, time taken for loading of seedling mat on to the transplanter, total time taken for transplanting, total area covered, width of coverage and quantity of fuel consumed for the operation. Using the above information the following parameters were computed for the mechanical transplanter:

1. Theoretical field capacity was calculated based on the forwarded speed and the width of the equipment.
2. Actual field capacity was calculated based on area covered, and actual time taken for covering the area including the time lost in turning and loading of seedlings.
3. Field efficiency was obtained by dividing actual field capacity by the theoretical field capacity.
4. Labour saving by using the machines compared to manual operations was computed.
5. Cost of mechanical transplanting per hectare was determined after taking into consideration the fixed cost, labour cost, fuel cost, field capacity of the equipment and usage of the equipment in terms of hectares per year and was compared with the manual transplanting.

Result and Discussion

Picking Performance of the Tested Transplanters

Table 4 shows the comparative picking performance of the transplanters in actual field condition. From the table, it can be seen that the 8-row riding type transplanter had a higher percentage of missing hills, buried hills and floating hills than 4 -row walking type transplanter, without damaged hills in both cases. This was due to improper working of the picking forks as well as the seedlings condition in case of the 8-row riding type transplanter as compared to the 4-row walking type transplanter. The operator had to repeat his push stroke frequently when he observed the missing hills. Clogging of the picking fork was also a problem during operation. The number of seedlings per hill and plant depth for the 8-row riding and 4 -row walking type transplanter were 4.66, 4.8, 4.37 and 4.45 cm, respectively. However, in the case of manual transplanting, the number of seedlings per hill was much higher.

Field Performance

The field performance test of the transplanters was conducted in the actual field conditions described in the previous section to observe the machine maneuverability, field capacity, field efficiency, fuel consumption, slippage and ease of operation (**Table 5**). The 8-row riding type transplanter had a field capacity of 0.246 ha/h compared to 0.182 ha/h that of the 4-row walking type transplanter. The field efficiencies of the 8-row riding type and 4-row walking type transplanter were 73.85 % and 79.70 %, respectively. The 4-row walking type transplanter had a higher filed efficiency because of less turning and seedling supply time. The slippage of the machine in the field during operation was 19.58 % and 15.23 % for the 8-row riding type and 4-row walking type, respectively. The 8-row riding type transplanter consumed 1.09 L/h of gasoline at half throttle with an in-field actual speed of 1.295 km/hr. The fuel consumption of the 4-row walking type transplanter was 0.452 L/hr when operating at half throttle setting, or the field speed of 1.416 km/h. The 8-row riding transplanter gave a higher percentage of missing hills as described in the previous section. The operator required frequent resting time during operation which decreased the field efficiency significantly (Bahera et al, 2003).

Fig. 3 A view of crop stand by 4-row paddy transplanter at panicle emerging stage

Table 6 Working time of the transplanting

Operations	8-row riding type	4-row walking type
Planting Time, %	56.85	79.90
Turning Time, %	26.57	10.87
Refilling of seedling Time, %	16.58	9.23
Adjustments Time, %	0	0
Idle, %	0	0
Total	100	100

Table 7 Vegetative growth and yield of paddy as influenced by mechanical and manual transplanting

Parameters	8-row riding type	4-row walking type	Manual
Variety	Prabhat	Prabhat	Prabhat
Plant height, cm	87.69	87.15	86.83
Number of tillers per hill	21.20	19.85	18.78
Grain yield, q/ha	47.22	46.36	45.86
Straw yield, q/ ha	59.98	63.92	57.22

The performance of the mechanical transplanter was quite satisfactory and the labour requirement was 3 man days per hectare as compares to 45 man days per hectare for manual transplanting. Thus, a savings of 42 man days of labour per hectare was observed. The cost of transplanting by the mechanical transplanter was Rs. 1,090.66/ha for the 8-row riding transplanter and Rs. 1,625.23/ha for the 4-row walking transplanter as compared to Rs. 3,578/ha for manual transplanting. Taking this into consideration, the cost of mechanical transplanting would break even at 28 hectares of usage per year.

The working time of the transplanters in percentage of the total time is shown in **Table 6**. In each test the planting time, turning time, seedling supply time, adjustment time and idle time were recorded (Bahera *et al.*, 2009). The planting time of the 8-row riding and 4-row walking type transplanters accounted for 56.85 % and 79.90 % of the total time, respectively. The turning time of the 4-row walking type transplanters was observed to be 10.87 % of the total time compared to 26.57 % that of the 8-row riding type transplanter. This indicated that the 4-row walking type transplanter was more maneuverable on the headland than the 8-row riding type. The 8-row riding type transplanter required 16.58 % of the total time to supply seedlings which was much higher than that of the 4-row walking type which required 9.23 % of the total time. This time was spent mainly for cleaning the picking forks.

The yield data revealed that there was not much yield difference between manual and mechanical transplanting (**Table 7**). However, a marginal increase in straw yield was recorded for mechanical transplanting than manual transplanting. This may be attributed to a higher number of tillers/hill due to transplanting of more seedlings/hill for mechanical transplanting. Similar results were also reported by Khan and Guntel, 1988; Kanoksat *et al.*, 1988 and Ved Prakash and Varshney (2002);

A view of crop stand with 4-row and 8-row paddy transplanter is shown as **Figs. 3** and **4**, respectively.

Conclusion

The performance of the 8-row riding and 4-row walking transplanter in actual paddy fields was satisfactory. They gave good planting accuracy or picking performance. It was necessary to test these transplanters in different field conditions prepared by different methods before the conclusion on the suitable transplanters and the proper land preparation techniques for each transplanter could be drawn. Economical aspects as well as field conditions must be considered carefully before introducing the rice transplanters to farmers in different regions having different farm sizes and tillage implements. A view of a field day on paddy transplanted rice is shown in **Fig. 5**.

Fig. 4 A view of crop stand by 8-row paddy transplanter at panicle emerging stage

Fig. 5 A view showing Vice-chancellor's visit at the RAU Research plot

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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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Modelling Tomato Fruit Terminal Velocity In Water: **T. Pandiarajan,** Associate prof. Agril. Engg. College and Res Instt Kumulur- 621712, Trichy (TN) INDIA; **A. Tajuddin,** same.

The possibility of using terminal velocity of tomato as a means of hydro-sorting was studied. Terminal velocity of three tomato varieties PKM-1, 5005 and NANDHINI were determined using water column method. Some physical properties of tomato affecting terminal velocity were determined using standard methods. The best model for terminal velocity of PKM-15,005 and NANDHINI varieties as a function of water and fruit densities, shape factor and volume were modeled with determination co-efficient of 0.85, 0.88 and 0.98 respectively.

It was found that fruit density had a significant effect on terminal velocity. Volume and shape factor showed a little effect on terminal velocity.It can be concluded that the difference in terminal velocity of tomato can be used as an important factor for designing a hydro-density sorter.

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Thermal Control of Stored Grains Insects by Utilizing Solar Energy

by
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Abstract

Storage insect-pests are the major cause of damage and losses in food grain. For prevention of damage and losses by insects infestation, all insects present in the stored product must be eliminated at any stage of their development. Preservation methods which applied to food products for insect pests control, as chemical method, resulted in several problems and hazard for consumers. Heat treatment is one of the safe alternative measures for storage insects control but it is costy and requires special facilities for application. Therefore, the aim of this study is to utilize solar radiation as source of heat for thermal control of storage insects, in an attempt to find out a safer effective control measure at minimal cost.

To study the effect of material, black paint, and transparent cover on heat observation, four groups of containers were made from differernt materials (plastic, polythene, metal and jute). Two containers from each group (out of three) were painted black and one from these two black containers was covered with transparent polythene. All containers were filled with equal amounts of sorghum grains and kept out door for exposure to direct sun radiation. Temperature measurements were taken at two hours time interval from 8:00 a.m. to 1:00 p.m. for the first period and from 1:00 p.m. to 5:00 p.m. for the second period.

Five structures of different geometrical shapes made of black galvanized metal were used to study the effect of geometrical shape on heat absorption. All containers (pyramid, cylinderical, triangular, rectangular, and cubic) were filled with sorghum grain and temperature measurements were taken as mentioned above.

Different stages of the common storage insects in Saudi Arabia (Tribolium castaneum, Trogoderma granarium and Rhizoprha domonica) were subjected to high temperature (40-45 ºC) for different exposure periods to study the effect of heat on life cycle of these insects and to determine the lethal degree for all stages.

Quality tests were carried out for sorghum grains treated at 55 and 70 ºC for different exposure periods to study the effect of tenperature and exposure period on sorghum quality.

Highest maximum temperature were obseved in black plastic container (64.7 ºC), black polythene container (64.2 ºC) and black metal container (58.3 ºC) when covered with transparent polythene. These temperatures were found to be greater than the lethal temperature (45 ºC) for all developing stages of storage insects. The structures with inclined surface like pyramid and triangular recorded the highest maximum temperatures compared to vertical structures.

The lethal temperature for all developing stages of the insects ivestigated is 45 ºC when subjected to such temperature for one and half hour.

Treatment of sorghum grains at a temperature of 55 ºC for up to two hours did not indicate any harmful effect in all studied parameters except moisture content, 1,000 kernels weight and hectolitre weight. Treatment of sorghum grains at 55 ºC for two hours cold be safely used without affecting seed germinability. However, increasing temperature or treatment period resulted in slight decrease in germinability.

Generally, it could be concluded that solar energy could be utilized for contorol of storage insects with simple treatment of the containers tested in this study under Al-Ahsa conditions throughout the year.

Introduction

Grains are considered as the most important basic food and feed everywhere in the world. It is essential for mankind to produce, preserve and market grain optimally (Brooker *et al*., 1992). In the post-harvest sequence, grain storage constitutes the essential phase between harvesting and use of crop for direct consumption or for processing. Grain storage is important specially for developing countries where food grain still constitutes the staple food of human diet. In most countries, such as in Saudi Arabia, insects cause a lot of damage to stored grains (Crus and Diop, 1989). The enormous loss of stored products caused by insects has been mentioned in many papers since 1948, most of them illustrated by specific example or general losses to distinct categories. It is possible to differentiate between loss of weight, determination of quality and harmful contamination, which depend primarily on the numbers of insects causing them. FAO estimate of world wide annual losses in store has been given as 10 % of all storees grain; i.e. 13 million tons of grain loss due to insects (Hall, 1970). For prevention of damage and losses by insect infestation, all insects present in the stored product must be killed at any stage of their development; i.e. egg, larval, pupal and adult.

FAO (1989) reported that control of grain pests, as applied to food products, should not reduce their quality nor constitute a hazard to consumers or to pest control workers. It also should be able to kill all insects present in stored products at any stage of their development and to prevent infestation and reinfestation. The hazard caused by using chemicals in control of insects and pests was reported by many authors (Dennis, 1973; Upholt, 1977; Kenage, 1977 and Adams, 1977). They showed that improper use of expensive and extremely dangerous pesticides in developing countries resulted in several problems such as ineffective pest control, crop damages, dangerous residues and environmental contamination.

Because of all hazards mentioned above, many safe and cheaper alternative methods have been studied. One of the most promising and safer insect control measures is heat treatment method, but it is still expensive and requires special facilities and costy energy. Therefore, solar energy could be used because it has a potential cheaper energy support for agricultural production as compared to other sources of energy. In Saudi Arabia where solar energy is available all over the year, it may be considered one of the most available sources of energy.

Because of all the hazards caused by using chemicals in control of insects, an attempt will be made to furnish some basic information about the possibility of using solar energy as a source of heat for thermal control of stored insects. Therefore the objectives of this study were :

1. To detrmine the optimum temperature and time required to control all stages of insects of food grains and grain products.
2. Using solar energy to obtain a temperature that is lethal to all stages of insects by :
   a. Using containers manufactured from different materials to find the most suitable one for collection of radiation.
   b. Using different treatments to help in rising temperature to the required levels.
3. To study the effect of structure, design and geometrical shape on increasing heat absorption to the required levels.
4. To carry-out quality analysis to grains, floor and seeds subjected to maximum heat treatment.

Materials and Methods

To study the effect of material, black paint, and transparent cover on heat observation, four groups of containers were made from difterernt materials namely plastic, polythene, metal and jute. The first group contained three cylindrical bins constructed from metal with a capacity of 20 kg. Group two constituted three bags of polythene with a wall thickness of 25 μm and a capacity of 20 kg.Group three contained bags made of jute (used for rice package) with a capacity of 20 kg for each bag. Group four consisted of three plastic bags of the types used as flour sacks. Their capacity was the same as the previous containers (20 kg). Then two containers from each group (out of three) were painted black and one from these two black containers was covered with transparent polythene. Five structures of different geometrical shapes of 20 kg capacity were constructed from black galvanized metal and used to study the effect of geometrical shape on heat absorption. The geometrical shapes of these structures were pyramid, cylinderical, triangular, rectangular, and cubic. All containers were filled with equal amounts of grain sorghum and air tight sealed. A small hole was made on the top of each container for insertion of temperature thermocouple sensors in the center and then kept tightly closed with fixing tape. The containers were placed outdoors on a concrete floor from the first of October 2003 to the 31st of December 2003 in the Research Station at King Faisal University, Eastern Province, Saudi Arabia for exposure to direct sun radiation. Temperature measurements were taken at two hour time interval. In each container, thermocouple sensors were installed in the center to measure the temperatures of grain at the center. The sensors (accuracy 0.2 ºC) were connected to a data-logger system to test, display and record the data throughout the experimental work.

To detrmine the optimum temperature and time required to control all stages of insects of food grains and grain products, about 150 adults of the common storage insects in Saudi Arabia (Tribolium castaneum, Trogoderma granarium and Rhizoprha domonica) were obtained and each species was placed in a separate cylindrical jar of 8.6 cm diameter and 17.5 cm height containing 300 gm of grain sorghum. The jars were left in an incubator at 30-32 ºC for ten days to lay eggs. Then grains were sieved by means of a reasonable screen size to separate the adult insects. Ten individuals of each insect species were placed in each of twelve test tubes containing ten grams of grain sorghum. All tubes were covered and placed in the oven at 40 ºC. After each half an hour, three tubes were taken out of the oven and the live insects were counted. These steps were repeated for temperatures (41 ºC, 42 ºC, 43 ºC, 44 ºC and 45 ºC) then the results obtained were recorded. The same procedure mentioned above was repeated for eggs and larval stage for the three insect species.

To study the effect of temperature and exposure periods on grain quality, ten kilograms of grain sorghum were divided to five equal parts. Each part (2 kg) was placed in a glass container and exposed to different temperatures. Two of these containers were exposed to 55 ºC. One container was exposed for two hours and the other for four hours. The other two containers were exposed to 70 ºC. One container was exposed for two hours and the second one for four hours. The fifth container was left as control without any heat treatment. The content of each of these glasses was placed in a polythene bag and kept in deep freezer (about 4 ºC), then a quality test was carried on these samples. The quality tests carried out were germination test, kernel hardness test, 1,000 kernels weight test, hectolitre weight test, crude protein test, total fat content test, moisture content and fat acidity test. The data from all these tests were recorded and analyzed.

Results and Discussion

Effect of Container's Material, Treatment and Exposure Period to Sun Radiationon on Sorghum Grain Temperature:

The temperatures gained by sorghum grain kept in containers made from different materials when they were exposed to direct sun radiation are shown in **Table 1**. Generally the temperatures absorbed by all materials were lower than atmospheric temperature which was 25.2 ºC for the data collected at 9:00 a.m. (one hour from initial exposure to sun radiation). Analysis of variance for the above data revealed that the temperature gained by grains kept in the different containers varied significantly at 5 % and 1 % level. At 11:00 a.m. (after 3 hours of exposure) the grain kept in unpainted containers gained temperatures that were less than atmospheric temperature (29.5 ºC), while all other containers showed higher temperatures except black polythene and black jute. At 1:00 and 3:00 p.m. the temperatures gained by grains kept in all containers were found to be higher than atmospheric temperature (31.9 ºC and 33.1 ºC, respectively). The analysis of variance for the temperatures measured at 11:00 a.m., 1:00 and 3:00 p.m. showed highly significant difference at 5 % and 1 % level.

The black plastic container covered with transparent polythene showed the highest mean temperature (62.9 ºC at 3:00 p.m. or after 7 hours exposure to the sun radiation) over all other containers. The highest mean temperature gained was 29.8 ºC higher than atmospheric (33.1 ºC). The black polythene with transparent cover indicated the second higher temperature gained which was 50.9 ºC or 17.8 ºC higher than atmospheric temperature. The black metal container with transparent cover gained 49.5 ºC or 16.4 ºC higher than atmospheric temperature. Also the black jute with transparent cover gained 40.9 ºC or 7.8 ºC higher than atmospheric temperature.

At 9:00 a.m. the temperatures of grain inside all containers were lower than atmospheric temperature because during the night the atmospheric temperature was low and thereby the grain temperature droped. It was known that the thermal conductivity of grain was very

Table 1 Mean temperatures of grain sorghum stored in containers made of different materials (ºC)

Treatment	9:00 a.m.	11:00 a.m.	1:00 p.m.	3:00 p.m.
Unpainted metal	21.5 cd*	27. 0f	32.7 g	36.2 fg
Black metal	22.1 c	31.2 cd	38.0 cd	42.2 d
Black metal with cover	24.2ab	34.8 b	43.5 b	49.5 b
Clear polythene	19.1 e	26.2 f	33.6 f	38.2 ef
Blackpolythene	19.8 de	28.2 ef	37.0 de	41.5 de
Black polythene with cover	21.2 cde	32.6 c	43.3 b	50.9 b
Unpainted jute	20.2 cde	26.6 f	32.6 g	34.5 gh
Black jute	20.6 cde	28.1 ef	35.5 ef	39.5 de
Black jute with cover	22.4 bc	32.2 cd	42.4 b	46.9 c
Clear plastic	21.5 cd	28.1 ef	32.9 g	36.2 fg
Black plastic	21.8 c	30.2 de	38.4 c	41.4 de
Black plastic with cover	23.4 abc	38.4 a	55.8 a	62.9 a
Atmospheric temperature	25.2 a	29.5 de	31.9 g	33.1 h

*Within a column, values with the same letter are not significantly different at 5 % level according to Duncan's multiple range test.

low. Therefore, it was expected that the response of grain to gain temperature change would be slow and take longer to be transmitted to the grain bulk inside the containers. Also, grains have a fairly high thermal capacity so that temperature changes are transmitted slowly (Ward and Calverly, 1972).

The black containers gained higher temperatures compared to unpainted containers. This was due to the high solar absorptance of the black colour which ranged between 0.9 and 0.95 (**Table 2**). This result agreed with Brenndorfer *et al.* (1985) who showed that the black body is a perfect body which absorbs all radiation incident on it and the level of radiation emitted from it is a function of temperature only.

The temperature gained by grains kept in black containers covered with transparent polythene were very high due to reduced convection heat losses by shielding the absorber from the wind. The transparent cover also admited shortwave radiation to the absorber and reduced radiation heat losses by preventing the escape of longwave radiation from the absorber surface. Similar findings were observed by Kerider and Kreith (1975). They also showed that such covers were transparent to the incoming solar radiation and opaque to infra-red radiation from the absorber surface.

The clear difference observed in the performance of containers made of different materials was due to the difference in the properties of that materials. The solar absorptivity of plastic and polythene were higher than those of metal and jute (**Table 2**). Accordingly, grains kept in plastic and polythene gained higher temperatures. Also black plastic containers may give little resistance to passage of hot air than polythene. This is why grains in black plastic attain higher temperature than that in black polythene, as found by Brenndorfer *et al.* (1985).

The grain kept in jute containers gained the lowest temperature because the solar absorptivity is lower than wavelength emittance and also it has low thermal conductivity of 0.002 cal/sec.cm. ºC as shown in **Table 2**.

Table 2 Properties of some materials**

Material	Solar absorptivity	Wavelength emittance	Thermal conductivity cal/sec.cm. ºC
Polythene	0.89	0.80	-
Metal	0.65	0.13	0.11
Grass (jute)*	0.67-0.69	0.90	0.002
Grains			0.10-0.15
Black paint	0.95-0.97	0.95-0.97	

* Properties of jute were considered as similar to dry grass.
** Source: Brooks (1961).

Grain Temperature Loss with Time:

Grain temperature reached its maximum at 3:30 p.m. and then began to decrease (**Table 3**). At 5:00 p.m. the temperature of grain decreased 4 ºC in the black plastic containers compared to only 1 ºC decrease in the clear plastic container. **Table 3** showed that there was a significant difference between values of temperature gained by black polythene container with transparent cover and all other containers at 1 p.m. and 2:00 p.m. Periodical observation at 2:30, 3:00, 3:30, 4:00, 4:30 and 5:00 p.m. revealed insignificant difference between black plastic and black polythene containers with transparent covers, however there was a significant difference between these two containers and the others (**Table 3**). The highest maximum temperature was observed in the black plastic container (64.7 ºC), black poylthene container (64.2 ºC) and black metal container (58.3 ºC) when covered with transparent poylthene. These temperatures were found to be greater than the lethal temperature (45 ºC) reported by Kumar (1984) and Abdalla (1987) for all developing stages of storage insects.

The data indicated that maximum temperatures were attained in all

Table 3 Maximum temperatures of grain sorghum stored in containers made of different materials (ºC)

Treatment	1:00 pm	2:00 pm	2:30 pm	3:00 pm	3:30 pm	4:00 pm	4:30 pm	5:00 pm
Unpainted metal	43.3 f*	44.2 f	45.6 de	46.4 f	46.6 e	46.6 f	46.2 f	46.0 f
Black metal	47.9 d	50.9 d	51.6 c	52.4 de	52.8 d	52.7 de	52.2 de	51.9 cd
Black metal with cover	52.0 c	54.8 bc	55.5 b	57.4 b	58.3 b	58.2 b	57.7 b	56.8 b
Clear polythene	47.5 de	50.1 d	51.1 c	52.0 de	52.4 d	51.8 e	50.4 e	50.2 de
Black polythene	51.5 c	54.3 bc	55.2 b	56.1 bc	56.5 bc	55.9 bc	55.0 c	55.0 bc
Black polythene with cover	58.4 a	61.8 a	63.1 a	64.2 a	63.7 a	63.3 a	62.9 a	63.4 a
Clear plastic	45.1 ef	47.1 e	47.5 d	48.2 f	48.4 e	48.2 f	47.7 f	46.6 ef
Black plastic	49.4 cd	52.4 cd	53.0 bc	54.2 c	54.8 cd	54.6 cd	53.9 cd	52.7 cd
Black plastic with cover	56.6 b	59.4 b	61.4 a	64.7 a	63.1 a	63.4 a	62.6 a	61.1 a
Atmospheric temperature	39.0 g	39.8 g	40.2 e	40.2 g	40.2 ef	40.1 g	39.6 f	38.8 g

*Within a column, values with the same letter are not significantly different at 5 % level according to Duncan's multiple range test.

containers at 3:30 p.m. or after 8.5 hours of exposure to direct solar radiation as presented in **Table 3**. After reaching the maximum, the temperature started to decline specially in the black containers, that may be due to the high emittance of the black paint that ranges between 0.95 to 0.99, which agreed with Rai (1987) who reported that the ideal black body has not only the highest absorption rate but also the highest coefficient for all wavelength. Also the reduction of temperatures may be due to the changes of angle of incidence of the sun radiation, which is zero at mid-day and it is in maximum value at early morning and the late afternoon. This is in agreement with Prevett and Halliday (1961) and MWPS-22 (1980) who reported that the maximum amount of solar is available at mid-day and the maximum temperature rise in the solar collecor occurs near solar noon.

The results of the study discussed above indicated that the black plastic container with transparent cover, exposed directly to sun radiation, maintained highest temperature followed by black polythene with transparent cover, but these containers had been damaged by high temperature for long exposure.

The Effect of Structure's Geometry and Shape on Temperature Changes of Grain Sorghum:

The mean values of temperature gained by sorghum in different geometrical designs after exposure to direct sun radiation at different times are shown in **Table 4**. At 8:00 a.m. temperatures gained by grain sorghum in all geometrical shapes were 31.5-32.0 ºC higher than atmospheric temperature (31.4 ºC) except in pyramid shape (29.8 ºC). At 10:00 a.m. sorghum grain in all structurs gained temperatures (31.9-33.2 ºC) less than atmospheric temperature (34.4 ºC) except in triangular shape (36.1 ºC). Grain sorghum in pyramid and triangular shapes gained highest temperatures (40.8 ºC) and (39.4 ºC) at noon, where grain in other structures gained temperatures lower than atmospheric temperature. Also at 2:00 p.m. the grain in pyramid and triangular structures recorded higher temperatures than in other structures. At 4:00 p.m. grain sorghum in all geometrical shapes gained temperatures higher than atmospheric temperature. The highest temperatures (47.6 ºC and 44.1 ºC) were gained by grain sorghum in pyramid and triangular shapes, respectively.

Table 5 shows the maximum temperatures gained by grain in different structures of metal. The highest temperatures were gained by grain in pyramid and triangular shapes followed by grain in cylindrical shape, cubic and rectangular shapes. The statistical analysis of variance indicated that there was a significant variation between maximum grain sorghum temperatures in the five structures at 5 % and 1 % levels (**Table 6**). Duncan's test indicated that there was insignificant difference between temperatures gained

Table 4 Mean grain sorghum temperature in metal containers with different geometrical designs (ºC)

Time	Cubic	Cylinderical	Pyramid	Triangular	Rectangular	Atmosphere
8:00 a.m.	31.4	31.8	29.8	31.5	32.0	31.4
10:00 a.m.	32.4	32.6	31.9	36.1	33.2	34.4
12:00 noon	34.1	34.5	40.8	39.4	35.0	35.1
2:00 p.m.	36.0	35.8	43.8	42.6	36.3	36.4
4:00 p.m.	38.2	38.4	47.6	44.1	37.9	36.1

Table 5 Maximum grain sorghum temperature in metal containers with different geometrical designs (ºC)

Design	1	2	3	4	5	6	7	8	9	Mean
Cubic	42	38	42	36	35	42	39	40	40	39 b*
Cylinderical	43	50	42	36	35	42	40	38	41	40 b
Pyramid	54	45	53	43	45	45	49	43	50	48a
Triangular	48	44	47	41	43	45	41	38	39	43 a
Rectangular	38	40	36	36	38	37	33	36	39	37 b
Atmospheric	39	40	40	36	36	38	39	35	39	38 b

*Within a column, values with the same letter are not significantly different at 5 % level according to Duncan's multiple range test.

Table 6 ANOVA table for maximum grain sorghum temperatures in metal containers with different geometrical designs (ºC)

Source of variation	df	SS	MS	F calculated	F tabulated	
					1 %	5 %
Total	54	85,483.2				
Treatment	5	84,971.6	16,994.3	1,634.1**	2.93	2.15
Error	49	511.6	10.4			

by grain in pyramid and triangular. Duncan's test also indicated that there was insignificant difference between temperatures gained by the grain in the other three structures, but there was a significant difference between temperatures gained by grain sorghum in pyramid and triangular shapes and temperatures gained by grain in other three structures (**Table 5**).

The increase in grain temperatures in the different structures could be related to many factors. One of these factors was the geometrical center (was chosen as sampling point) which differs from one structure to another in terms of relative distance from the exposed surface of the horizontal, sloped and vertical sides. The other factor is that when the surface set perpendicular to the sun rays (the incident angle Θ is zero) it provided maximum interception and minimum reflection. MWPS-22 (1980) showed that when the sun rays strike the earth atmosphere, at much flatter angle the greater fraction is reflected. Neubauer and Cramer (1968) showed that the structure's shape had a great effect on the interior temperature and the cubic gave the lowest temperature followed by cylindrical, wedge and dome. The last factor was the top surface area that was exposed to direct sun rays at noon time when the sun was vertical. This top surface area differs greatly for different geometrical designs (Abdalla, 1987).

The Effect of High Temperature and Exposure Period on Control of Storage Insect Pests:

The hatchability and development of eggs to adults of the three insects studied (Tribolium castaneum, Trogoderma granarium and Rhizoprha domonica) were decreased with increase of temperature and exposture period. At 44 ºC the number of insects that emerged from live eggs dropped to zero after two hours whereas at 45 ºC a 100 % mortality was recorded after one and half hour. At 40 ºC the alive larvae were 100 % for all periods of exposure which meant that the time of exposure had no effect on percent of mortality up to that temperature. Above 40 ºC the percent of mortality increased with the increase of temperature and exposure period. At 45 ºC the larvae mortality recorded 20 % after half an hour and increased to 80 % after one hour and reached 100 % after one and half hour exposure period. At 40 and 41 ºC the recorded percent of alive adult insects was 100 % for all periods of exposure which means there was no effect of exposure time up to 41 ºC temperature. Above this temperature the mortality percentage increased with the increase of temperature and exposure periods until it reached 100 % after one hour exposure period. These results indicated that 45 ºC was the lethal temperature for all developing stages of insects under investigation.This result agreed wih Hall (1970) who showed that at up to about 42 ºC temperature, most of insects will die if exposed for long enough period.

The Effect of High Temperature and Exposure Period on Quality of Grain Sorghum:

Treatment of sorghum grains at a temperature of 55 ºC for up to two hours did not indicate any harmful effect in all studied parameters except moisture content, 1,000 kernels weight and hectolitre weight. Decrease in moisture content resulted in decrease in 1,000 kernels weight, hectolitre weight and sorghum grain hardness. Slight changes in chemical constituent were observed in protein and fat acidity without exceeding the recommended levels. Treatment of sorghum grains at 55 ºC for two hours could be safely used without affecting seed germinability. However, increasing temperature or treatment period resulted in slight decrease in germinability.

Conclusions

Grain temperature could be increased above atmospheric temperature just by keeping it in a closed container exposed to solar radiation for few hours. The increase of grain temperatures was higher in black containers irrespective of the container material. This was due to the absorptance of the black colour. Covering the black containers with transparent polythene could even result in further increase in temperature of grain kept in these containers. The maximum temperatures were observed in black plastic container, black polythene container, and black metal container when covered with transparent polythene.

The rate of heat losses from different containers, after reaching the maximum temperature, ranged from 4 ºC for black plastic container to 1 ºC for clear plastic container.

Material of metal containers resisted the damage by high temperature compared to plastic, polythene and jute which damaged by high temperature for long exposure.

Solar radiation could easily be utilized to increase grain temperature above 55 ºC in containers of different materials with simple treatment like black painting and covering the containers with transparent polythene even during the coolest months of the Winter season. This temperature was greater than the lethal temperature (45 ºC) for all developing stages of storage insects.

The structures with inclined surfaces like pyramid and triangular recorded the highest maximum temperatures compared to vertical structures. The inclination of pyramid and triangular sides and their large surface areas that exposed to sun at mid-day are the main reasons for such behavior.

Study of the effect of temperature and exposure period indicated that 45 ºC is the lethal temperature for all developing stages of the three insects investigated when subjected to such temperature for one and half hour.

Treatment of sorghum grains at a temperature of 55 ºC for up to two hours did not indicate any harmful effect in all studied parameters except moisture content, 1,000 kernels weight and hectolitre weight. Treatment of sorghum grains at 55 ºC for two hours cold be safely used without affecting seed germinability. However, increasing temperature or treatment period resulted in slight decrease in germinability.

Generally, it could be concluded that solar energy could be utilized for control of storage insects as represented by the selected insects with simple treatment of the containers tested in this study. It should be clear that for small quantities of sorghum grain such treatment could be applied under Al-Ahsa conditions throughout the year.

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■■

NEWS

Tractor and Agricultural Machinery Manufacturers Meet (TAMM -2014) at IISR Lucknow during Feb. 15-16, 2014

The All India Agricultural Machinery Manufacturers Association (AMMA-India) and Indian Institute of Sugarcane Research, Lucknow are planning to organize a two-day Tractor & Agricultural Machinery Manufacturers Meet (TAMM-2014) during February 15-16, 2014 at IISR Lucknow.

The purpose of this meet is to discuss the problems faced by the tractor, power tiller, combine and agricultural machinery manufacturers, testing of farm equipment, financing, credit policies and subsidy related issues etc for farm equipment.

This Meet would be attended by the Tractors, Power Tillers, Combines and Agricultural Machinery Manufacturers from all over the country, government and semi-government officials from the State and Central Governments, Scientists from Institutions, representative from Banks, NABARD, Insurance Sectors and farmers.

Abstracted from *ISAE Newsletter* Page 14. ■■

Current Status of Electrostatic Spraying Technology for Efficient Crop Protection

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Abstract

Pesticide application to protect crops against diseases and pests is an integral part of modern farming. Electrostatic spraying of pesticides improves not only the deposition efficiency but also the spatial distribution of deposited droplets throughout the plant canopy, particularly under leaf application where pests usually hide and reside. A review of current status in the field of electrostatic spraying technology for agricultural applications is presented in this paper. Current results of research conducted on the electrostatic spraying, charging methods, induction parameters, sprayer testing, and bio-efficacy have been presented. Research findings on the induction charging method, charge to mass ratio, air flow speed, electrode radius and distance from nozzle, voltage, spray distribution pattern, spray deposition, image analysis and drift losses are summarized in this review. It is found that induction charging is the most widely used method, as the high voltage for particle charging does not directly contact the liquid, the electric field strength is below the breakdown strength of the air, its working voltage is relatively low, and electrode insulation is easier. The high charging voltage leads to high charge to mass ratio and higher underside deposits. The average deposit does not increase with the charging voltage. The charging factor increases first and then decreases or remains unchanged with the increasing distance between electrode and nozzle. The use of machine vision combined with image analysis is considered to increase speed, ease of use and to reduce the cost of spray deposition assessment. With the electrostatic spraying, the mortality of pests is also higher than non-electrostatic spraying. Reducing spray volume from 250 l/ha to 1 l/ha does not change bio-efficacy in the electrostatic spraying.

Introduction

Application of pesticides is still one of the most frequently used methods to protect crops and tree against diseases and insects in agriculture. Over dosage of pesticide is common in most countries and its application leads to many problems such as chemical waste and environmental pollution from spray drift (Laryea & No, 2004). There have been many approaches to reduce the amount of pesticide applied in agricultural spray. Small-scale farmers usually apply dilute pesticide solution using a knapsack sprayer with a hydraulic nozzle. This method is simple but has several disadvantages. Spray distribution is poor and labour costs are high (Heijne, 1980). More than 80 % of pesticides are deposited on the ground by using these sprayers (Zhou & He, 2010). The application of chemicals through electrostatic spraying technology is being claimed to be simple, safer, and easy to use without any material losses with increasing the deposition characteristics of spray and also for bringing several environmental improvements and cost saving benefits (Elmoursi, 1992). Electrostatics has also been adapted to agricultural application of crop production and protection materials (Bowen *et al*., 1952).

Crops like cotton and soyabean have fairly very dense canopies at the latter growth stage. There are about 40 million farmers cultivating cotton on approximately 9 million hectares in India. Cotton cultivation in India accounts for about 5 percent of the total land cultivation, but requires nearly 50 percent of the pesticides used in the country. Soyabean has also become an important crop in India. The area coverage of soyabean was 8.72 million hectares with estimated production of 8.87 million tons in 2007. During the year 2010, area sown under soyabean was 9.31 million hectares. More than 90 % of these pesticides are applied by hydraulic sprayers especially knapsack sprayers (Lalitha, 2008). Electrostatic spraying technology is new to Indian agriculture. If a suitable high voltage circuit is developed, this technology will become viable for many countries like India. Therefore, there is a need to initiate research in the field of electrostatic sprayers. A few researchers have attempted to design high voltage circuits and reported stability problems with their circuitry (Ganapathy and Singh, 1993). This has led to significant advanced research and development of electrostatic spraying technology for beneficial agricultural applications. Application efficiency up to 80 % with 50 % less pesticide doses is reported to have been achieved with charged sprays (Giles and Blewett, 1996) and resulted in increased biological efficacy (Palumbo and Coates, 1996). The application of electrostatic pesticides spraying covers the hand-held sprayers, tractor mounted systems such as boom sprayer and rotary sprayers, orchard sprayers and aerial sprayers (Chang *et al*., 1995).

The objective of this paper is to present a global review about the present status and potential of this technology for efficient protection of crops.

Fig. 1 Principle of Electrostatic Spraying

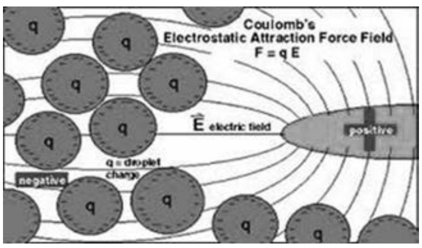
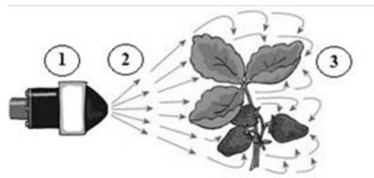


Fig. 2 Electrostatic Spraying to the Plant



1. Nozzle, 2. Spray Particle, 3. Plant Canopy

Fig. 3 Induction charging Method

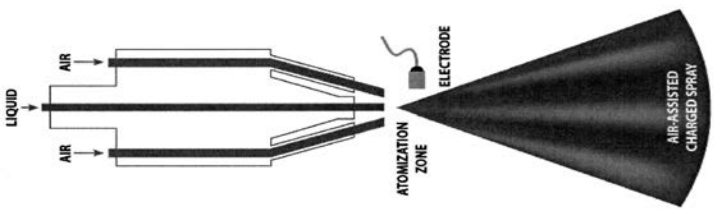
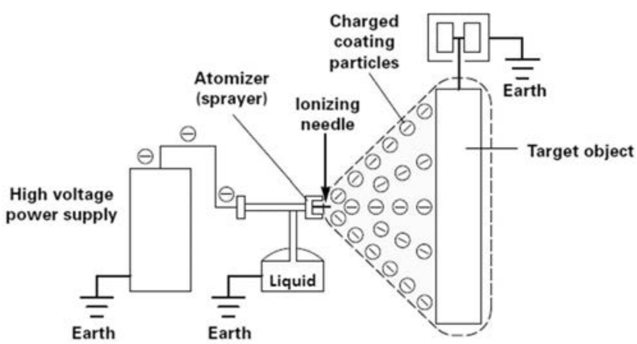


Fig. 4 Corona charging Method



Electrostatic Principle and Charging Methods

The principle that opposite charges attract is Coulomb's Law. The charged spray droplets are attracted by the positively charged leaf surface as shown in **Fig. 1**.

The charged spray droplets bend upward the underside of the leaf surface (**Fig. 2**). Once the leaf has been adequately covered in spray material, the positive charge on the leaf dissipates allowing other droplets to find places in the canopy that have not been covered.

Charging methods of pesticides include induction charging, ionized charging (corona charging), and direct charging (contact charging or conduction charging) (Matthews, 1989).

In induction charging, the grounded spray liquid stays near high voltage electrode for sufficient time so that opposite charges are induced on the spray droplets (**Fig. 3**). Voltage requirement is 5-15 kV and this method is reported to be suitable for spray liquids having electrical conductivities in the range of 10-6 to 10-4 ohms (Law, 1978). Induction charging method is used for conductive spray mixture.

In Corona charging, a high voltage electrode (30-70 kV) ionizes the surrounding air by emitting electrons (**Fig. 4**). The negatively charged ions form a cloud surrounding the electrode and some of them are attracted back to the high voltage electrode. The droplets emanating from the nozzle pass through the vicinity of the electrode, pick up the ions, and become charged sprays. The maximum level of charge on a droplet by this method is defined as Rayleigh limit (Rayleigh, 1882). Ionized charging method is used for either conductive or non-conductive pesticide solution. A needle tip connected to a high voltage can ionize the air to create an intense electric field. The spray particles passing through the electric field are charged by ion attachment. This method was tried on pressure and rotary atomizers by Marchant and Green, 1982.

In conduction charging, the high voltage electrode makes direct contact with the spray liquid (**Fig. 5**). The charged liquid is atomized later to form droplets and the charged droplets are driven to the target. For conduction charging, voltage of 25-30 kV needs to be applied on the spray liquid (Law, 1980). Direct charging method can be used for semi-conductive liquid like oil based spray.

There are merits and demerits of each of these methods for charging the spray liquid. In Corona charging systems, insulating the spray tank from high potential is reported to be a difficult task. In conduction charging, the voltage electrode may attract some spray droplets and gets wet, which in turn will reduce the electric field strength. In order to keep the electrode dry, some researchers (Law, 1980) used compressed air. In contact charging method or conduction charging, oil based spray liquid works better than water based liquids since evaporation of small droplets is a serious problem with water-based solutions. Out of these methods, the induction charging is most widely used because it offers several advantages compared with conduction charging:

1. High voltage does not directly contact the liquid.
2. Electric field strength is below the breakdown strength of the air, so its working voltage can be lower and electrode insulation becomes easier.
3. In principle, there is no current drawn from the power supply, therefore the current capacity can be very small (Zhao *et al*., 2005).

Fig. 5 Conduction charging Method

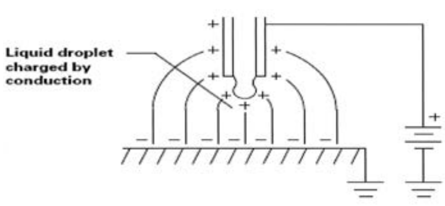


Table 1 Design Parameters for Electrostatic Spraying

Parameter	Range of Parameters
Nozzle Diameter, mm	1.5-2.0 mm (air assisted), (Juste *et al*., 1990)
Charging Type	Contact charging (Ganpathy and Singh, 1993), Induction charging (Scherm *et al*., 2007 and Maynagh *et al*., 2009), Corona Charging (Marchant and Green 1982 and Yu Ru and Zheng, 2011)
Electrode Radius (R), mm	15 (Maynagh *et al*., 2009)
Distance from Nozzle (l), mm	10 (Maynagh *et al*., 2009)
Voltage Input, V	6 (Ganpathy and Singh, 1993), 2-9 (Zhou *et al*., 2009), 24-36 (Yu Ru and Zheng, 2011)
Voltage output, kV	0-1.2 (Scherm *et al*., 2007), 14-24 (Cooper *et al*., 1998 and Yu Ru and Zheng, 2011), 1.5-7 (Maynagh *et al*., 2009)
Charge to mass ratio, mC/kg	0.27 (Gabriel &, Soo, 2003), 1.032 (Maynagh *et al*., 2009), 7.8 (Scherm *et al*., 2007), 3.8 (Carlton & Bouse, 1985), 0.8 (Law & Lane, 1981), 2.35 (Yu Ru and Zheng, 2011)

Out of the various liquid charging methods, the induction charging approach has appeared to be more convenient and practical for the electrification of aqueous pesticides.

Borra *et al*., 1999 reported a similar influence of applied voltage on the modes of electrostatic spray for ethanol and water. They also indicated that corona discharge plays an important role in changing the spray pattern. Jaworek and Krupa (1999) studied the corona discharge in electro hydrodynamic (EHD) spraying and found that the region of corona discharge was highly correlated to the spray pattern. Some prototype electrostatic sprayers were developed on the basis of the three kinds of charging methods. Law (1978) described a twin-fluid electrostatic atomizer; Marchant and Green (1982) developed an induction charging system for hydraulic nozzles; Ganzelmeier and Moser (1980) designed a hydraulic-based electrostatic sprayer using a 70 kV voltage to generate the ions; Coffee (1979) developed a hand-held sprayer used for a semi-conductive spray liquid.

Effect of Induction Parameters on Droplets Charging

Several parameters such as solution characteristics, physical properties of the nozzle, and the characteristic of electrical potential have influence on droplet charging. The independent parameters in this review included voltage, air flow speed, radius of charging electrode, liquid flow rate, and horizontal distance between the electrodes. The design and operational parameters of electrostatic sprayer (Hand held, Knapsack sprayer and Tractor Mounted sprayer) for various crops are shown in **Tables 1** and **2**.

Charge-to-mass ratio (q/m) is a critical factor in electrostatic enhancement of agricultural aerial spray deposits. Inculet and Fischer

Table 2 Operational Parameters for Electrostatic Spraying

Parameter	Values Range
Nozzle flow rate, l/min	0.691 (Gabriel &, Soo, 2003), 4.775 (Salyani & Whitney, 1990), 0.6-8 (Yu Ru and Zheng, 2011)
Volume flow rate, l/ha	5.25 (Cooper *et al*., 1998); 250-750 (Juste *et al*., 1990); 37.5-oil, 220-3750- water (Salyani & Fox, 1999)
Droplet Size, µm	80-380 (Juste *et al*., 1990), 100 (Coffee, 1979)
Air Flow speed, m/s	5 (Scherm *et al*., 2007), 8.5 (Gabriel &, Soo, 2003), 14-23 (Maynagh *et al*., 2009),
VMD, µm	30 (Scherm *et al*., 2007), 116 (Gabriel &, Soo, 2003), 80 (Yu Ru and Zheng, 2011)
Ground Speed of sprayer, km/h	6.4 (Scherm *et al*., 2007), 1.8 (Cooper *et al*., 1998), 1.6-6.4 (Salyani & Whitney, 1990)
Operating Pressure, MPa	0-0.5 (Scherm *et al*., 2007), 1.38 (Salyani & Whitney, 1990), 2.0 (Gabriel &, Soo, 2003), 0.2 (Zhou & He, 2010)

(1989) reported only a marginal increase in electrostatic aerial spray deposition with a charge-to-mass ratio (q/m) of 0.3 mC/kg. Carlton and Bouse (1985) with simulated aerial field deposition reported relatively low increases in spray deposits as mass flow rate of liquid (Qm) increased in the lower range, but depicted dramatic increase in deposits with charge-to-mass ratio (q/m) of 3.8 mC/kg or greater. Law and Lane (1981) in controlled laboratory studies with electrostatic spray rates of 9.4 l/ha (1 gal/acre) and charge-to-mass ratio (q/m) from 2 to 8.2 mC/kg reported increase in deposits of 1.4 to 4.4 fold with electrostatic charging as compared to conventional spray rates and similar uncharged sprays.

The ratio of charge to mass at all voltage levels decreased with an increasing flow rate (Dante and Gupta, 1991). At higher voltage, on increasing the liquid flow rate, the charged current spray was reported to first increase and then remains constant or decline. The high charging voltage amounted to high charge to mass ratio and high underside deposits (Zhou and He, 2010). The average deposits did not increase with the charging voltage. Air pressure was considered as an important parameter to affect the average and underside deposits. Optimum air pressure should be chosen in terms of combination forces applied on the drops. For the prototype electrostatic nozzle, air pressure used was 0.2 MPa (29 psi) which was better than others, as it led to higher average and underside deposits. Like air pressure, there was an optimum flow rate, because of the sensitive point of atomization. Flow rate at 70 ml/min appeared to get higher deposits and better deposition uniformity, while high or low flow rates reduced deposits.

Sprayer Testing Procedures

Spray Deposition and Distribution Pattern

Electrostatically charged application of spray increases deposition, especially under-leaf deposition, and improves the distribution pattern of spray significantly. It was reported that electrostatically charged application significantly increased deposition of B. subtilis on the flower stigmas by a factor of 4.5 compared with hydraulic spraying. Using the electrostatic system with zero induction-charging, voltage resulted in population counts not significantly different from hydraulic spraying. Electrostatic application of a B. thuringiensis-based bioinsecticide to broccoli plants at reduced application rates showed equal or greater control of insect infestation afforded by as little as a 1.9 fold increase in spray tracer deposition on treated plants (Law & Mills, 1980). Electrostatic spraying could increase the total deposits on the target and meanwhile improve the distribution (Franz *et al*., 1987). When an air-assisted atomizing induction-charging nozzle was used, the deposition achieved by charged spray was 1.5 to 2.4 fold greater than uncharged condition. Charged sprays also increased spray depositional efficiency (Babu *et al*. 1990).

Gupta and Duc, 1996 reported that Laboratory experiments were carried out to determine spray distribution pattern and deposition characteristics of an air-assisted electrostatic spinning disc sprayer at various conditions. Spray distribution patterns were obtained with the aid of a patternator. Fluorometric analysis was done by quantified tracer deposit on different levels of the soyabean plants. Parameters studied were disc rotational speed, liquid flow rate, fan speed, tilt angle between disc plane, and air stream direction. When electrode voltage was maintained at 2.5 kV, the results indicated that the ratio of deposition density of air-assisted and non air-assisted application at top, middle, and bottom levels was 1.38, 1.37, and 1.5 fold respectively. Mean deposition on plant target increased 1.44 fold due to air assistance. The leaf underside deposition occupied 27 % of the total deposition. It increased 7 % over that of the electrostatic unit because of air assistance.

The magnitude of increase in deposition of the two biocontrol agents on flower stigmas afforded by electrostatically charged spraying was from 2 to 7 fold increase reported for synthetic chemically formulated pesticides applied to crop foliage and 5.6 fold increase for electrostatic pollen sprays onto almond flower stigmas (Law *et al*., 2000).

One of the important benefits provided by charged sprays is the ability to increase the deposits on the abaxial (underside) surface of leaves. Some insects like aphids, spider mites and whiteflies, feed on the underside surfaces of cotton leaves which result in inefficiency of conventional spraying method. Air-assisted electrostatic spraying was found to improve abaxial deposition with uniform coverage at all target heights (Maski and Drairaj, 2006).

Application orientation is reported to affect the deposits. Maximum average deposits occurred at vertical degree (direct to the targets). Forward angles achieved higher average deposits, while backward angles achieved higher underside deposits meant to assess the characteristics of charged deposition (Zhu *et al*., 2008).

Chemical methods for deposition analysis include colorimetry, fluororimetry (Salyani and Whitney, 1988) and chromatography (Sundaram, 1994), which have been commonly used in the agricultural research field for several years, but they are quite time-consuming and expensive to analyze a large area with the chosen accuracy (50 mm × 50 mm) and with numerous repetitions. The use of machine vision combined with image analysis was considered to increase speed and ease of use and to reduce the cost of spray deposition assessment (Evans *et al*., 1994). The spray width was measured by employing a digital image processing technique that captured multiple image of the spray with a 720 × 480 pixel 3-CCD digital video camera and the frame-grabber board (Gabriel and No, 2003). Direct light source from the stroboscope illuminated the spray cloud from dark background. The spray width is measured from the nozzle tip to an axial distance of 120 mm at 10 mm interval.

Drift Losses

Charged spray reduced drift by about 40 % using an electrostatic hydraulic nozzle (Sharp, 1984). Cooke and Hislop (1987) reported similar results. The reduction in drift was due to the larger electrostatic force on smaller droplets than the gravitational force. A minimum charge-to-mass ratio of 0.8 mC/kg was needed to get the beneficial results in crop spraying (Law and Lane, 1981).

Western and Hislop (1991) tested electrostatic sprayers using fine spray droplets in a wind tunnel for their capacity to reduce drift. They compared a conventional sprayer, an air-assisted sprayer, and an electrostatic sprayer, with and without air assistance. All tests showed that spray drift increased with wind speed and decreased with air-assistance. Drift from conventional application was reduced by 71 % using minimum air-assistance and by 88.3 % using maximum air-assistance, at 2 m/s wind speed.

A laboratory study was conducted to evaluate the effectiveness of an air jet on reducing drift from an electrostatic nozzle and increasing canopy deposits. The results indicated that an air jet with 11 m/s downward air velocity at the point spray greatly increased the amount of spray deposited in the target area and also improved penetration of the spray downward into the canopy while reducing drift (Almekinders *et al*., 1993). Spray deposits of air-assisted charged sprays with volume median diameter (VMD) of 92 μm, were collected in a wind tunnel with wind velocities up to 5 m/s. Computational fluid dynamic software (Fluent®) was used to determine the effects of several variables on drift distances of individual spray droplets (Zhu *et al*., 1995). Drift distances of water droplets as large as 200 μm diameter were influenced by initial droplet velocity and height of discharge. Smaller droplets are evaporate quicker when the humidity is low and may not reach the target. Miller, 1998 presented data comparing drift from a conventional boom equipped with nozzles giving a medium or a fine spray. Typically, the amount of drift associated with the fine spray is twice as large as the amount produced using a medium spray.

Bio-efficacy of Sprayer

A study (Lund and Jensen, 2002) specifically suggested that the biological efficacy of various nozzles used for band spraying was not related to the measured horizontal spray distribution pattern. Zhou *et al*., 2009 reported that with the electrostatic spraying, the average cumulative mortality of pests was 94.5 % and with the non-electrostatic spraying, the average cumulative mortality of pests was 76.7 %. Weevil mortality was counted twenty-four hours after treatment. Percent mortality compared to check samples was computed by the Abbott (1925) procedure. The highest mortality of pests appeared on the fourth and the fifth day after spraying and the total number of dead pests reached up to 76 % of total deaths. There was a sharp decline in deaths after the seventh day. It was shown in the tests that with the electrostatic spraying, the mortality of pests was significantly higher than that of the non-electrostatic spraying. It was positively correlated with the fact that the droplet deposition effect with electrostatic spraying was obviously better than that of non-electrostatic spraying. The reason was that with the electrostatic spraying, the droplet deposition density was larger, the distribution was more uniform and the larvae had more chance to contact pesticide leading to higher mortality.

Carlton, 1996 reported that aerial electrostatic applications in spray rates of 4.7 l/ha were compared with conventional aerial applications in spray rates of 46.8 l/ha. The charge/mass ratio (Q/M) for the electrostatic applications was typically ±1.15 mC/kg. Applications were initiated and repeated at least weekly when whitefly counts reached threshold levels of 5 adults per leaf. It was shown that the effect of aerial electrostatic spraying was superior to conventional aerial spraying. It was beneficial for reducing spraying drift losses, improving the density of droplet deposition. Hislop et al (1983) reported that reducing spray volume from 250 l/ha to 1 l/ha did not change bio-efficacy in electrostatic spraying. Therefore, it had the outstanding advantages of high spraying efficiency and low spraying cost.

Commercial Electrostatic Sprayers

Successful commercial versions of electrostatic sprayers for greenhouses, ground, and orchards have been available for several years (Kabashima *et al*., 1995 and Sumner *et al*., 2000). Electrodyn Electrostatic Sprayer from ICI Plant Protection Division is commercially available for small farmers in the developing countries. It has the advantage of immobile parts and works well with oil-based formulations because of their electrical characteristic advantages in atomization and less evaporation from the droplets (Coffee, 1981). However, Electrodyn Sprayer cannot be of general use as most of the pesticides in the market are water-based which cannot be applied efficiently because of difficulty in atomization and increased evaporation from spray droplets. Some other commercial versions of electrostatic sprayers are available now, such as twin-fluid air-assisted sprayer from Electrostatic Spraying Systems (ESS), INC., USA; aerial electrostatic sprayer and air blast orchard sprayer from Spectrum Electrostatic, INC., Houston, TX, USA and LectroBlast® Electrostatic Orchard/Vineyard Sprayer, California, USA. Aerial electrostatic application has also been a subject of research and development (Carlton and Isler, 1966; Inculet and Fischer, 1989). Kirk *et al*., 2001 had compared the cotton spraying effects with aerial electrostatic spraying technology and conventional aerial spraying technology. It was shown that the aerial electrostatic spraying efficiency was nearly doubly higher than that of conventional aerial spraying, especially on the back of vane.

Conclusions

In the paper, research and development on the electrostatic spray charging methods, various induction parameters, sprayer testing, bio-efficacy, and commercial versions of electrostatic spraying for agriculture have been reviewed. Out of the various liquid charging methods, the induction charging approach has appeared to be more convenient and practical for the electrification of aqueous pesticides. The results obtained show that as the voltage on the electrode increases, the greater charge of the opposite sign to that of the induction surface (electrode) is induced on the droplets generated. Electrostatic sprayers work ideally on dense and broad leafy crops like cotton, soyabean, etc. The electrostatic spray can also be used in citrus, cereal, orchard, etc.

At higher voltages, the charged current spray is first increased on increasing the liquid flow rate and then becomes constant or dropping. The high charging voltage meant high charge to mass ratio and high underside deposits. The average deposits did not increase with the charging voltage. Air pressure was one of the most important factors to affect the average and underside deposits. Induction charging is the most widely used charging method for an electrostatic sprayer because of several advantages compared with conduction charging. These include high voltage does not directly contact the liquid; Electric field strength is below the breakdown strength of the air; so its working voltage can be lower and electrode insulation becomes easier; There is no current drawn from the power supply; therefore the current capacity can be very small. The electrostatic spray improves deposition efficiency and coverage uniformity, accelerates the droplet settling speed, reduces the drift loss, and lowers the pesticide application rate. With the electrostatic spraying, the average cumulative mortality of pests was reported to be 94.5 % and with the non-electrostatic spraying, the average cumulative mortality of pests was reported to be 76.7 %. Reducing spray volume from 250 l/ha to 1 l/ha did not change bio-efficacy in electrostatic spraying. Therefore, it had the outstanding advantages of high spraying efficiency and low spraying cost. Electrostatic sprayers are commercially available for green houses and orchards in the countries like USA, Korea etc. The results of this technology are encouraging but still it is in infancy stage due to its high initial cost, lesser mobility having high tech electrical system for spray charging, lack of awareness among the farmers about the technology etc.

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Color Image Analysis of Green Bean and Green Pea Pods for Determining the Optimal Harvest Time

by

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Abstract

The main objectives of this research were to study the optimal harvest time of green beans (*Phaseolus vulgaris L. var Paulista*) and green peas (*Pisum Sativum L. var Sugar Lays*) by color image analysis depending on maturity, and creating the color standards at different ages. The results sowed that: 1). The percentages of color components increased for red (R), green (G) and blue (B) from 29.0 % to 60.4 %, from 44.3 % to 76.5 %, and from 15.3 % to 49.0 % for pod ages from 10 to 31 days, respectively. Values for sweet pea pods increased from 26.67 % to 51.76 %, from 41.18 % to 61.57 %, and from 15.29 % to 29.80 % for pod ages from 6 to 33 days, respectively. 2). The relationships between red color (R), green color (G) and blue color (B) as functions of the pod age (A) were:

$R = 39.490 + 3.909\,A$, $G = 78.203 + 3.755\,A$, and $B = 3.826\,A - 1.063$ (green bean pods)

$R = 52.767 + 2.423A$, $G = 96.462 + 1.817\,A$, and $B = 34.027 + 1.080\,A$ (sweet pea pods)

3). According to this study, this criteria as a standard for quality depending on color to determine the optimal harvest time appeared 22 and 18 days for green bean and pea pods (from appearing of the pod flower), which were 34.12 % (R), 43.04 % (G) and 22.83 % (B) while for green bean were 33.45 % (R), 45.99 % (G) and 20.56 % (B).

Introduction

Gunasekaran and Paulsen (1986) evaluated several non-destructive testing techniques and concluded that computer vision is the most suitable form of automatic quality evaluations.

Mayer and Davison (1987) used electronic image analysis as a method for non-destructive measurement of in situ leaf area, stem diameter, and leaf and petiole angles of several crops.

Choi et al. (1995) developed a color image analysis procedure to classify fresh tomatoes into six maturity ages according to the USDA standard classification: Green, Breakers, Turning, Pink, Light Red, and Red. RGB (Red, Green, and Blue) images of each tomato were captured and converted to HIS (Hue, Saturation, and Intensity) values.

Ng. et al. (1998) stated that the extent of color changes in each of the RGB channels was calculated based on an equation derived from the spectral reflectance models. These values formed a transformation matrix that was used to transform the image RGB values to compensate for the color changes.

Hutchings (1999) said that the color scales are often required to describe the changing colors occurring during ripening, processing, or aging. These colors were transitional and change progressively. The dominant color becames the background as maturity develops. Colormatching functions were as follow: colors can be specified by

$$r = R/(R + G + B),\ g = G/(R + G + B) \text{ and } b = B/(R + G + B)$$

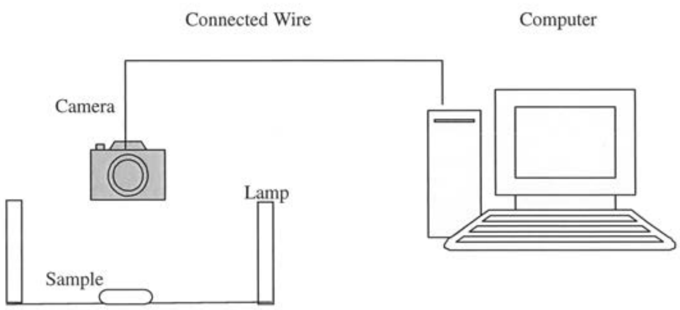
weighted sums of red, green, and blue in equation 1; where light-wavelength, visible part (for humans) is from 400 nm (violet) to 700 nm (red). The amount C of each particular stimulus (R), (G) and (B) that is,

$$C = rR + gG + bB \qquad (1)$$

Where: r, g, b are the amounts of R, G, B colors, respectively.

Whiteman (1999) stated that the additive color process begins with black or the absence of light and therefore no color. And it involves transmitted light before it is reflected by a substrate. Adding and mixing the three primary wavelengths of light (red, green, and blue) in different combinations produce a full spectrum of colors. Adding all primary colors in relatively equal amounts produces "white" light. ***The Color Management Company (2000)*** reported that there were three components necessary for the perception of color: 1) light, which supplies the spectral energy required for viewing color. We cannot see color in the dark and 2) an object that modifies the spectral energy from the light source. The different colors affect the light in different ways. For instance, red objects modify the light differently than green objects, and 3) an observer, whose eye and mind perceive color and appearance. ***Laykin et al. (2002)*** developed image–processing algorithms and implemented them to provide the following quality parameters for tomato classification: color, color homogeneity, defects, shape, and stem detection. The vision system consisted of two parts: a bottom vision cell with one camera facing upwards, and an upper vision cell with two cameras viewing the fruit at 60°. The bottom vision cell determined fruit stem and shape. The upper vision cell determined fruit color, defects, and color homogeneity. Experiments resulted in 90 % correct bruise classification with 2 % severely misclassified; 90 % correct color homogeneity classification; 92 % correct color detection with 2 % severely misclassified, and 100 % stem detection. ***Helmy et al. (2003)*** concluded that the images processing of digital camera were transmitted to into software program by using color analysis, to obtain color component red, green and blue (R, G, and B) and grading of color (hue degree). Fruit mature tomatoes were classified according to color component and grading color into fifteen classes as follows: green, spring, light green, breaker, sand, light orange, peach, turning, faded pink, soft pink, pink, tropical pink, light red, neon red and red. Color component values (R, G and B) of class 1 (green color tomato mature) were 142, 206 and 9 by the percentages were 39.8, 57.7 and 2 %, respectively. While, the value for class 15 (red color tomato ripeness) was 255, 49 and 19 by percentage of 81.1, 15.7 and 3.2 %, respectively. ***Robert et al. (2004)*** said that when farmers or ranchers observe their fields or pastures to assess their condition without physically touching them, it is a form of remote sensing; observing the colors of leaves or the overall appearances of plants can determine the plant's condition. Remotely sensed images taken from satellites and aircraft provide a mean to assess field conditions without physically touching them from a point of view high above the field. The main objective of the present investigation were to measuring of color properties and color analysis of green bean and green peas pods

Fig. 1 The experimental setup and a vision apparatus for color analysis



a) The schematic set up of color analysis.

b) A vision apparatus for color analysis.

at different ages, determining the optimal harvest time of pods according to color components.

Material and Methods

A vision apparatus was used to make color analysis of the samples. It consistsed of an illumination unit (two 400 watts lamps), a digital camera and a personal computer (**Fig. 1**): 1) The digital camera was a digital (Sony, DSC-P200) and was used to take a photo image for different ages of the pods. 2) Images were transferred from the camera to the personal computer for processing and image analysis. The image was 640 × 480 pixels true color (24 bits) resolution of 118 pixels/cm and image bytes of 921600.

Results and Discussion

The color properties were analyzed by software using the personal computer for the photos of green bean pods and sweet peas pods at different ages. The data show the distribution components of main colors Red (R), Green (G) and Blue (B) for green bean and sweet pea pods at different ages.

Green bean pods:

The values and the percentages of color components (R, G, and B) at different ages from the appearance of the pods from the flowers are shown in **Table 1**. Values of G = 255 increased from 113 to 195 at pod ages 10 and 31 days, respectively. The green values were higher than the values of red or blue. The values of (R = 255) component increased from 74 to 154 and for (B = 255) it increased from 39 to 125 for pod's ages from 10 to 31 days, respectively as shown in **Fig. 2**. The percentages of color components increased for (R), (G) and (B) from 29.0 to 60.4 %, from 44.3 to 76.5 %, and from 15.3 to 49.0 % at pod's ages from 10 to 31 days, respectively. The green color was dominant in color component for all ages. Color components, red and blue (R + B), increased gradually when the pod age increased, which affected the appearance of green color. Therefore, when (R + B) decreased, the appearance of green color increased highly although the percentage of green color component increased when the age increased. Therefore, the earliest ages were darker than the later ages.

Table 1 The values and the percentages of color components for sweet peas at different ages

Age, day	Value and percentages of color component						Color %		
	R = 255	%	G = 255	%	B = 255	%	R	G	B
10	74.0	29.0	113.0	44.3	39.0	15.3	32.74	50.00	17.26
13	92.0	36.1	127.0	49.8	50.0	19.6	34.20	47.21	18.59
16	107.0	42.0	141.0	55.3	60.0	23.5	34.74	45.78	19.48
19	108.0	42.4	148.0	58.0	68.0	26.7	33.33	45.68	20.99
22	130.0	51.0	164.0	64.3	87.0	34.1	34.12	43.04	22.83
25	140.0	54.9	168.0	65.9	90.0	35.3	35.18	42.21	22.61
28	152.0	59.6	182.0	71.4	101.0	39.6	34.94	41.84	23.22
31	154.0	60.4	195.0	76.5	125.0	49.0	32.49	41.14	26.37

Using the mean values shown in **Table 2**, the following general equations were deduced to express the relationships between the value of red color component (R), the value of green color component (G) and the value of blue color component (B) for green beans pods at different ages from the appearance of the pods.

For the first age (pods at 10 days):

$R = 1.527\ G = 0.527\ B$ .... (2)

For pods at 16 days:

$R = 1.318\ G = 0.561\ B$ .... (3)

For pods at 22 days:

$R = 1.262\ G = 0.669\ B$ .... (4)

For the last age (pods at 31 days):

$R = 1.266\ G = 0.812\ B$ .... (5)

Generally, the following equations summarize the relationships between R, G and B as a function of the pod age (A):

$R = 39.490 + 3.909A$,
$R2 = 0.219$,
$FRegression = 223$ .... (6)
$G = 78.203 + 3.755\ A$,
$R2 = 0.954$,
$FRegression = 16364$ .... (7)
$B = 3.826\ A - 1.063;$
$R2 = 0.865$,

Fig. 2 The values of color components (RGB=255) for green bean pods at different ages

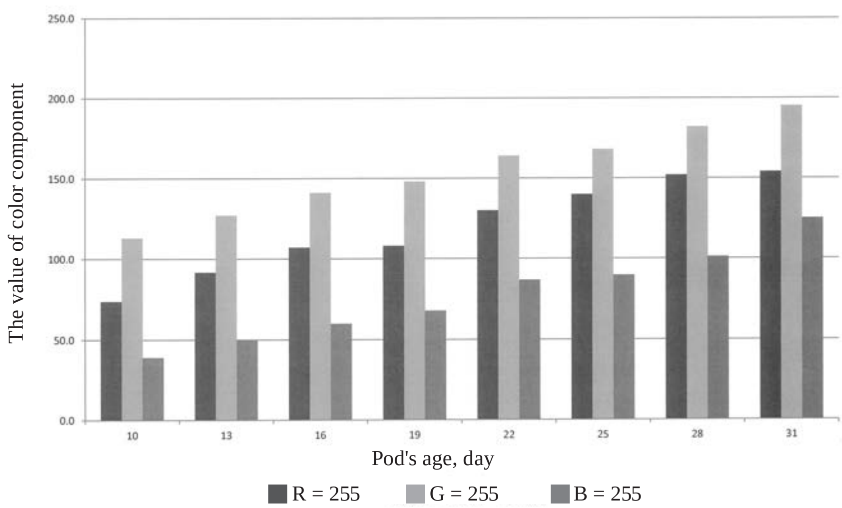


Table 2 The values and the percentages of color components for green beans at different ages

Age, day	Value and percentages of color component						Color %		
	R = 255	%	G = 255	%	B = 255	%	R	G	B
6	68.00	26.67	105.00	41.18	39.00	15.29	32.08	49.53	18.40
9	75.00	29.41	113.00	44.31	45.00	17.65	32.19	48.50	19.31
12	82.00	32.16	121.00	47.45	47.00	18.43	32.80	48.40	18.80
15	87.00	34.12	124.00	48.63	55.00	21.57	32.71	46.62	20.68
18	96.00	37.65	132.00	51.76	59.00	23.14	33.45	45.99	20.56
21	105.00	41.18	135.00	52.94	54.00	21.18	35.71	45.92	18.37
24	112.00	43.92	137.00	53.73	50.00	19.61	37.46	45.82	16.72
27	113.00	44.31	140.00	54.90	56.00	21.96	36.57	45.31	18.12
30	130.00	50.98	155.00	60.78	70.00	27.45	36.62	43.66	19.72
33	132.00	51.76	157.00	61.57	76.00	29.80	36.16	43.01	20.82

Fig. 3 The percentage of color components (RGB %) for green bean pods at different ages from the appearance of the pods from flowers

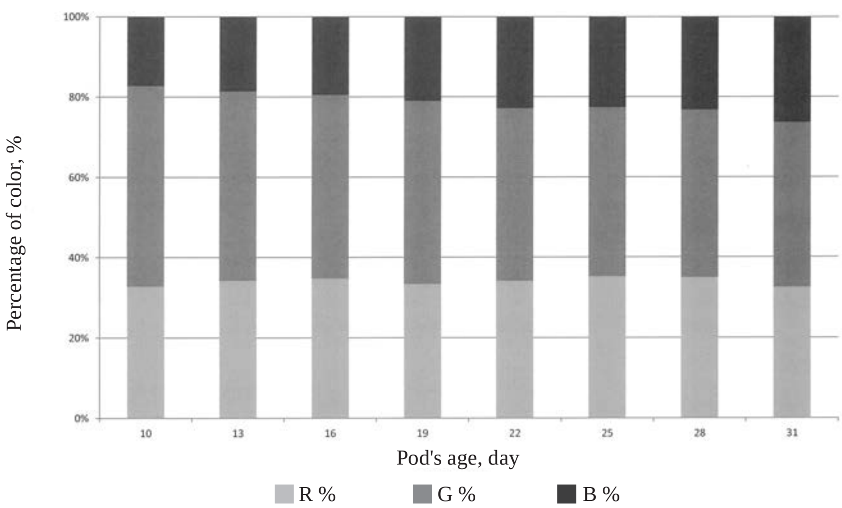
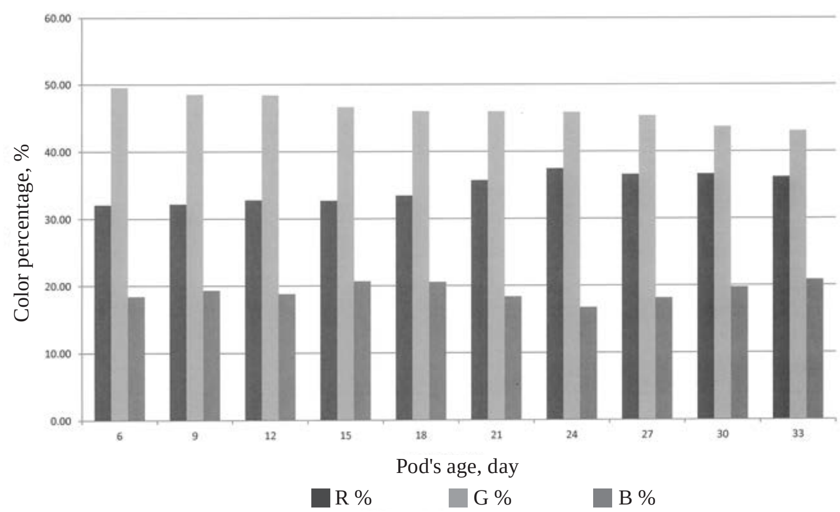


Fig. 4 The values of color components (RGB=255) for sweet peas pods at different ages



$$FRegression = 5134 \quad (8)$$

The equations (6 through 8) indicate that: the age affects green color by percentage higher than the other color (red and blue).

Fig. 3 illustrates the color percentage of main color components (R, G, and B) at different ages of green bean pods. The percentage of color components based on maximum value of red, green, and blue colors, which were 255 for each. For the green color, the component percentage decreased from 50.00 % to 41.14 % when the pod's age increased from 10 to 31 days, respectively. While the other percentages of red or blue colors do not show any trend to increase or decrease. The (R) and (B) percentages lie between 32.49 and 35.18 % and between 17.26 and 26.37 %, respectively.

Sweet peas pods:

The values and the percentages of color components (R, G, and B) at different ages are shown in **Table 2**. Values green color (G = 255) increased from 105 to 157 for pods ages 6 to 33 days, respectively. The green values were higher than the values of red or blue. The values of (R = 255) component increased from 68 to 132 and for (B = 255), there increased from 39 to 76 for pods ages from 6 to 33 days, respectively, shown in **Fig. 4**.

The percentages of color components increased for (R), (G) and (B) from 26.67 to 51.76 %, from 41.18 to 61.57 %, and from 15.29 to 29.80 % for pod's ages from 6 to 33 days, respectively. The green color was sovereignty in color component for all ages.

Values of red and blue (R + B), increased gradually when the pod's age increased, which affected on the appearance of green color. Therefore, when (R + B) decreased, the appearance of green color increased highly although the percentage of green color component increased when the age increased. Therefore, the early ages were darker than the later ages.

The green values were higher than the values of red or blue. The values of (R = 255) were increased from 68 to 132 and for (B = 255) and were increased from 39 to 76 for pods ages from 6 to 33 days, as shown in **Fig. 4**. The percentages of color components increased for (R), (G) and (B) from 26.67 to 51.76 %, from 41.18 to 61.57 %, and from 15.29 to 29.80 % for pod ages from 6 to 33 days, respectively. The green color was sovereign for all ages.

Values of color components, red and blue (R + B), increased gradually when the pod's age increased, which affected on the appearance of green color. Therefore, when (R + B) decreased, the appearance of green color increased highly, although the percentage of green color component increased when the age increased. Therefore, the early ages were darker than the later ages. Using the mean values shown in **Table 2**, the following general equations were deduced to express the relationships between the value of red color component (R), the value of green color component (G) and the value of blue color component (B) for green pea pods at different ages from the appearance of the pods.

For the first age (pods at 6 days):

$R = 1.544, \; G = 0.574\, B$ ....(9)

For pods at 12 days:

$R = 1.476, \; G = 0.573\, B$ ...... (10)

For pods at 18 days:

$R = 1.375, \; G = 0.615\, B$....... (11)

For the last age (pods at 33 days):

$R = 1.189, \; G = 0.576\, B$.......(12)

Generally, the following equations summarize the relationships between R, G and B as a functions of the pod's age (A).

$R = 52.767 + 2.423A,$
$R^2 = 0.934,$
$FRegression = 14197$ .... (13)

$G = 96.462 + 1.817\, A,$
$R^2 = 0.920,$
$FRegression = 11485$ .... (14)

$B = 34.027 + 1.080\, A,$
$R^2 = 0.518,$
$FRegression = 1073$ ....(15)

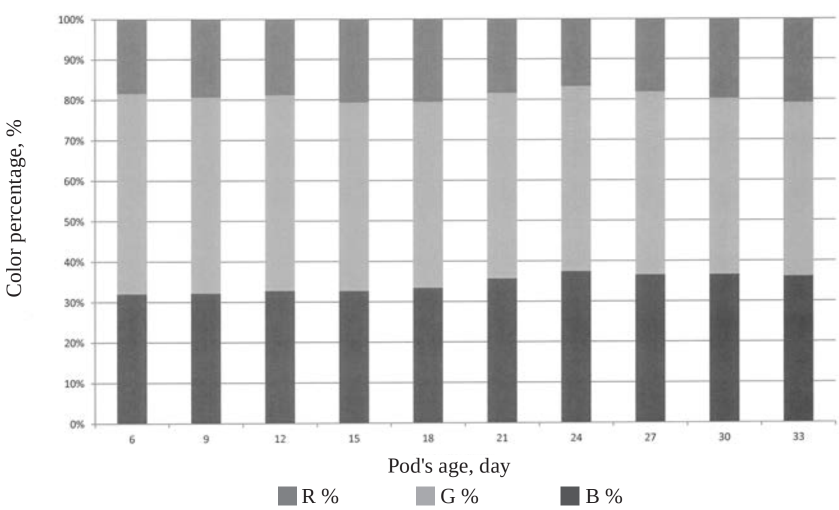
The Equations (from 13 to 15) indicate that: the age affects green color and red color by percentages higher than the blue color.

Fig. 5 illustrates the color percentage of main color components (R, G, and B) at different ages of sweet pea pods. The percentage of color components was based on maximum value of red, green, and blue colors, which was 255 for each. For the green color, the component percentage decreased from 49.53 % to 43.01 % when the pod's age increased from 6 to 33 days. On the other hand, the other percentages of red or blue colors do not have any trend to increase or decrease. The (R) percentage lies between 32.08 and 37.46 % and (B) percentage lies between 16.72 and 20.82 %.

Table 3 Comparison between green bean and sweet pea pods to detect the optimal harvest time from the appearance of the pod

Parameter	Green bean pods	Sweet pea pods
Optimal harvest time	22 days from the appearance of the flower	18 days from the appearance of the flower
The amount of red color (R)	= 1.262 G = 0.669 B	= 1.375 G = 0.615 B

Fig. 5 The percentage of color components (RGB %) for sweet pea pods at different ages from the appearance of the pods from flowers



Conclusion

1. The value of green color component increased from 113 to 195 from green beans pods ages from 10 to 31 days, respectively. And this value increased from 105 to 157 for sweet pea pod's ages from 6 to 33 days, respectively.
2. The value of red color component increased from 74 to 154 and, for blue color, increased from 39 to 125 for green bean pod ages from 10 to 31 days, respectively. For sweet pea pods, the value of red color component increased from 68 to 132 and the value of blue color increased from 39 to 76 for pod ages from 6 to 33 days, respectively.
3. The percentages of color components increased for red, green and blue from 29.0 % to 60.4 %, from 44.3 % to 76.5 %, and from 15.3 % to 49.0 % for pod's ages from 10 to 31 days, respectively. The values for sweet peas pods increased from 26.67 % to 51.76 %, from 41.18 % to 61.57 %, and from 15.29 % to 29.80 % for pod's ages from 6 to 33 days, respec-

tively.

4. The following equations summarize the relationships between red color (R), green color (G) and blue color (B) as functions of the pod's age (A):

   $R = 39.490 + 3.909\,A, G = 78.203 + 3.755\,A$, and $B = 3.826\,A - 1.063$ (green bean).

   $R = 52.767 + 2.423A$, $G = 96.462 + 1.817\,A$, and $B = 34.027 + 1.080\,A$ (sweet peas).

5. The optimal harvest time was 22 and 8 days for green bean and peas pods (from appearing the pod from its flower) which were 34.12 % (R), 43.04 % (G) and 22.83 % (B) while bean means were 33.45 % (R), 45.99 % (G) and 20.56 % (B), respectively.

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Energy Analysis of Cotton Production in Akola District of Maharashtra State

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Abstract

This study was conducted to determine the influence of various factors on the cotton crop production as yield and output energy. The factors considered were area under crop, irrigation, input energy, hoeing, power sources and FYM application. The influence and relation of these factors were determined for the output energy and the yield of the cotton crop for the small, medium and large farmers. The data were collected from the farmers of the Akola district. Crop yield and output energy were greatly influenced by the power sources, hoeing application and the total input energy. The input-output energy analysis, source-wise energy use and the various energy coefficients of the field operation were determined to identify the energy use in small, medium and large farmers of the studied area. The cost of energy for production of cotton crop was estimated. The cost of energy was more in small farming and minimum in large farming. The economics of the cotton crop showed that the small farmers have benefit-cost ratio more than the larger farmer.

Introduction

In recent years cotton cultivation in the Vidarbha region of the Maharashtra state has declined. The causes may be that the cost of cultivation has increased day by day. The Western Vidarbha region of the Maharashtra state has been known as the cotton belt in the India. Due to the inadequate package of practices and the high cost of production lower productivity has resulted along with net income of farmers. The present study has highlighted the situation of small, marginal and large farmers. The details regarding the various operations during the cotton crop production were studied to learn the factors responsible for the cotton crop production. Energy forms one of the most crucial inputs in agriculture. In the Vidarbha region, human and animal energy are the main sources of energy. The tractor, oil engines, electric motors and power tillers are the mechanical energy sources to perform various farm operations with very low intensity. Large quantities of the energy inputs are used in the form of physical inputs like fertilizers, chemical, seed and farm yard manure. Information pertaining to the energy requirements and its respective sources, together with cost of production, is of immense utility and importance to agriculture. Investigation on the use of energy per unit area for different crops is very important, particularly when the crop pattern of the region is diversified. This research project studies energy use patterns and the possibility of optimizing the returns of the selected crop.

Materials and Methods

Locale of Study

The present study was undertaken in Akola district of Maharashtra State, India. The district was selected purposively, as Akola is a major contributing cotton growing area in Vidarbha region. Akola district is situated at the central east side of Maharashtra state. The district lies between at 20º 42´ North latitude and 70º 21´, East longitude. The total geographic area of the Akola district is 5,417 km^2. The average annual precipitation is 760 mm; out of which approximately 85 % is received during June to September. The climate of the area is semi-arid. The majority of crops grown are dependent on rainfall. Cotton, sorghum and green gram are the major rainy (Kharif) crops.

This study was mainly designed

to collect pertinent facts about energy requirements in cotton production. Samples for the study from each Panchyat Samiti of Akola district were selected. Five villages were randomly selected from each of the Panchyat Samiti for the study. Thus, 35 villages were selected from seven Panchayat Semites of the Akola district. Five farmers were selected for data collection from each village of small, medium, and large land holdings. Overall, five hundred and twenty five (525) farmers were randomly selected out of which 175 were small, 175 were medium, and 175 were large farmers. The location of the study area is shown in **Fig. 1**.

Fig. 1 Geographical location and villages selected for the study

Energy Estimation

The study focus centered on the computation of energy requirement for performing different farming operations. Three types of energy were considered in the quantification of requirements of energy for performing the operations. The first one was mechanical energy used by mechanical devices in field operations. The consumption of fuel was collected for the various field operations. The total estimated quantity of energy was determined in MJ/hectare. The important farm operations like land preparation, crop residue management, crop growing, intercultural, irrigation and harvesting were considered. Similarly, the energy used in field operation by humans such as the number of labours for the considered field operations was determined. The energy consumption in the field operation was determined for the bullock used in the field. The basic inputs required for the cotton production of seed, fertilizer, farm yard manure (FYM) and irrigation was considered to show the outlet of stated parameters in terms of energy for the input energy required for cotton production. Finally, in order to workout total requirement of energy, summation of mechanical energy, human energy, bullock energy and the primary input were considered together and, thus, total energy for crops under study was estimated.

Energy Analysis

Energy analysis attempted to take into account all forms of energy inputs and outputs to establish the relationship for the energy requirement of the various operations. The total energy input included direct and indirect energy requirement. The total output energy was calculated from cotton fiber and stalk and their energy equivalent. Input-output analysis was primarily done to examine the quantity of energy produced by the system against expending a certain quantity of energy. The ratio of output energy to input was called energy ratio. The energy equivalents of inputs and outputs were obtained from literature (Odum, 1971, Canakci and Akinci 2006, Cetin and Vardar, 2006, Djevic and Dimitrijevic, 2004, Helsel 1992, Esengun *et al*., 2007, Ibrahim *et al*., 2005).

Study Variables and their Measurements

Two sets of variables were selected considering their relevancy. The effect of independent variables on the dependent variables (yield of cotton and the output energy) were determined by using the rational analysis. The paradigm is illustrated in **Fig. 2**.; the hypothesized association between independent and dependent variables.

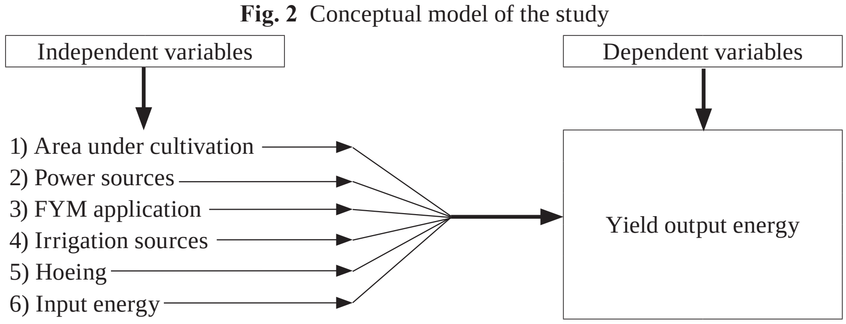
Statistical Techniques Used to Measure the Effect of the Independent Variable

The following statistical tests and techniques were used for analyzing the effect of the independent variable on the dependent variables.

Coefficient of correlation (r)

The relational analysis comprised of computing relationships between the selected independent variables with dependent variables. The coefficient of correlation (r) was worked to find the relationship of independent variables with dependent variables. The significance of the calculated coefficient of correlation (r) was tested against the table value of ‘r’ at n-2 degrees of freedom. The relationship was considered to be significant if the calculated value of ‘r’ was greater than the table value at either 0.01 or 0.05 level of prob-

Fig. 2 Conceptual model of the study



ability.

Multiple linear regression analysis

Regression analysis as a statistical tool was used to find the relationship between two variables which followed a linear relationship. If we have two variables x and y, we have two regression lines as the regression of x on y and regression of y on x. The regression line of y on x gives the most probable values of y for given values of x and regression line of x on y gives the most probable values of x for given value of y.

Path analysis

Path analysis helps to identify the independent variables affecting the dependent variables directly as well as indirectly. Path analysis was employed to isolate the direct and indirect effect of independent variables on each of dependent variables. Path coefficients were considered to be significant if calculated 't' value was greater than table 't' value at either 0.01 or 0.05 level of probability.

Cost of Energy

It is essential to work out energy consumed and cost incurred for performing various agricultural operations. The aspects were taken into account for current rates of charges for; human labours, bullock pairs, tractor (fuel), consumption of electricity in terms of total energy used for irrigation, cost of seed sown, cost of fertilizer applied and cost of FYM applied.

Cost of production

The total input cost for production of cotton cost of operations and actual cost for different input products.

Cost of production (Rs/ha) = cost of operations + cost of inputs... ....(1)

Benefit-cost ratio (considering income from yield)

By adopting relationship between gross income and cost of production, output-input ratio for farm, considering yield (cotton fiber) was identified as,

Benefit-cost ratio = Gross income in (Rs) / Cost of production (Rs) ....(2)

Cost of energy

By adopting the below relationship between cost of production and total input energy, the cost of energy was calculated as,

Cost of energy (Rs/MJ) = Cost of production (Rs/ha) / Total input energy (MJ/ha)......................(3)

Results and Discussion

Profile of Selected Respondent

The information about land holdings of selected farmers indicated land holdings under various categories for total as well as average value of area under cultivation. In the category of small holdings the average land holding was 1.65 ha, while in medium and large categories it was 3.48 and 6.05 hectares, respectively.

The selected characteristics; situational, socio-personal, communication and psychological parameters of respondent were studied. The characteristics, namely; land holding, power sources, farm yard manure, hoeing and irrigation input energy were considered exploiting the effect on output energy and cotton yield. It is the actual area of land in hectares possessed by farmer for cotton cultivation. The distribution according to actual area under a holding for cotton cultivation is given in **Table 1**. **Table 1** indicates that farmers with actual area under cotton cultivation were the same

Table 1 Distribution of respondent according to study variables

Category	Frequency (N = 525)	Percentage
Area under cultivation		
Up to 2 ha	175	33.33
2.1 to 6 ha	175	33.33
above 6 ha	175	33.33
Power sources		
Bullocks operated	6	2
Bullock+ tractor operated	272	52
Tractor operated	248	46
FYM application		
Up to 150 quintal	165	32
151 to 400 quintal	253	48
above 400 quintal	107	20
Irrigation		
Non Irrigation	379	72
Irrigation	146	28
Hoeing		
Up to 4 times	174	33
Up to 5 times	285	54
Up to 6 times	66	13
Input Energy		
Up to 20,000 MJ	125	24
20,001 to 40,000 MJ	227	43
Above 40,000 MJ	273	53
Yield		
Poor Yield (1 to 10 quintal)	23	5
Medium Yield (11 to 20 quintal)	341	65
High Yield (above 21 quintal)	161	30
Output energy		
Low (up to 15,000 MJ)	162	31
Medium (15,001 to 30,000 MJ)	149	29
High Yield (above 30,000 MJ)	241	40

for land up to 2 ha, up to 6 ha, and above 6 ha, and followed by 33.33 percent each for the above mentioned categorization. The actual power sources used like to influence yield and output energy. Hence, this variable was selected and studied. It included bullock drawn, tractor operated and both tractor + bullock operated respondent separately. The power source-wise distribution of the respondent given in table 4 revealed that a majority (52 %) of respondents were both bullock and tractor operated. As much as 46 % of tractor operated and 2 percent respondents was bullock operated only. The above findings are in conformity with the observation that the majority of respondents prefers, both bullock and tractor for performing operations in cultivation of the cotton crop.

Fym Application and Irrigation Facilities:

FYM application refers to actual quantity of FYM used by the respondent and the influence on the yield. It is apparent from table 1 that the majority (48 %) of respondents allied FYM from 151 to 400 quintal. As much as 32 % of the respondents applied FYM to about 150 quintal. The remaining, 20 % applied large quantities of FYM; i.e. above 400 quintal.

The irrigation source-wise distribution of respondent in the table reveal that a majority (72 %) of respondents did not irrigate. The remaining 28 % respondents have irrigation.

Hoeing and Input Energy:

It is evident from the data in **Table 1** that the maximum percentage of respondents (54 %) did five times hoeing. As much as 32 % of respondents applied hoeing up to four times. And remaining (20 %) of the respondents had done hoeing up to six times and had maximum yield and output energy. It evident from the **Table 1** that the majority (53 %) of the respondents applied maximum input energy for cotton cultivation for intimating higher yield. As much as 43 % of the respondents applied input energy, and the remaining 24 % applied lowest input energy and had lowest yield.

Profile of Yield of Selected Respondent:

The distributional analysis pertaining to yield of respondent in **Table 1** indicates that a majority (65 %) of respondents had medium yield; from 11 to 20 quintal. The percentage of respondents having higher yield was 30 %. The respondents having poor yield (from 1 to 10 quintal) were 5 %. The majority of respondents had medium yield. This helped in undertaking the corrective measures and increasing, not only yield, but also overall work.

Profile of Output Energy of Selected Respondent:

The majority (40 %) of respondents had higher output energy, above 30,000 MJ. The respondents having low output energy (31 %) belonged to the category of up to 15,000 MJ. The respondents having medium output energy (29 %) belonged to the category of 15,001 to 30,000 MJ. Thus, this analysis helped in concluding the correct approach and measures for increasing output energy and yield to overall work performance.

On the basis of objectives set forth in the study, the relationship of the characteristics of independent variables on dependent variable and their influence, direct and indirect effect for analysis of the data, the correlation, multiple regression and path analysis was carried out.

Relationship and Influence of Selected Characteristics of Respondent on Yield:

The correlation analysis was done to find out the relationship of the selected characteristic of the respondent on yield and findings obtained in this regard (**Table 2**). A closer look at 'r' values in table bring to light that selected characteristics; namely, area under cultivation, power sources, FYM application, irrigation, number of hoeings, and input energy show highly and positively significant in relation with their yield. Land holdings were highly and positively significant with yield. This indicated that with increased land holdings there had been considerable increase in yield. The power sources in selected characteristics exhibited positive and highly

Table 2 Coefficient of correlation between selected characteristic on yield and output energy

Characteristics	Coefficient of Correlation 'r'	Cal. 't' value
Yield		
Actual land cultivated area	0.8330**	34.04
Power sources	0.4181**	10.52
FYM application	0.1314**	3.03
Irrigation	0.8435**	35.91
Hoeing	0.8435**	8.08
Input energy	0.8625**	38.97
Output energy		
Actual land cultivated area	0.9329**	59.28
Power sources	0.4405**	11.22
FYM application	0.0779*	1.78
Irrigation	0.8552**	37.45
Hoeing	0.1966**	4.58
Input energy	0.9119**	50

** Significant at 0.05 level of probability significant relationship with yield. This showed that increase in use of power sources increased the yield. The maximum use of power sources had an effect on the use of energy efficiently for producing higher yield. FYM application was positive and highly significant with yield. This indicated that with increase in use of FYM there was an increase in the yield. The reason may be that with an increase of FYM the soil acquires more energy for growing the yield. Irrigation was highly and positively significant in relation with producing a higher yield. This indicated that the increase in irrigation in the field there had been an increase in higher yield.

Hoeing was positive and highly significant in relation with yield. This indicated that increase in hoeing there had been an increase in yield. The reason may be that due to increase in number of hoeings the growth of crop was improved for obtaining higher yield. Input energy in selected variables was observed to be highly and positively significant in relation with yield. This clearly indicates that increase in input energy in the field there had been an increase in yield. The reason may be that an increase in the more inputs the factor favorable for increasing the yield. The present finding with regard to relationship between the characteristics of the selected variable on yield leads to partial acceptance of the hypothesis formulated for the purpose of study. The hypothesis stands accepted with respect of area under cultivation, power sources, FYM application, irrigation, hoeing and input energy toward energy requirement.

Relationship and Influence of Selected Variable on Output Energy:

In order to ascertain the relationship of selected variables, the data were subjected to correctional analysis and results are presented in **Table 2**. A closer look at 'r' values in **Table 10** brings in to light that FYM shows a significant relationship with output energy. The null hypothesis of this variable has, therefore, to be accepted. The non-significant relationship of this variable with output energy indicates that this variable did not affect output energy. The other variables were highly and positively significant with the output energy. Land holding was highly and positively significant with output energy. Thus, actual area under cultivation showed a considerable increase in yield. Irrigation in the selected variable was observed to be highly and positively significant with producing higher output energy. This clearly indicated that with the increase in the use of irrigation there had been an increase of higher output energy. The reason may be that with an increase in irrigation there had been an increase in the yield, which increases the output energy. The power sources in selected characteristic exhibited positive and highly significant relationship with output energy. This indicated that increase in the use of maximum power sources increases the output energy.

Hoeing application was highly and positively significant in relation with output energy. This showed that with increase in number of hoeings there had been an increase in output energy. The input energy was positively and highly significant in relation with the output energy. Thus, with an increase in input energy to the farm there was an increase in the output energy. The reason may be that with increase of input energy to the field leads to the yield and, therefore, output energy also increases. As input energy increases the stalks also increase and output energy also increases. The present finding with regards to the relationship of selected variables output energy leads to acceptances of hypothesis formulated earlier for the purpose of this study. The hypothesis stands accepted with respect of FYM application. The same was in respect of power sources, irrigation, hoeing, input energy, land holding, for determining energy requirement in cotton production.

Multiple Linear Regression Analysis for Independent Variable Yield and Output Energy:

Table 3 represents the multiple liner regression analysis of independent variables on dependent variables (yields and output energy). When regression analysis was carried out with variable, namely, area under cultivation, power sources, irrigation, FYM application, hoeing, and input energy the value of the coefficient of determination was R^2 = 0.821. Thus, six variables area under cultivation, power sources, irrigation, FYM application, hoeing, and input energy were significant and the major determinant in yield.

When regression analysis was carried out with the variables; area under cultivation, power sources, irrigation, FYM application, hoeing, and input energy the value of coefficient of determination was R^2 = 0.9208. Thus, it can be concluded that the six variables were signifi-

Table 3 Regression analysis showing relative contribution of independent variables in influencing yield and output energy

Variables	Regression coefficient (Yield)	Regression coefficient (output energy)
Actual land cultivated area	10.966 (0.9384)	48,612.16 (2,191.02)
Power sources	2.1466 (1.7045)	6,517.02 (3979.53)
FYM application	3.3391 (1.2990)	7385.55 (3,032.76)
Irrigation	0.07575 (0.0119)	138.16 (27,862)
Hoeing	18.81 (2.255)	24,241.4 (5,266.4)
Input energy	0.00016 (0.000148)	1.1405 (0.2448)
	R^2 = 0.8210	R^2 = 0.9208

cant and a major determinant in output energy.

Path Analysis of Dependent Variable

The path analysis was carried out with the six variables (area under cultivation, power sources, irrigation, FYM application, hoeing, and input energy and yield and output energy) as dependent variables to estimate the direct effect produced by each of independent variable as well as indirect effect produced by them through other variables on yield. **Table 4** shows that the variables had the following direct effect in descending order: area under cultivation (0.5143), irrigation (0.2814), hoeing (0.1872), input energy (0.0890), FYM application (0.0496), and power sources (0.0262). The FYM application and power source had least direct effect on yield. The total indirect effect of independent variables on performance as dependent variables was input energy (0.7735), irrigation (0.5620), power sources (0.3919), area under cultivation (0.3157), hoeing (0.1461), and FYM application (0.0818) have exerted maximum positive indirect effect on yield in descending order of magnitude.

The correlation coefficients of the influence of selected independent variables on output energy, both direct and indirect were put to path analysis. Based on numerical values of path coefficient for all independent variables, the total indirect effect for each independent variable was presented in **Table 4**.

The total direct effect of the independent variable on output energy was area under cultivation (0.6492), input energy (0.1800), irrigation (0.1462), hoeing (0.0686), FYM application (0.0312), and power sources (0.0265) in descending order of magnitude. The total indirect effect of independent variables on output energy the variables (input energy (0.7319), irrigation (0.7090), power sources (0.4179), area under cultivation (0.2837), hoeing (0.1279), and FYM application (0.0467)) exerted maximum positive indirect effect on output energy in the above descending order of magnitude.

Table 4 Direct and indirect effect of independent variable on yield and output energy

Independent variable	Correlation coefficient 'r'	Direct effect	Rank order	Total indirect effect	Rank order
Yield					
Area under Cultivation	0.8330**	0.5143	1	0.3157	4
Power sources	0.4181**	0.0262	6	0.3919	3
FYM application	0.1314**	0.0496	5	0.0818	6
Irrigation	0.8435**	0.281	2	0.562	2
Hoeing	0.3333**	0.1872	3	0.1467	5
Input energy	0.8625**	0.089	4	0.7735	1
Output energy					
Area under Cultivation	0.9329**	0.6492	1	0.2837	4
Power sources	0.4405**	0.0265	6	0.4197	3
FYM application	0.0798*	0.0312	5	0.0467	6
Irrigation	0.8552**	0.1462	2	0.7090	2
Hoeing	0.1966**	0.0686	3	0.1279	5
Input energy	0.9119**	0.1800	4	0.7319	4

* Significant at 0.01 level of probability, ** Significant at 0.05 level of probability

Energy Evaluation of Cotton Crop Production:

Operation-wise and source-wise energy input utilization for Telhara Panchayat Samiti

Table 5 represents the average energy, operation-wise, for cotton cultivation in Telhara Panchayat Samiti. The energy consumed in land preparation was 1,138 MJ/ha. Irrigation and picking operation consumed more energy than other operations. The total energy consumption in Telhara Panchayat Samiti was 3381 MJ/ha. Singh et al (2004) optimized the energy inputs for wheat crop in the Punjab state, India.

Table 6 represents the energy input utilization for small, medium, and large farms. Human energy was 1,184 MJ/ha on large farms followed by medium (875 MJ/ha) and small farms (801 MJ/ha), respectively. The use of fertilizer was highest (5,846 MJ/ha) followed by mechanical and bullock energy with 1,005 MJ/ha and 515 MJ/ha, respectively. The seed was the least energy consuming item with 45 MJ/ha and almost same in different categories of farms. The electrical energy was highest (489 MJ/ha) on large farms in comparison to medium (167 MJ/ha) and small (102 MJ/ha) farms, respectively. The bullock energy was highest (794 MJ/ha) in small farms in comparison of medium (453 MJ/ha) and latge farms (298 MJ/ha). The input and output yield relationship in Garhwal Himalaya was determined by Munesh (2011).

Operation-wise and sources wise energy input utilization for Akot Panchyat Samiti

Table 5 shows the average operation-wise energy in Akot Panchyat Samiti. Maximum energy was consumed in land preparation (1,147.17 MJ/ha) followed by hoeing (396 MJ/ha), uprooting and collection (393 MJ/ha) and picking (364 MJ/ha). The minimum energy was consumed in FYM application (26 MJ/ha) and was the same under different categories of farms. Irrigation the highest (626 MJ/ha) energy on large farms followed by medium (184 MJ/ha), and small farms (101 MJ/ha). Sowing was almost the least energy (53 MJ/ha) component. The energy input study was carried out for the dryland and irrigated fields and for mechanized and bullock power (Khan and Singh, 1996).

Table 6 shows energy input utilization on small, medium, and large farms. In this category maximum energy was provided by the fertilizer (5,522 MJ/ha) followed by mechanical energy (1,350 MJ/ha), human energy (789 MJ/ha) and bullock energy (527 MJ/ha). The electrical energy highest (294 MJ/ha) for large farms and was (76 MJ/ha) for medium and for small farms (58 MJ/ha). Seed energy was lowest (46 MJ/ha) and was the same among all three categories of farm. The maximum bullock energy (784 MJ/ha) was used on small farms in comparison with medium (435 MJ/ha) and large farms (361 MJ/ha). The FYM energy was highest (1,957 MJ/ha) on middle farms. The fertilizer energy was highest (6,486 MJ/ha) on small farms (5,274 MJ/ha) on medium and (4,805 MJ/ha) on large farms. Human energy was equal in all three size groups. The energy requirement of wheat and rice crop was determined for the various field operations by Sarkar, 1997.

Operation-wise and source-wise energy input coefficient (MJ/ha) for Balapur Panchyat Samiti

Table 5 shows the operation-wise average energy used Balapur Panchyat Samiti. The maximum energy was consumed in land preparation (1,014 MJ/ha) followed by uprooting and collection (408 MJ/ha) picking (374 MJ/ha) and hoeing (343 MJ/ha). The residue management and FYM application consumed minimum energy of 34 MJ/ha and 36 MJ/ha. The sowing energy was higher on small farms (135 MJ/ha) in comparison to middle (86 MJ/ha) and large farms (81 MJ/ha). Nautiyal *et al.*, 2007 determined production cost in terms of energy for introduced crops such as tomato (Lycopersicon esculentum) and bell pepper (Capsicum annum). Cultivation was 90,358-320,516 MJ/ha as compared to between 19,814 and 42,380MJ/ha for traditional crops within Himalayan agro-ecosystems.

Table 6 shows information on small, middle, and large farms. The fertilizer provided maximum energy (4,647 MJ/ha) and electrical energy was minimum (40 MJ/ha). The fertilizer energy followed by FYM (1,743 MJ/ha), mechanical energy (1,141 MJ/ha) and human energy (639 MJ/ha). The small farms utilized maximum human energy (723 MJ/ha), bullock energy (1,013 MJ/ha) FYM (2,139 MJ/ha), fertil-

Table 5 Operation-wise average energy input coefficient (MJ/ha) for panchayat samiti of Akola district

Panchayat Samiti	Farmers Category	Farm operations										Total Energy
		Land preparation	Residue management	FYM management	Sowing	Fertilizer application	Irrigation	Hoeing	Weeding	Picking	Uprooting & collection	
Telhara	Small	905	37	37	42	132	219	418	246	452	409	2,897
	Medium	1,249	32	40	39	113	410	424	261	394	403	3,365
	Large	1,259	33	45	41	119	1,127	325	184	374	373	3,880
	Average	1,138	34	41	41	121	585	389	230	407	395	3381
Akot	Small	1,039	32	29	68	114	101	451	331	384	402	2,951
	Medium	1,143	33	27	44	106	184	380	254	351	412	2,934
	Large	1,258	20	24	50	110	626	359	178	359	367	3,351
	Average	1,147	28	27	54	110	304	397	254	365	394	3,079
Balapur	Small	835	37	49	135	91	72	426	282	391	376	2,694
	Medium	1,070	34	32	86	90	104	335	227	394	435	2,807
	Large	1,138	30	26	81	85	134	269	192	336	413	2,704
	Average	1,014	34	36	101	89	103	343	234	374	408	2,735
Akola	Small	858	40	45	44	113	181	392	271	422	379	2745
	Medium	1,042	40	39	41	114	221	324	228	442	374	2,865
	Large	1,151	38	35	40	116	437	399	226	391	431	3,264
	Average	1,017	39	40	42	114	280	372	242	418	395	2,958
Patur	Small	949	40	39	44	97	207	416	248	412	411	2,863
	Medium	1,074	38	34	39	101	389	335	259	395	418	3,082
	Large	1,190	37	39	40	108	641	394	216	397	400	3,462
	Average	1,071	38	37	41	102	412	382	241	401	410	3,136
Barshitakli	Small	1,041	45	56	44	110	242	320	296	431	377	2,962
	Medium	1,077	38	49	41	115	458	351	224	369	368	3,090
	Large	1,144	38	42	40	117	901	406	231	380	404	3,703
	Average	1,087	40	49	42	114	534	359	250	393	383	3,252
Murtizapur	Small	895	48	40	44	117	221	334	285	427	603	3,014
	Medium	930	39	34	40	114	419	352	220	393	400	2,941
	Large	1,114	37	37	40	111	758	393	226	371	415	3,502
	Average	980	41	37	41	114	466	360	244	397	473	3,152

izer (5,740 MJ/ha) energy followed by medium and large farms. The maximum (1,464 MJ/ha) mechanical energy was utilized on large farms in comparison with medium (1,348 MJ/ha) and small farms (611 MJ/ha). The seed energy was lowest (52 MJ/ha) and same among all three categories of the farm. Maximum bullock energy (1,013 MJ/ha) was used on small farms in comparison with medium (486 MJ/ha) and large (340 MJ/ha) farms. The FYM energy was highest (2,139 MJ/ha) on middle farms. The fertilizer energy was highest (5,740 MJ/ha) on small farms in comparison to medium (4,217 MJ/ha) and large (3,984 MJ/ha) farms. The human energy was equal in all three size groups. The specific energy requirements of eight implements were evaluated as crop production practices were determined by Smith (1993).

Operation-wise and source-wise energy input coefficient (MJ/ha) for Akola Panchayat Samiti

Table 5 represents the operation-wise average energy used for cotton cultivation. The maximum energy (1,017 MJ/ha) consumed in land preparation was highest and almost equal energy in all three categories of the farms. Ploughing followed by picking energy (418 MJ/ha), uprooting and collection (394 MJ/ha), hoeing energy (372 MJ/ha). The minimum energy consumed was in FYM application and in sowing. The fertilizer energy (115 MJ/ha) was the same among all three categories of the farms. The irrigation energy was highest (437 MJ/ha) on large farm in comparison with small (181 MJ/ha) farms and medium farms (221 MJ/ha). The sowing energy was minimum (42 MJ/ha) and equal in all three categories of farms. Mittal *et al.* (1991) determined energy requirements for the no tillage practices in dryland agriculture.

Table 6 shows information about average energy input coefficient for small, medium, and large farms. Human energy was highest (822 MJ/ha) on large farms followed by medium (744 MJ/ha) and large farms (801 MJ/ha). Fertilizer was the highest (5,287 MJ/ha) energy consuming item. The energy consumption by seed was lowest (45 MJ/ha) and almost the same in different categories of farms. The energy supplied by the mechanical energy sources was highest (1,497 MJ/ha) for large farms followed by

Table 6 Sources wise average energy input coefficients (MJ/ha) for panchayat samiti of Akola district

Panchayat Samiti	Farmers Category	Sources wise energy							Total energy
		Human energy	Bullock energy	Mechanical energy	FYM	Seed	Fertilizer	Electrical energy	
Telhara	Small	801	794	839	2,101	45	6,924	102	11,606
	Medium	875	453	1,037	2,072	45	5,577	167	10,226
	Large	1,184	298	1,138	2,090	44	5,038	489	10,281
	Average	953	515	1,005	2,088	45	5,846	253	10,704
Akot	Small	780	784	1,032	1,939	45	6,486	58	11,124
	Medium	720	435	1,441	1,957	47	5,274	76	9,950
	Large	867	361	1,576	1,859	46	4,805	294	9,808
	Average	789	527	1,350	1,918	46	5,522	143	10,294
Balapur	Small	723	1,013	611	2,139	52	5,740	37	10,315
	Medium	621	486	1,348	1,806	51	4,217	39	8,568
	Large	573	340	1,464	1,284	52	3,984	43	7,740
	Average	639	613	1,141	1,743	52	4,647	40	8,874
Akola	Small	801	885	639	2,257	48	5,578	81	10,289
	Medium	744	401	1,278	1,878	44	5,179	86	9,610
	Large	822	420	1,497	1,970	44	5,103	194	10,050
	Average	789	569	1,138	2,035	45	5,287	120	9,983
Patur	Small	545	697	987	1,827	48	6,395	96	10,595
	Medium	507	359	1,510	1,813	50	5,120	152	9,511
	Large	473	382	1,541	2,193	48	5,113	313	10,063
	Average	508	479	1,346	1,944	49	5,543	187	10,056
Barshitakli	Small	835	616	1,043	2,872	46	5,625	124	11,161
	Medium	873	414	1,321	2,232	50	5,287	186	10,363
	Large	1,073	428	1,462	2,233	47	5,581	433	11,257
	Average	927	486	1,275	2,446	48	5,498	248	10,927
Murtizapur	Small	835	780	956	2,647	52	5,712	101	11,083
	Medium	851	494	1,118	2,099	52	5,074	162	9,850
	Large	986	424	1,432	1,953	46	4,909	361	10,111
	Average	891	566	1,169	2,233	50	5,232	208	10,348

medium (1,278 MJ/ha) and small (801 MJ/ha) farms. Thakur and Makan (1997) studied energy scenarios of the various crops of the Madha Pradesh agriculture.

Operation-wise and source-wise average energy input coefficient (MJ/ha) for Patur Panchyat Samiti

Table 5 shows the average energy operation-wise used for cotton cultivation in Patur Panchyat Samiti. It was observed that maximum energy was consumed in land preparation (1,104 MJ/ha) followed by irrigation (412 MJ/ha). The minimum energy was consumed in FYM application and sowing of 37 MJ/ha and 41 MJ/ha. Irrigation was the highest (641 MJ/ha) energy consuming item on large farms followed by medium (389 MJ/ha) and small farms (207 MJ/ha). Hoeing, weeding, and picking energy was the same in all three categories of farms. Seyed and Singh (2009) determined the energy use efficiency of paddy crop using the data development analysis.

Table 6 shows the average energy input coefficients in (MJ/ha). In this category, maximum energy was by fertilizer (5,543 MJ/ha). It was followed by FYM (1,944 MJ/ha) and mechanical energy (1,346 MJ/ha). Electrical energy was highest (313 MJ/ha) for large farms in comparison to medium (152 MJ/ha) and small farms (96 MJ/ha). The seed energy was lowest (49 MJ/ha) and was of equal amounts on all three categories of farms. The bullock energy was (697 MJ/ha) on small farms. The mechanical energy was lowest (987 MJ/ha) on small farms in comparison with middle (1,510 MJ/ha) and large farms (1,541 MJ/ha). Singh *et al.* (1998) studied the parameters to improve the technical efficiency of marginal, small and medium farmers.

Operation-wise and source-wise energy input utilization in (MJ/ha) for Barshitakali Panchayat Samiti

Table 5 shows operation-wise average energy used for cotton cultivation. Maximum energy was consumed in land preparation (1,087 MJ/ha) followed by irrigation (534 MJ/ha) and picking (393 MJ/ha). The sowing energy was minimum (42 MJ/ha). The irrigation energy was (534 MJ/ha), the cultivation, harrowing, weeding energy was maximum in all categories of farms. The study optimized the energy use patterns of different wheat growing regions (Western Rajasthan, Punjab, Uttar Pradesh (UP) and Madhya Pradesh (MP) of the Country in order to maximize yield (Singh *et al.*, 2007).

It may be seen from **Table 6** that the minimum energy (48 MJ/ha) was on seed, and was equal in all three categories of farms. Maximum energy (5,498 MJ/ha) was provided by fertilizer. It was followed by FYM (2,446 MJ/ha), mechanical energy (1,275 MJ/ha) and human energy (927 MJ/ha). The maximum mechanical energy was (1,462 MJ/ha) on large farms, in comparison with medium (1,321 MJ/ha) and small farms (1,043 MJ/ha). The small farm utilized maximum bullock energy (616 MJ/ha) and FYM (2,872 MJ/ha) energy, followed by medium and large farms. The electrical energy was highest (433 MJ/ha) on large farms followed by medium and small farms. Ibrahim *et al.* (2005) determined the cost of energy of cotton crop production.

Operation-wise and average energy wise utilization in (MJ/ha) for Murtijapur Panchayat Samiti

Table 5 shows the operation-wise average energy used for cotton cultivation. The energy consumption in land preparation for the cotton crop was 895 MJ/ha, 930 MJ/ha and 1114 MJ/ha for small medium and large farms with the overall energy consumption in land preparation of 978 MJ/ha followed by uprooting (472 MJ/ha), irrigation (466 MJ/ha), picking (397 MJ/ha) and hoeing (359 MJ/ha). The FYM application and sowing consume minimum energy of 37 MJ/ha and 42 MJ/ha among all three types of categorization. The irrigation energy was maximum (758 MJ/ha) on large farms followed by medium (419 MJ/ha) and small farms (221 MJ/ha). The weeding energy (285 MJ/ha) was maximum on small farms. The harrowing energy was lowest (94 MJ/ha) on small farms in comparison to medium (121 MJ/ha) and large farms (234 MJ/ha). The cultivation energy (284 MJ/ha), fertilizer application (114 MJ/ha), and picking (397 MJ/ha) was almost equal among all three categorization of farms.

Table 6 shows source-wise energy utilization for small, medium, and large farms. In this category, maximum energy was provided by fertilizer (5,232 MJ/ha). Electrical energy was highest (361 MJ /ha) on large farms in comparison to medium (162 MJ/ha) and small farm (101 MJ /ha). The energy for FYM was (2,233 MJ/ha). It was followed by mechanical energy (1,169 MJ/ha) and human energy (891 MJ/ha). The maximum (1,432 MJ/ha) mechanical energy was utilized on large farms, in comparison with medium (1,118 MJ/ha) and small farms (956 MJ/ha). The small farm utilized maximum bullock energy (780 MJ/ha), FYM (2,647 MJ/ha) energy, followed by medium and large farms. The electrical energy was highest (361 MJ/ha) on large farm followed by medium and small farms. Singh *et al.* (2000) concluded that cotton crop seedbed preparation, irrigation and weeding consumed about 70 % of the total energy input.

Comparative energy utilization (operation-wise) in cotton crop for Panchyat Samities in Akola district

Table 7 shows the average energy utilized operation-wise in the cotton crop. The energy consumption in land preparation for the was 1,137 MJ/ha, 1,147 MJ/ha, 1,014 MJ/ha, 1,017 MJ/ha, 1,104 MJ/ha, 1,087 MJ/ha and 978 MJ/ha for various panchayat samiti. The minimum energy for ploughing was 523 MJ/ha for Balapur Panchayat Samiti. It was followed by Patur Panchayat Samiti (529 MJ/ha). The minimum energy was consumed in residue management, FYM application, and sowing. For sowing the maximum energy consumed was highest (101 MJ/ha) for Balapur Panchayat Samiti because sowing was done by applying traditional practices methods. Remaining Panchayat Samities consumed considerable energy and did not show any variability. The irrigation energy was consumed to be highest for Telhara Panchayat Samiti (585 MJ/ha) and was followed by Barshitakali (534 MJ/ha), Murtijapur (466 MJ/ha) Panchyat Samiti. The minimum irrigation energy (103 MJ/ha) was for Balapur Panchayat Samiti. It was followed by Akola Panchayat Samiti (274 MJ/ha). Hoeing and weeding were highest (397 and 254 MJ/ha) for Akot Panchayat Samiti. The lowest hoeing and weeding was (343 and 234 MJ/ha) of Balapur Panchayat Samiti. The fertilizer application energy was highest (121 MJ/ha) of Telhara Panchayat Samiti. The lowest fertilizer energy consumption was of Balapur Panchayat Samiti (89 MJ/ha). The Telhara Panchayat Samiti exhibited maximum picking energy (406 MJ/ha), and lowest was of Balapur Panchayat Samiti (374 MJ/ha). The cultivation energy consumed was highest for Akot Panchayat Samiti (346 MJ/ha) and lowest for Murtijapur Panchayat Samiti (285 MJ/ha). Harrowing was highest (225 MJ/ha) for Akot Panchayat Samiti and lowest (150 MJ/ha) for Murtijapur Panchayat Samiti.

Comparative energy utilization (source-wise) in cotton crop for Panchyat Samities in Akola district

Table 8 shows the average energy utilized source-wise in. Maximum energy was obtained from fertilizer, and exhibited highest for Telhara P.S. (5,846 MJ/ha) and lowest for Balapur P.S. (4,647 MJ/ha) lowest energy was obtained from seed and highest (52.03 MJ/ha) for Balapur P.S. For FYM, highest energy was exhibited (2,088 MJ/ha) for Telhara P.S. and lowest for Balapur P.S. (1,743 MJ/ha). Bullock energy was highest (613 MJ/ha) for Balapur P.S. and lowest (479 MJ/ha) for Patur panchyat samiti Other Panchyat samiti did not show any variability. Maximum human energy (953 MJ/ha) was for Telhara Panchyat samiti and minimum for Patur Panchyat Samiti (509 MJ/ha). The mechanical energy was maximum (1,350 MJ/ha) in Akot Panchyat samiti followed by patur Panchyat samiti (1,346 MJ/ha) and Telhara Panchyat samiti (1,332 MJ/ha) and minimum for Akola Panchyat samiti (1,138 MJ/ha). Irrigation energy was highest (253 MJ/ha) for Telhara Panchyat samiti and lowest (40 MJ/ha) for Balapur Panchyat samiti and Akola Panchyat samiti (120 MJ/ha).

Comparative energy utilization (operation-wise) in cotton crop for Akola district according to land holdings

Table 9 shows district-wise energy utilization for small, medium, and large farms. The energy consumption in land preparation for cotton was 932 MJ/ha, 1,098 MJ/ha and 1,129 MJ/ha for small medium and large farms, respectively. The lowest energy in a district was obtained from operation residue

Table 7 Operation-wise average energy input coefficient (MJ/ha) for selected panchyat samities

Operations	Telhara	Akot	Balapur	Akola	Patur	Barshitakali	Murtijapur
Land preparation	1,137	1,147	1,014	1,017	1,104	1,087	978
Residue management	34	29	34	39	39	40	42
FYM application	41	27	36	40	37	49	37
Sowing	41	54	101	41	41	42	41
Fertilizer application	121	110	89	114	102	114	114
Irrigation	585	304	103	274	413	534	466
Hoeing	389	397	343	372	382	359	360
Weeding	230	254	234	242	241	250	244
Picking	406	365	374	418	401	393	397
Total of uprooting	395	394	408	395	409	383	473

Table 8 Source-wise average energy input coefficient (MJ/ha) for selected Panchyat samities

Operations	Telhara	Akot	Balapur	Akola	Patur	Barshitakali	Murtijapur
Bullock Energy	515	527	613	569	479	486	566
Human energy	953	789	639	789	509	927	891
Mechanical energy	1,332	1,350	1,141	1,138	1,346	1,275	1,169
Irrigation energy	253	142	40	120	187	248	208
Seed	44	46	52	45	48	48	50
Fertilizer	5,846	5,522	4,647	5,287	5,543	5,498	5,232
FYM	2,088	1,918	1,743	2,035	1,944	2,446	2,233

management, FYM application, and sowing. For sowing, the maximum energy consumption (60 MJ/ha) was for small farms and minimum (47 MJ/ha) for medium farms. Fertilizer application energy was maximum (110 MJ/ha) for small farm and minimum (108 MJ/ha) for medium farms. Maximum harrowing energy was on small farms (394 MJ/ha) then medium and large farms. The weeding and picking energy was maximum (280 and 417 MJ/ha) for small farms and minimum (214 MJ/ha and 384 MJ/ha) for large farms. The medium farms exhibited lowest uprooting and collection energy (401 MJ/ha). The total sequestered energy was calculated to be 82,600 M J/ha with irrigation and fertilizers as major inputs and the cotton yield was 1,024 kg/ha lint and 2,176 kg/ha seed determined by Tsatsarelis (1991).

The large farms consume maximum energy (528 MJ/ha) in irrigation as compared to medium farms (312 MJ/ha) and (178 MJ/ha), which clearly indicate that lowest irrigation energy was used by small farms. Cultivation and harrowing did not show maximum variability. The small farms exhibited lowest harrowing energy (131 MJ/ha) then large farms (218 MJ/ha). Small farms consumed maximum energy (42 MJ/ha) for FYM application then medium and large farms. The analysis of the farm audit by developed software on the management and operation methods adopted showed the total energy inputs for these farms ranged from 3.7 to 15.2 GJ/ha of primary energy, which corresponds to \$80-310/ha and 275-1,404 kg CO^2 equivalent/ha greenhouse gas emissions [Chen and Baillie, 2009].

Comparative energy utilization (source-wise) in cotton crop for Akola district

Table 10 represents Source-wise energy utilization of Akola district. Maximum energy was provided by fertilizer, in all categories of the farm. It was highest on small farms (6,066 MJ/ha) then large farms (4,933 MJ/ha). It was followed by the energy provided by FYM maximum (2,255 MJ/ha) for small farms. The minimum energy was provided by seed in all three categories of the farm. The highest bullock energy was utilized on small farms (795 MJ/ha) then medium (434 MJ/ha) and large farms (379 MJ/ha). Large farms utilized minimum bullock energy (379 MJ/ha). High mechanical energy was utilized on large farms (1,511 MJ/ha) and minimum energy (872 MJ/ha) was utilized by small farms. The large farms utilized highest human energy (854 MJ/ha) and minimum human energy utilized by small farms (760 MJ/ha). The maximum electrical energy was utilized on large farms (304 MJ/ha), then medium farms (124 MJ/ha) and small farms (86 MJ/ha). Lowest irrigation energy was utilized by small farms (86 MJ/ha).

Input-output energy, energy ratio, specific energy, and energy productivity for cotton production

The input-output analysis examined the quantity of energy produced by the system against energy expenditure. Total energy comprised both direct and indirect from. Output energy was calculated considering energy of stalk and cotton fiber. Working out of input and output energy together with other relevant aspects such as energy ratio, specific energy (cotton fiber and stalk) and energy productivity both for cotton fiber and stalk was within the preview of an inquiry in the present study. These were, therefore, worked out separately with respective formulas for different Panchayat Samiti separately under study and have been presented in **Table 11**. **Table 11** has clearly brought out that Telhara Panchayat Samiti exhibited maximum output energy (72,884 MJ/ha), which is due to more pro-

Table 9 Farmers category operation-wise average energy input coefficient (MJ/ha) for Akola district

Operation	Small	Medium	Large	Overall
Land preparation on location and villages selected for the study Yavatmal, Washim, Buldhana and Wardhabha/aricleshow/1,698,070.cms	932	1,098	1,129	1,053
Residue management	40	37	34	37
FYM application	42	37	34	38
Sowing	60	47	48	52
Fertilizer application	110	108	111	110
Irrigation	178	312	528	339
Hoeing	394	358	377	376
Weeding	280	239	216	245
Picking	417	391	384	397
Total of uprooting	423	401	406	410

Table 10 Farmer category source-wise average energy input coefficient (MJ/ha) for Akola district

	Small	Medium	Large	Overall
Items	Small	Medium	Large	Overall
Bullock Energy	795	434	379	536
Human energy	760	742	854	785
Mechanical energy	872	1,367	1,511	1,250
Electrical energy	86	124	304	171
Seed	48	49	47	48
Fertilizer	6,066	5,104	4,933	5,368
FYM	2,255	1,980	1,940	2,058

duction of cotton fiber and stalk. Output energy of Akot, Barshitakli, Murtijapur, Patur Panchayat Samiti was 70591, 68548, 60858, 57984 MJ/ha, respectively. The lowest output energy was for Balapur and Akola Panchayat Samiti and was 42,364 and 55,595 MJ/ha, respectively. This was due to less cotton fiber and stalk yield. The highest input energy was 11,564 MJ/ha for Barshitakli Panchayat Samiti, which was due to use of maximum operational energy input and use of mechanical energy. It was followed by input energy of Telhara (11,359 MJ/ha), Murtijapur (10,667 MJ/ha) Akot (10,566 MJ/ha), and Patur (10,704 MJ/ha) Panchayat Samiti, respectively. The Balapur Akola Panchayat Samiti exhibited the minimum input energy of 9,178 and 10,319 MJ/ha, respectively, which was due to less use of farm operational energy input and use of traditional energy factors. The energy use efficiency for Akot, Telhara, Barshitakli, Murtijapur, Patur Panchayat Samiti was 6.70, 6.41, 5.93, 5.73 and 5.41, which indicated that energy use efficiency of Akot Panchayat Samiti was higher. This was due to more output energy, less input energy and maximum yield per unit area, followed by Telhara Panchayat Samiti, which was followed by Barshitakali, Murtijapur and Patur Panchayat Samiti. The lowest energy use efficiency was for Balapur Panchayat Samiti and was 4.70, which was due to minimum yield per unit area and, therefore, the result accordingly. The benefit?cost ratio was the highest in orange production (2.37) followed by lemon (Burhan *et al.*, 2004).

The specific energy (fiber) requirement was highest for Patur Panchayat Samiti 7.17 MJ/kg. It was followed by Murtijapur (6.43 MJ/kg), Barshitakali (6.29 MJ/kg), Akola (6.10 MJ/kg) and Balapur (5.96 MJ/kg) Panchayat Samiti. The lowest specific energy (fiber) was (5.46 MJ/kg) for Akot Panchayat Samiti. This meant that minimum energy of 5.46 MJ/kg was required to produce 1 kg cotton fiber. It was followed by Telhara Panchayat Samiti and was 5.60 MJ/kg. The specific energy of the stalk was highest (6.60 MJ/kg) for Balapur Panchayat Samiti. This meant that maximum energy of 6.60 MJ/kg was required to produce 1 kg of cotton stalk. It was followed by Akola, Patur, Murtijapur and Barshitakali and was 5.15, 4.77, 4.68 and 4.41 MJ/kg. Akot Panchayat Samiti exhibited lowest specific energy (3.99 MJ/kg) for stalk, which indicated that minimum energy of 3.99 MJ/kg was required to produce 1 kg cotton stalk. It was followed by Telhara Panchayat Samiti (4.22 MJ/kg). Energy productivity, which measured the quantity of product produced per unit input energy (kg/MJ) was the inverse of specific energy. Akot and Telhara Panchayat Samiti exhibited maximum (0.18 kg/MJ) energy productivity for fiber. This meant that 0.18 kg/MJ cotton fiber was produced per unit of input energy. The lowest energy productivety (fiber) was clearly indicated that 0.14 kg/MJ of cotton fiber was produced per unit of input energy. The energy productivity of Balapur, Akola, Barshitakali, Murtijapur was 0.17, 0.16, 0.16 and 0.16 kg/MJ, respetitively, and did not show any variability. The energy productivity of fiber for Patur Panchayat Samiti was 0.14 Kg/MJ, which clearly indicated that, although it used a higher amount of input energy as compared to Balapur, Akot, and Murtijapur Panchayat Samiti, yet it did not result in higher energy productivity. The Balapur Panchayat Samiti exhibited lowest (0.16 Kg/MJ) energy productivity (stalk). This indicated that 0.16 Kg/MJ stalk was produced per unit of input energy. The maximum energy productivity (stalk) was observed to be highest (0.25 kg/MJ) with Akot Panchayat Samiti, which indicated that 0.25 kg/MJ stalk was produced per unit of input energy. It was followed by Telhara, Barshitakali, Murtijapur and Patur Panchayat Samiti and was 0.24, 0.23, 0.22 and 0.21 kg/MJ. Net energy was highest for Telhara Panchayat Samiti (61,525 MJ/ha), which indicated that it had higher input as well as output energy. It was followed by Akot, Barshitakali and Murtijapur and was 60025, 56984 MJ/ha of energy and was of Balapur Panchayat Samiti, which clearly indicated that it had lowest input as well as output energy. It

Table 11 Input-output energy ratio, specific energy and energy productivity for different Panchyat Samiti

Energy parameter	Panchyat Samiti						
	Telhara	Akot	Balapur	Akola	Patur	Barsitakali	Murtijapur
Input energy (MJ/ha)	11,359	10,566	9,178	10,319	10,704	11,564	10,667
Output energy (MJ/ha)	72,884	70,591	42,364	55,595	57,894	68,548	60,858
Energy use efficiency	6.41	6.70	4.70	5.39	5.41	5.93	5.73
Specific energy A) Fiber (MJ/kg)	5.60	5.46	5.97	6.10	7.17	6.29	6.43
B) Stalk (MJ/kg)	4.22	3.99	6.60	5.15	4.77	4.41	4.68
Energy Productivity A) Fiber (kg/MJ)	0.18	0.18	0.17	0.16	0.14	0.16	0.16
B) Stalk (kg/MJ)	0.24	0.25	0.16	0.19	0.21	0.23	0.22
Net Energy (MJ/ha)	61,525	60,025	33,186	45,277	47,190	56,983	50,190

was followed by Akola, and Patur Panchayat Samiti and was 45,277 and 47,190 MJ/ha.

Cost Economy of Energy in Cotton Production

Computation of cost of production and cost of energy for different operations was one of requirements in the present investigation. With this objective, cost of production and cost of energy for different Panchyat Samities were worked out taking in to account expenditure incurred for different operations besides cost of input such as seed, fertilizer and FYM. The cost of seed cotton (fiber) was taken Rs. 3,000 per 100 kg of produce.

Comparative operation-wise average cost of production for different panchyat samities

Table 12 represented the average operation-wise cost estimation for different Panchyat Samities. FYM exhibited maximum cost of 3,487 Rs/ha and was higher for Barshitakali Panchyat Samiti (4,124 Rs/ha) than Balapur Panchyat Samiti (2,891 Rs/ha). Telhara panchyat samiti exhibited maximum fertilizer cost (3,424 Rs/ha) and was lowest for Akola panchyat samiti (1,789 Rs/ha). Weeding cost was maximum for Akot Panchyat Samiti (3,844 Rs/ha) and was minimum for Murtijapur Panchyat Samiti (1,862 Rs/ha). The overall average lowest cost of selected Panchyat Samities was for irrigation (79.64 Rs/ha) and higher (141.50 Rs/ha) for Telhara Panchyat Samiti and lower (28.39 Rs/ha) for Balapur Panchyat Samiti. Telhara Panchyat Samiti exhibited higher cost of production of 21,581 Rs/ha and lower for Balapur Panchyat Samiti of 13,837 Rs/ha. It has been sure that, this cost of production was highly influences by the input given by the respondent for growing the cotton crop and resulted in higher yield (i.e., Telhara 21.31 quintal/ha and Balapur 9.54 quintal/ha). The average cost of production for the district was Rs 17,093 per hectare with an average yield of 13.12 q/ha. The most important cost items were labour, machinery, land rent and pesticide (Bahattin and Vardar, 2008).

Cost of energy in cotton production:

The cost of energy was determined with the help of cost of production and total input energy required for cotton production. It represented the measures in terms of the cost required per unit of energy. The costs of energy were maximum in Telhara Pachyat Samiti of 6.38 Rs/MJ and lowest in Patur Panchyat Samiti of 4.83 Rs/MJ. The average cost of energy for a district was 5.50 Rs/MJ.

Benefit-cost analysis of cotton production:

Table 12 shows that cost of production was maximum (21,581 Rs/ha) for Telhara panchyat samiti and minimum (13,837 Rs/ha) for Balapur panchyat samiti. The overall average cost of production was 17,093 Rs/ha. Telhara Panchyat Samiti exhibited maximum gross income (66,064 Rs/ha) and Balapur Panchyat Samiti exhibited minimum gross income (29,569 Rs/ha). The overall average gross income was 40,668 Rs/ha. The benefit-cost ratio was highest (3.06) for Telhara Panchyat Samiti and lowest (2.07) for Balapur Panchyat Samiti. The overall average benefit-cost ratio of selected Panchyat Samities was 2.29.

Table 12 Cost analysis operation-wise for panchyat samities (Rs/ha)

Cost parameters	Telhara	Akot	Balapur	Akola	Patur	Barshitakali	Murtijapur	Overall
Land preparation	2,125	2,250	2,000	2,000	2,125	2,125	1,875	2,071
Residue management	220	214	214	250	245	256	267	238
FYM application	422	335	358	404	383	511	384	399
Sowing	396	303	117	344	366	371	261	308
Fertilizer application	842	713	562	731	643	739	1,033	752
Irrigation	142	56	28	61	84	96	90	80
Hoeing	247	250	250	159	250	157	250	223
Weeding	2,481	3,844	1,935	2,158	1,999	2,390	1,863	2,382
Picking	4,795	1,343	791	1,661	835	1,240	3,303	1,996
Uprooting	625	625	500	500	500	500	500	536
Collection	73	78	69	71	70	70	73	72
Seed	1,987	2,036	1,977	1,804	1,834	2,004	2,005	1,949
Fertilizer	3,424	2,687	2,144	1,789	2,714	2,772	2,673	2,601
FYM	3,803	3,211	2,892	3,394	3,275	4,125	3,711	3,487
Cost of production (Rs/ha)	21,582	17,944	13,838	15,328	15,323	17,355	18,287	17,094
Yield, quintal/ha	21.3	12.2	9.5	10.6	10.0	11.7	16.5	13.1
Gross income (Rs/ha)	66,064	37,775	29,569	32,879	30,877	36,312	51,202	40,668
Benefit cost ratio	3.1	2.0	2.1	2.1	2.0	2.0	2.8	2.3
Total input energy (MJ/ha)	3,380	3,079	2,657	2,952	3,169	3,252	3,152	3,103
Cost of energy (Rs/MJ)	6.4	5.8	5.2	5.2	4.8	5.3	5.8	5.5

Comparative energy economics according to land holding of Akola district

Table 13 represents operation-wise average cost estimation for small, medium and large land holdings of Akola district. FYM exhibited overall average maximum cost of 3,487 Rs/ha, and was higher (3,790 Rs/ha) for small farms and lower (3,293 Rs/ha) for large farms. The overall average lowest cost for irrigation was (79.64 Rs/ha) and maximum (82.36 Rs/ha) for small farms and minimum (75.93 Rs/ha) for large farms. The specific energy requirements for the production of crops did not differ significantly with irrigation methods (Mittal and Dhawan, 1989).

Cost of energy according to land holdings:

The average cost of energy (Rs/MJ) in cotton production of Akola district according to land holdings was 7.45 Rs/MJ. The small farms exhibited maximum cost of energy (8.49 Rs/MJ) and large farms a exhibited minimum (6.48 Rs/MJ) cost of energy, at which average yield of small and large land holdings of the district was 17.22 quintal/ha and 9.96 quintal/ha, respectively. The cost of energy for the cotton and soybean crop production using the traditional and mechanized practices was determined (Karale *et al*., 2008).

Benefit-cost analysis of cotton production:

Overall average cost of production for Akola district was 17093 Rs/ha. The cost of production was maximum (18,791 Rs/ha) for small farms and minimum (15,920 Rs/ha) for large farms. Maximum gross income (53,369 Rs/ha) for small farms and minimum (30,867 Rs/ha) for large farms. The benefit-cost ratio was maximum (2.84) for small land holdings. The overall average benefit cost ratio for Akola district was 2.29. The energy and economic evaluation for the various crops were carried out for the various field operations considering the traditional and mechanized practices (Khambalkar *et al*., 2010).

Table 13 Cost analysis according to land holdings for Akola district (Rs/ha)

Cost parameters	Cost incurred in (Rs/ha)			
	Small	Medium	Large	Overall
Land preparation	2,071	2,071	2,071	2,071
Residue management	257	239	217	238
FYM application	446	385	368	399
Sowing	322	301	302	308
Fertilizer application	713	708	835	752
Irrigation	82	81	76	80
Hoeing	265	213	192	223
Weeding	2,738	2,329	2,078	2,382
Picking	2,746	1,755	1,485	1,996
Uprooting	536	536	536	536
Collection	74	68	74	72
Seed	1,956	1,976	1,916	1,949
Fertilizer	2,794	2,530	2,477	2,601
FYM	3,791	3,377	3,294	3,487
Cost of production (Rs/ha)	18,791	16,570	15,921	17,094
Yield, quintal/ha	17.2	12.2	10.0	13.1
Gross income (Rs/ha)	53,369	37,768	30,868	40,668
Benefit cost ratio	2.8	2.2	1.8	2.3
Total input energy (MJ/ha)	2,891	3,012	3,375	3,092
Cost of energy (Rs/MJ)	8.5	7.4	6.5	7.5

Conclusions

Based on the findings from the investigation the following conclusions were drawn:

The average per hectare operation-wise and source-wise energy utilized was maximum for Telhara panchyat samiti and minimum for Balapur Panchyat Samiti. The net energy was maximum for Telhara Panchyat Samiti and minimum for Balapur Panchyat Samiti. The operation-wise per hectare energy utilization was maximum for large farms and minimum for small farms of Akola district. The source-wise per hectare energy utilization was maximum for small farms than large and medium farms of Akola district.

The independent variables (area under cultivation, power sources, FYM application, irrigation, hoeing and input energy) were highly and positively significant on yield as dependent variable. For output energy as dependent variable the independent variable FYM application was significant, at 0.01 level of probability and other independent variable; (area under cultivation, power sources, irrigation, hoeing and input energy) were observed to be highly significant on output energy at the 0.05 level of probability. Variables (area under cultivation, power sources, irrigation, FYM application, hoeing and input energy) were found to contribute to the extent of 82.10 % in variation in yield, and contributed 92.08 % in variation in output energy. As for path analysis area under cultivation factor show maximum direct effect on yield and power sources show minimum direct effect on yield. The variable input energy show maximum indirect effect on yield while area under cultivation show minimum indirect effect. For output energy as dependent variable, it was concluded that maximum direct effect on output energy was exhibited from independent variable area under cultivation and minimum direct effect was power sources on output energy. The maximum indirect effect was input energy and minimum was FYM application on output energy.

The cost of energy was maximum (6.38 Rs/MJ) for Telhara Panchyat Samiti and minimum (4.84 Rs/MJ) for Patur Panchyat Samiti. The benefit-cost ratio was maximum (3.06) for Telhara Panchyat Samiti and minimum (1.98) for Patur Panchyat Samiti. The average per hectare cost of production and gross income was higher (cost of production 21,581 Rs/ha; gross income 66,064 Rs/ha) for Telhara panchyat samiti due to higher yield and lower (Cost of production 13,837 Rs/ha; gross income 29,569 Rs/ha) for Balapur Panchyat Samiti due to lower yield. The cost of production and gross income was higher (cost of production 18,791 Rs/ha; gross income 53,369 Rs/ha) for small farms and lower (cost of production 15,920 Rs/ha; gross income 30,867 Rs/ha) for large farms of Akola district. The benefit cost ratio was found to be higher (2.84) for small farm and lower (1.82) for large farm for Akola district. The cost of energy was maximum (8.49 Rs/MJ) for small farms as compared to medium (7.38 Rs/MJ) and large (6.48 Rs/MJ) farms for Akola district.

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EVENT CALENDAR

◆ **2013 AMC Conference**
—The 28th annual Agricultural Machinery Conference—
May 6–8, 2013, Waterloo, Iowa, USA
http://www.amc-online.org/About.html

◆ **XI International Controlled & Modified Atmosphere Reserch Conference**
June 3–7, 2013, Trani, ITALY
http://www.ishs.org/news

◆ **Suprofruit 2013**
—12th International Workshop on Sustainable Plant Protection Techniques in Fruit Growing—
June 28–30, 2013, Valencia, SPAIN
http://www.suprofruit2013.org.es/

◆ **CIOSTA xxxv**
—(commission internationale de l'organisation scientifique du travail en agriculture) from effective to inteligent agriculture and forestry—
July 3–5, 2013, Aarhus, DENMARK

◆ **ICSAEF 2013**
—International Conference on Sustainable Agriculture, Environment and Forestry—
July 08-09, 2013, London, UK
http://www.waset.org/conferences/2013/london/icsaef/index.php

◆ **ECPA**
—9th European Conference on Precision Agriculture—
the auspices of the International Society of Precision Agricultture (ISPA) and the Universitat de Lleida (UdL)
July 07-11, 2013, Catalonia, SPAIN
http://www.ecpa2013.udl.cat/index.html

◆ **SEAgIng SECH**
—SDCH Agricultural Engineering and Horticul Tural Sciences—
August 26–29, 2013, Madrid, SPAIN
http://www.sechaging-madrid2013.org

◆ **Agricontrol 2013**
—The 4th IFAC Conference on MO delling and Control in Agriculture, Horticulture and Post Harvest Industry—
August 28–30, 2013, Espoo, FINLAND
http://agricontrol2013.automaatioseura.com

◆ **5th International Conference**
—Trends in Agricultural Engineering—
September 3– 6th, 2013, Prague, CZECH REPUBLIC
http://www.conference.cz/tae2013/home.htm

◆ **Joint European Conference on Precision Livestock Farming**
September 10–12, 2013, Leuven, BELGIUM
http://agricontrol2013.automaatioseura.com

◆ **Synergy in the Technical Development of Agriculture and Food Industry III. International Conference**
October 13–19, 2013, Gödöllő, HUNGARY
http://www.acss.ws/News.aspx?id=360

◆ **AGRITECHNICA 2013**
—World's leading international exhibition for agricultural machinery and equipment—
November 12-16, 2013, Hannover, GERMANY
http://www.agritechnica.com/home-en.html

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

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

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

◆ **18th World Congress of CIGR**
—International Commission of Agricultural and Biosystems Engineering—
September 16–19, 2014, Beijing, China
http://www.cigr2014.org

Conventional vs. Radio Frequency Identification (RFID) Controlled Cattle Handling Technology Review: The Way Forward


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Abstract

There are limitations in conventional beef cattle management practices in South African feedlots. This is due to a lack of an adequate system for monitoring and controlling activities when handling cattle. In order to find a solution to these limitations, this document outlines a literature review to investigate an alternative automated system using Radio Frequency Identification (RFID) as a management tool. Case studies indicate the success of application of RFID where labour costs, data control errors and handling time were reduced and thus promotes the integration of this technology in conventional cattle management systems. The application of an automated system for beef cattle management that utilises RFID technology, where animals will be identified, weighed and automatically sorted in order to achieve best practice, is proposed. This research into technology development will further on yield prototype development of RFID controlled technology which is likely to result in improved operations. Thorough evaluation and assessment in the South African environment is proposed to be undertaken at a higher research level.

Introduction

A feedlot is a closed and intensive feeding system for finishing cattle before slaughter. It comprises of pens and infrastructure for animal handling where all the management practices such as identification, sorting, feeding and dipping are carried out (Grandin, 2003). According to the South African Feedlot Association SAFA (2008) there are approximately 70 feedlots in South Africa which account for 75-85 % of all the beef produced in the country. The Census for Commercial Agriculture CCA (2008) reported that there are approximately 12 large feedlots comprising of more than 20,000 cattle and there are more than 50 small to medium feedlots with the mode being the range 2,000 cattle and below. Ford (2008) highlighted the fact that lower profit margins of most feedlots in the range of 4,000 cattle and below may be as a result of current management practices and further identified the shortcomings of conventional manual management systems as having long animal handling times, errors in the practice, low standards of record keeping of animal and less consideration of animal welfare.

In order to achieve the optimum levels of success it is important to incorporate the best management practice into cattle management systems. It is required that the management system incorporates precision and accuracy in its operation as compared to the conventional manually operated procedures being utilised in South Africa (Ratsaka, 2009).

It has been shown that the use of electronics in the management of livestock improves data management, reduces animal handling time and enables easy planning of animal handling activities (SACO, 2008). Radio Frequency Identification (RFID) is defined in the RFID Journal (2005) as a wireless means of information or data passage from source to a user system. The most common example is information interchanges between electronic tags and a reader.

The NDA (2008) abstract for agriculture statistics highlights the need for a study that evaluates management practices currently being utilised in feedlots, documents their limitations and then develops and asses an alternative management system. This document contains a review of the application of RFID technology and is essential in developing solutions that may be applied to address these shortcomings.

The aim of the study is to develop advanced technology for cattle management systems as an alternative to the current manually based. The objectives of this research are:

- to investigate limitations in the current management practices that are being utilised in feedlots
- to review, through the use of case studies and experience from other countries, the benefits of incorporating RFID technology in animal management and
- to outline proposed future work in the development and assessment of an alternative management system that incorporates electronics, in particular RFID technology for the South African feedlot industry and compare it to the manually based system.

Future work is proposed, of which this research into technology development will yield prototype development of RFID controlled technology which is likely to result in improved operations. Thorough evaluation and assessment in the South African environment is proposed to be undertaken at a higher research level.

Conventional Manual Cattle Management Systems

A feedlot refers to facilities for intensive cattle finishing operations before slaughter. Concentrated animal feeding operations can accommodate hundreds of cattle in pens arranged in a special way in order to achieve the best management practices (Grandin, 2003). In order to have a better understanding of electronic management, it is necessary to review relevant literature in the feedlot applications (Collyer and Viljoen, 2002).

Working Cattle in Feedlots

According to Breedt (2003) construction of cattle feedlots should be on a slope of between 3-6 % taking into consideration the soil type, prevailing winds, possible future extensions and space for pollution control dams. Grandin (1999) explained that a typical layout consists of feedlot pens where the animals are kept, handling facilities where management practices are performed, a unit for storing and processing feed, an office and workshop area, manure, waste and drainage handling structures.

A feedlot setup should also include facilities for staff and business operations (Meuling, 2006). According to NDA (2008), 95 % of South African feedlots are manually operated with little or no automation thus relying on human accuracy for their success.

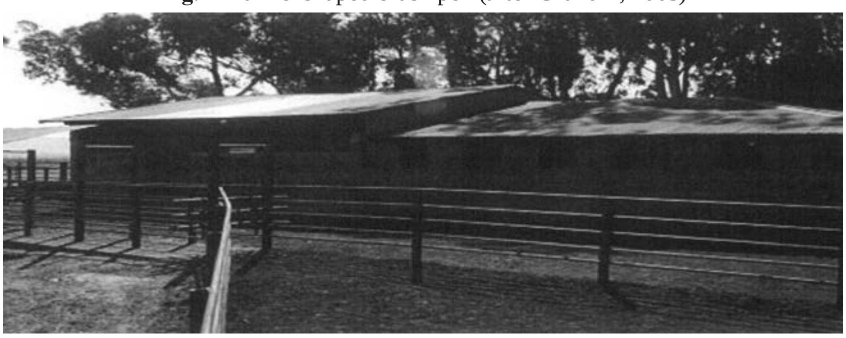
Butchbaker *et al.* (1999) highlighted that it is important to review the management practices that are undertaken in the handling facility as they may limit profitability and hinder smooth running of the enterprise. Hence, it is important to also review the processes of animal identification, weighing and sorting of cattle in facilities.

Handling Facility for Cattle

According to Grandin (2004) the handling facility is the section where the cattle are initially received into the feedlot system. The rest of the management activities occur after this stage. Collyer and Viljoen (2002) highlighted that under the current manual management practices, once the animals are received in the handling facility the sequential activities are weighing, tagging and dehorning, sorting, followed by dipping and, lastly, inoculation. Handling facilities comprise the following basic handling zones: leader crush, weighing area, neck and body clamp, sorting pens, spray race or dipping passage, working area, feeding area and loading/offloading zones (Fulwider *et al.*, 2003).

Meuling (2006) defines crush pens as channels or passages where cattle move throughout the handling zones, i.e. from sorting to the loading platform or even in the reverse direction. These pens are usually provided with moveable gates that are used for leading the cattle into the crush. The gates restrict the

Fig. 1 Funnel shaped crush pen (after Grandin, 2003)



area behind the animal such that the animal moves forward to where it is led. A funnel-type crush is usually used in handling facilities with a rectangular layout.

Fig. 1 shows a typical funnel shaped crush pen, with a passageway that directs animals from the off-loading ramp to the scale where their weight will be measured and recorded (Collyer and Viljoen, 2002). According to Collyer and Viljoen (2002), in the conventional method, the animals are manually driven through the passageway to the weighing scale prior to tagging and identification. Fulwider *et al.* (2003) cautions that, the practice is likely to result in difficulties in animals identification as they would have been weighed without tagging and identification.

Cattle Weighing System

It is important to choose and place scales in a manner that is easy and effective for animal handling. There are basically four categories of scales namely; spring balance scales, hydraulic scales, oil bath scales and electronic scales (Grandin, 2003). Cattle arrive at the weighing area where their weight is captured. If an electronic scale is used the reading is displayed on the dial and if an analogue scale is used the animal's weight is indicated by the counter weight it balances (Ford, 2008). The observed reading is manually recorded in the data book by the attending registrar/clerk for later compilation and information storage. There are limitations associated with this manual capturing of cattle weight data which include the risk of loosing information recorded during weighing, risk of data mix-up as identification and tagging is done after weighing and the risk of recording or capturing incorrect reading from the scale as influenced by the skill and fatigue of the operator obtainable by re-measuring the obtained information and verification (Collyer and Viljoen, 2002).

Tagging and Identification

Tagging of an animal refers to the placement of identifiers on the cattle's ear. The identifier could be a unique plastic tag with a code or a number (Meuling, 2006). Tagging and identification is done when the animal is held in the neck and body clamps which are located in the working area of the handling facility. **Fig. 2** shows a typical working area showing the neck clamp where the animal is restrained during the tagging process. SAFA (2008) stated that there is a risk of having two or more animals with the same identity number or code which could have been as a result of tagging after data acquisition. After tagging and identification, the animals are then forwarded to the sorting gates for them to be allocated to their respective pens.

Cattle Sorting

Sorting refers to the allocation of cattle to a holding pen according to various categories such as weight and stage of growth (Grandin, 1997). The sorting system comprises usually of gates that lead to different pens from a central passage where the tagging and identification was done. **Fig. 3** shows a typical plan view of a sorting gate leading from a neck and body clamp.

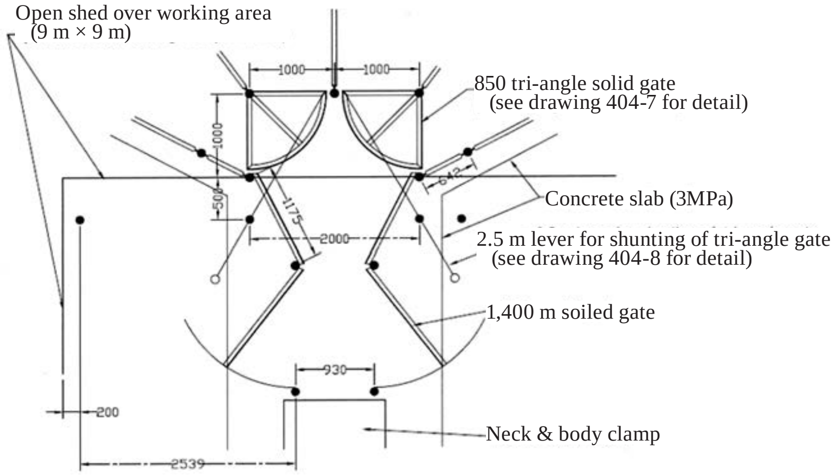
A decision of how the animals are to be sorted is based on the weight data and the management requirements (Breedt, 2003). According to Ratsaka (2009), due to the fact that errors and mistakes are not easily verified along the procedure a manual system increases the chance of incorrectly sorting animals as a result of mistakes carried over from the identification and weighing systems. After sorting, the animals are either directed to the feeding troughs or to the dipping system.

Feeding and Dipping System

According to Butchbaker *et al.* (1999) a fully grown cow consumes approximately 6-10 kg of dry matter and between 40-50 litres of water per day. Conventional feeding uses a community feeding method whereby the animals feed from a common trough without rationing feed quantities and without limiting or monitoring individual consumption (Ford, 2008). NDA

Fig. 2 Typical working area (after Breedt, 2003)

Fig. 3 Typical sorting gates leading from clamp (after Mutenje, 2009)



(2008) highlights that in a setup as described data on individual animal feed consumption would not be available to aid good management practices for the successful operation of the enterprise. After feeding, cattle can either be directed to the holding yards, or if treatment is required, then the animal is sent to the dipping facility. SAFA (2008) highlighted that many cattle diseases are transmitted by ticks and, in cases of a serious infection, it can cause anaemia. In South Africa the widely used control methods are: spray race, immersion dipping, and pour-on remedies (Ratsaka, 2009). The major limitation of this management practice is that the remedies are administered from a manually calculated instruction which is based on the measured animal data, thus, a mistake is carried over from the initial data to treatment system.

Management Practice Summary

In the European community it is mandatory to follow certain management guidelines in order to be issued an operating licence. The final report of Joint Research Commission to the European Commission proposed that an electronic management system be introduced in order to improve the current management practice in developing and underdeveloped countries (IDEA Project, 2003). SACO (2008), states that electronics management of cattle is being practised in many developed countries whilst less than 5 % of the South African feedlots make use of the technology. It is, thus, necessary to evaluate electronics management as applied in other countries and adapt it for local applications in South Africa.

Electronic Cattle Management Systems

The technology of electronic identification (RFID) of livestock is currently available in simple or complex forms (Artman, 1999). It works with both an identifier and an interrogator. The transponders and readers are the most common components. A transponder is a device that transmits and responds to electronic interrogation by a reader panel. A reader panel is a device that interrogates a transponder by sending an electromagnetic signal thereby activating it for data transmission (RFID Journal, 2005b). Some of the identifiers currently utilised include implantable chips, rumen boluses and ear tags. Implantable chips consist of identifying integrated circuits that are implanted underneath the animal's skin. Rumen boluses are electronic devices for identification that are placed in a container and administered to the cow through the mouth. Electronic ear tags may be made up of plastic or metal tags which house an integrated circuit that has an identification number or code. These are pinned onto the cattle's ear cartilage for identification (IDEA Project, 2003).

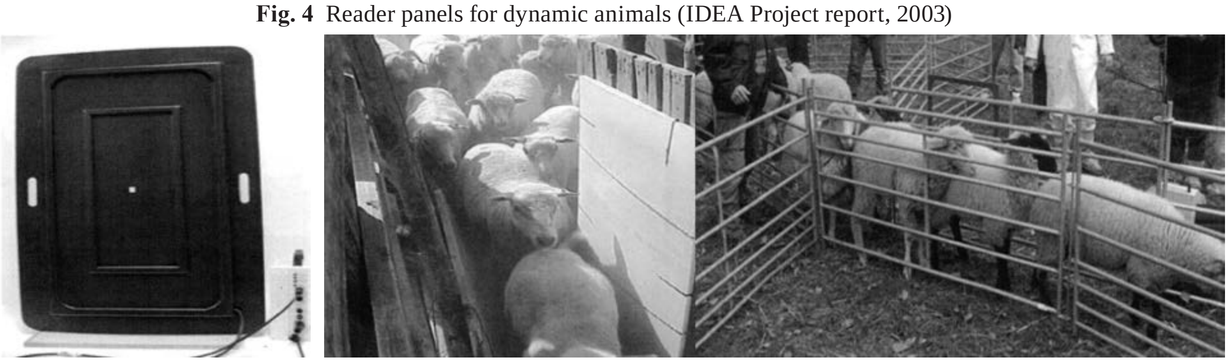
According to IDEA Project (2003), the three main types of readers are hand-held, portable and stationery readers. It is essential that the reader creates a field and as soon as the identifier enters the field it is activated and the reader then receives the signal that comes from the transponder. Stationary readers, as illustrated in **Fig. 4**, are widely used for mobile animals and where the animals are unattended. This unit is placed in a chute where the animals will pass through for optimum handling.

Aarts *et al*. (1989) state that for optimum working conditions the readers should be placed 750 mm apart. This will enable one cow to be in the readers' range at a time and avoid collisions which are caused by having two identifiers in the reader's range at a particular moment. Normally the transponders are best read if travelling at a speed of no more than 10 $kmhr^{-1}$ (Aarts *et al*., 1989).

Reading of Electronic Identifiers and Control Interfaces

The IDEA Project (2003) recommended that reading be undertaken by a skilled operator to avoid mistakes and errors. The identifier is first tested before it is applied to the animal to ensure that it is not defective. As a rule of thumb, an identifier that shows signs of damage or fault must not be applied to the animal as it may not be reliable when in use.

Fig. 4 Reader panels for dynamic animals (IDEA Project report, 2003)



Stationary or static reading involves the use of hand held readers on an animal that is restrained. This method is time consuming and tiresome as it requires the reader to be passed exactly over the identifier's positioning and it is, thus, mainly utilised for small herds (IDEA Project, 2003). Hanton (1992) states that in dynamic reading the animals pass through a single file raceway where the panel readers will be on the sides of the corridor. As the transponder comes into the field of the reader it is activated and identified.

Applicability of Electronic Management in Cattle

According to Lambooij and Merks (1989), the technology of electronic identification can be utilised in the recording and identification for good farm practices. According to the tests and research at the Grange Research Centre (GRC) in Dublin, Ireland, it was concluded that implantable electronic transponders, also referred to as IETs, offer a more reliable system in individual animal identification compared to visual tags alone (Lambooij and Merks, 1989).

From about 150 experiments conducted under different conditions and climates, the tests resulted in a 97.5% success and recovery of the technology after use. Before 1989 there was still controversy on the implantation site for the various IETs. Studies were then undertaken by Aarts *et al*., (1989) on four sites on beef cattle. Different sites on the cattle body were chosen as tests sites in the initial phase and only 4 remained after the ethics, health and animal safety considerations were adhered to.

It was concluded that the most suitable position on which the RFID tag was to be applied was under the scutiform cartilage of the ear. This was first recommended by Fallon and Rogers (1991) and confirmed as suitable by Hasker *et al*. (1992).

Experience in Electronic Management

Hanton (1991) highlighted that a drawback of the utilisation of injectable transponders was that there is risk of not recovering the device after slaughter and thus IETs are usually regarded as an unacceptable method of identification. The other experiments conducted showed the possibility of utilising a rumen bolus as a means of identification.

However, according to Lambooij and Merks (1989), careful consideration is required when selecting the type of identifier to use between the rumen bolus and ear tag as they both have similar advantages. When comparing the rumen bolus and the ear tags it was found that reading a bolus was more difficult when applied to hand held readers.

Electronics Tags and Bolus Comparison

According to Eradus *et al*. (1999), an experiment to compare the use of electronic tags and rumen boluses as means of identification was conducted at the Teagasc, Grange Research Centre. In this experiment 1,120 cattle were used in the study. The categories varied from beef cows, 1-5 weeks old calves, weaners, replacement heifers and feedlot cattle that were due for slaughter within 100 days. The experiment made use of rumen boluses and tags supplied from key manufactures, namely Allflex and Nedap (Allflex, 2009). The experiments started in September 2000 and the results after 7 months are as contained in **Table 1**. From these results it was concluded that boluses are more durable and reliable as compared to electronic ear tags.

Table 1 Results of bolus and tags comparison (after Eradus *et al*., 1999)

PERIOD (When readings were taken)	ALFLEX (Units still active)		NEDAP (Units still active)	
	Bolus	Ear tag	Bolus	Ear tag
Day 0	510	511	511	510
Day 7	510	511	511	499
Day 28	510	506	511	489
Not reading at 7 Months	5	8	5	23
After 7 Months	505	503	506	487
% Change	0.98	1.57	0.98	4.51

Eradus *et al*. (1999) conducted a holistic analysis that included economics, applicability and effect on animal welfare of the boluses and tags. They concluded that although boluses seem to be more durable, analysing all other factors like cost, reading distance and applicability, the result favoured the use of electronic ear tags as they are easily available, cheaper than bolus and also easy to administer.

According to Walker (2009) electronic ear tags in cattle makes use of radio waves operating at a low frequency. The waves are able to pass through living tissue. ISO 11784 is the set of guidelines that explains the identification code itself whilst ISO 11785 focuses on the technicalities of the tag and reader to ensure compatibility. Normally the 134.2 kHz band is the operating frequency in animal identification. Information interchange between tag and reader is based normally on either a half duplex or a full duplex defined and symbolised by (HDX) AND (FDX-B), respectively. After the transponder sends a signal to uniquely identify itself it reverts back to its passive state waiting to be activated again by a reader field.

The limitations in the conventional manual feedlot management practices have been discussed and the need of an automated system has been highlighted. The next chapter uses case studies where the suggested RFID technology has been applied in other countries to evaluate the performance and success thereof.

Case Studies of Rfid Technology Implementation

RFID technology is used globally and its current popularity as a tool for better management of cattle. It could possibly lead to being utilised for beef cattle management in South Africa (SACO, 2008). Dean *et al.* (1992) stated that electronic ear tags are the most widely used identifiers and they consist of two basic components, namely the internal integrated circuit and the outside shell holder that is fastened onto the ear. An animal is fitted with two tags, an electronic tag attached to the left ear and a visual tag on the right ear.

Application in RFID Tags to Cattle Management

According to Naas (2002) the use of RFID electronic ear tags has many advantages for management of feedlots. Naas (2002) stated that electronic tags can be regarded as a great improvement compared to the visual reading of codes and numbers. The reduction of labour cost is highlighted as one of the major advantages of the use of RFID tags. Artman (1999) concluded that the use of RFID tags reduced incorrect readings from 6 % to 0.1 %.

According to Geers (1997) the use of electronic tags in animal production and management practices opens possibilities for the monitoring of more complicated tasks such as automatic sorting, feeding and health treatments as evident from tests and experiments that were conducted by Artman (1999) where specific technology was developed and tested successfully for the management practices.

Animal Identification, Weighing and Automatic Sorting Applications

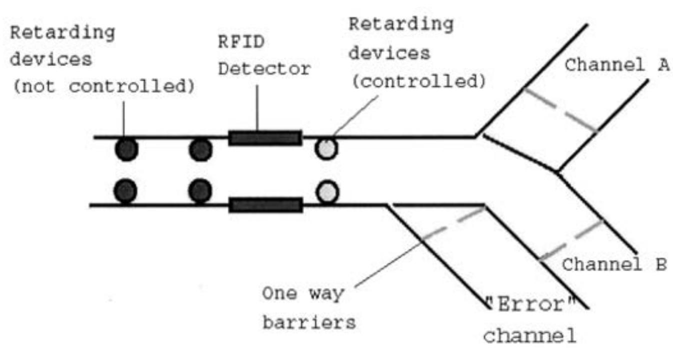
The first case study entails the application of electronic ear tags equipped with TROVAN ID-100A tags (TROVAN, 2009) and visual tags for the management of a 35000 head of cattle at Campo ranch in Argentina. A GR-100 GRIP computer and management software were utilised in the study. It was found that the processing of animals was 60% faster with consequent less strain on the animals and time saving in the operations (TROVAN, 2009).

The second case study was on the application of RFID on a dairy farm in Dublin, Ireland (Dairymaster's, 2009). RFID technology operating at 125 KHz with passive tag and short read range was used. The objective of the study was to identify cattle using RFID technology and use the information in cattle management practices of dairy cattle. This was applied in the identification of cattle when weighing, milking, feeding, dipping and sorting. The system also incorporated management software that recorded data and also performed feeding schedules based on the software instructions. The feed was also quantified and rationed for each animal according to the milk yields. There was a reduction in labour costs as the labour requirements were reduced from 13 to 6 personnel where one operator could milk 800 cows in a period of 3.5 hours compared to manually managed systems.

In a study in Route d'Arles, France, the Institute of Natural Resources Arles INRA (2009) in collaboration with the WALLACE foundation developed and tested an automatic sorting system for sheep using RFID. The technology which made use of electronic tags in sheep sorting resulted in time and manpower savings. As indicated in their test the system was able to sort an average of 700 ewes in 20 minutes which was 80 % faster than manual sorting, resulting in a reduction of an equivalent of almost 200 labour hours per week. **Fig. 5** shows a plan view of a sorting system that was developed by INRA and which makes use of RFID technology. As explained by the INRA (2009) experts, the sheep are passed through the RFID detector and an RFID compatible electronic scale system after which, through the use of management software, the sheep are sorted to either camp A or B based on the sheep's weight. Should the device fail to be read then the animal is taken to a device error channel where it is marked by an ink for further attention.

According to Boote and Mavundza (2009) a four way automated sheep sorter was developed at a cost of less than R50,000.00 and which is capable of sorting an average of 720 sheep per hour on weight basis. Boote and Mavundza (2009) report that the sheep sorter was designed and constructed to be portable to the extent that it only required two health people to be able to lift it into the back of a truck. Mavundza (2009) highlighted that the sorting

Fig. 5 Sorting unit making us of RFID technology (INRA, 2009)



module was part of the electronic management of livestock using RFID technology project of the ARC-IAE and the idea would be adopted for cattle systems.

Case Study of Total Management System

Another case study for investigating the benefits of using RFID ear tags to complement individual animal record-keeping was conducted at Corona Range and Livestock Research Centre (Cox *et al*., 2006). In the investigation they made use of visual and electronic ear tags, a reader system, a compatible electronic scale, indicators, various management software suites (e.g. Beeflink, Cow sense, CattleMax2, GMP Basic) with RFID compatibility, an image capturing device and a computer system. In their research and testing they established a system which included capabilities such as records of individual animal performance, automated electronic weight recording, monitoring performance during weighing, and information interchange with herd management software without any information loss.

It was also established that a comprehensive recording system working on 150 head of cattle would cost an equivalent of US$ 4,393-00, excluding the feeding and dipping mechanism. In the 3 year duration of the project, of the 150 electronic tags fitted to cattle there was 100% responsive tags and only one tag was lost, whilst the replacement rate for the visual tag was in the range of 2.7 %. Cox *et al.* (2006) argued that the use of RFID technology/tags also come with a price to pay in maintaining the technology as there is need of regular servicing of all the equipment, software upgrades, computer maintenance and upgrades and keeping up with technology. It was observed that the technology reduced the labour force by almost 50 % and reduced data recording errors by almost 5 %. It was also discussed that this management practice reduced sorting time by 3-4 h per day for 500 cattle, which in turn reduced animal stress and worker fatigue, thus increasing the operations profit margins.

Discussion and Conclusions

General Discussion and Conclusion

In order to successfully monitor and manage animal growth and production, it is necessary to have good data for the entire feedlot operation. There is a challenge in the management of cattle feedlots in South Africa as the conventional methods used are limited to manual techniques for identification, weighting, sorting, feeding and dipping of animals.

South African feedlots are operated manually and use very little to no electronics in their operations. It has also been shown from the studies that manual management practices result in high labour costs, high operation costs, is time consuming, can result in inaccurate records and storage of data and sometimes takes less consideration of animal welfare thus causing injuries and harm to the animal.

From the studies reviewed, it can be concluded that the current manual management practices in South Africa are a less effective way of cattle management for optimum production.

Key Findings

The two key aspects in successful management are good identification and control systems. The importance of RFID technology as applied to animal management was highlighted in the operations included in the case studies.

In the case studies it was demonstrated that RFID technology application in an operation reduced data handling errors by more than 5 %, reduced labour costs by almost 50 % and reduced animal stress through reductions in handling and sorting times.

There is great potential for the adaptation and use of electronic ear tags as a management tool in the South African context which has 95 % of the feedlots currently utilising manually based systems that have limitations and hence may benefit by adopting the new technology.

Proposed Further Work

It is thus necessary to research the development and assessment of technology for an alternative management system that incorporates electronics, in particular Radio Frequency Identification ear tags, for the South African feedlot industry, as outlined.

This research into technology development will yield prototype development of RFID controlled technology which is likely to result in improved operations.

Major aspects of the system being considered would be a deterring mechanism before cattle enters the reading area to enable smooth flow operations during inflow and out flow; and automatic cattle sorting gates after handling to improve the management practice through the reduction of capital and operational costs, labour costs, animal stress, handling/sorting time and reduction handling stress.

The first module design report will describe the Design Process involved in developing cattle deterring mechanism, which is controlled by instructions of sensors and the RFID system. The technology will include sensors to detect animal presence and departures and RFID technology to control. The research will terminate upon prototype development and prototype testing only.

The second module design report will fully highlight the design process involved in developing automatic electronic sorting gates that are controlled by instructions of the RFID management system. The technology will include readers to detect animal presence and departures, automated sorting gates and RFID technology to control. The research will terminate upon prototype development and prototype testing only.

Upon the establishment of the above technology the system/ prototypes will be tested and evaluated as per prototype development guidelines. The prototype testing would then be followed by a detailed review process under different conditions and environments in order to establish the performance parameters of the developed technology. The review process onsets as soon as the first prototype is developed thus continuous through phases and would be followed through thoroughly at a higher degree level.

Acknowledgements

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NEWS

Dr. Indra Mani Promoted as the Professor of IARI

Dr. Indra Mani, well known as the co-editor of AMA in India, was assigned for the professor of the Division of Agricultural Engineering at IARI (Indian Agricultural Research Institute), New Delhi. We extend our heartiest congratulations to this glorious promotion, and look forward to his continuous promotion of agricultural mechanization in India and the world.

■■

Design and Development of a Manually Operated Urea Supper Granule (Usg) Applicator

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Abstract

A study was conducted to develop a manually operated USG applicator at Farm Machinery and Postharvest Technology (FMPHT) Division of Bangladesh Rice Research Institute (BRRI) during the period of 2008-2009 to place the Urea Super Granules (USG) in the field more easily, effectively and rapidly. The applicator was designed for two rows considering a spacing of 20 cm × 20 cm and depth of placement 6-8 cm. It was designed using Auto CAD engineering tools and fabricated in the divisional research workshop. The applicator was tested in the BRRI research field. The final weight of the applicator was 10.5 kg that was suitable to operate in different types of soil. During laboratory test, there was more than 98% dispensing efficiency.

Considering walking speed of 1.75 km/hr, the design capacity of the applicator was around 35 decimal per hour. However, the average field capacity was 32.45 decimal per hour during field operation. The field capacity varied widely with soil condition, field condition and skill of the operator. Manual application capacity of USG also varied with the skill of operators. Average manual application capacity was around 32 decimal/man-day (4 decimal/hr) in this study. It should be remembered that the machine had to operate in the field through the middle row maintaining the forward motion to avoid the clogging of the outlet by muddy soil. During field operation, minimum standing water (0.5-1.0 cm) should be maintained for smooth operation. However, standing water should be maintained in the field till the date of USG application for maintaining the softness of the field that will help to make furrow opening and closing properly.

The average placement distance between granules in the field was 39.5 cm during field operation although design distance was 40 cm. The average depth of USG placement was 6.6 cm in the field. The distance between granules and depth of placement also varied with the depth of penetration of the applicator in the field.

Background

Urea is one of the major essential elements of plants. The plant takes fertilizer available in the root-zone as its food resulting in increased yield. The ultimate aim of applying fertilizer to the root-zone is for the beneficial use of the plant. Farmers use fertilizer to increase yield of crops. Farmers of Bangladesh, use urea as a source of nitrogen of which major portion is imported at the expense of hard earned foreign currency. In 2004-2005, the Bangladesh government imported 134 million tons of urea and its price was 4271 million taka (BBS, 2006).

The deep placement of USG by hand after transplanting is a slow field operation, thus, requiring much labor. The labor intensiveness and drudgery of placing have seriously limited USG adoption by rice farmers in South and Southeast Asia (Savant *et al*., 199l). About 6-8 man-day/ha is required for manual placement of USG in rice transplanted field. So, a mechanical device is necessary to improve the work efficiency of labor. Applicators of IFDC, IRRI and Chinese model have been tested in BRRI at 1998. All these are not found effective in the field and do not push the USG inside the soil surface. On the other hand, metering devices and skidding mechanisms do not work properly and leads to missed pickup of USG from the hopper. To overcome the problems of hand placement of the USG/UMG granules, a manually operated applicator was designed, fabricated and tested in the laboratory and research field with the following objectives.

Potential of USG Use

- The field efficiency of granular urea is more than prilled urea. Moreover, farmers can get 20-25 % more yield using granular urea (AIS, 2008).
- Fertilizer nitrogen utilization by transplanted rice is very low, rarely exceeding 40 % even under the best management practices. Low recovery is attributed to losses through ammonia volatilization, nitrification-denitrification, leaching and run off. Other important nitrogen transformations are biological immobilization, ammonia fixation by clay minerals, and soil organic mater (RAO, 1987). Proper placement of USG reduces the major losses and saves around 25-35 percent urea over prilled urea (BRRI, 2008).
- Deep placement of USG in transplanted rice is an agronomically efficient and environmentally safe. The proper deep placement of USG decreases urea-N losses, improves N availability to rice plants and eventually helps to increase grain yields significantly, especially at N rates that small rice farmers can afford (Savant *et al.*, 199l).

Available Size of Urea Granule and Recommended Dose

On the basis of size and weight, granules urea becomes different. Based on size and weight, different urea granules are shown in **Fig. 1**.

- 0.9 gm (width: 15 mm and height: 11 mm) granules known as urea supper granule (USG). Three USG are used in one place for Boro rice and two for Aus and Aman rice.
- 1.8 gm (width: 18 mm and height: 13 mm) and 2.7 gm (width: 20 mm and height: 14 mm) granule known as urea mega granule (UMG). For Aman and Boro rice cultivation, one UMG of 1.8 gm and 2.7 gm are used in one place, respectively.

Considering Factors

The proper deep placement of USG in transplanted rice makes it agronomically efficient. In using USG, consideration of the following factors should help to ensure agronomic efficiency of deep-placed USG and increase the chances of obtaining additional yield.

- Soil factors: Only use in soils having a low water peculation rate and a CEC ≥ 10 meq/ 100 g soil (Savanta *et al.*, 1991)
- Plant factors: Suitable to short to medium duration rice varieties. For long duration variety, basal deep placed USG with a topdressing of N as prilled urea at panicle initiation stage would be helpful.
- Management factors: Line transplanting is necessary to get good results maintaining line to line and plant to plant spacing of 20 cm. Granular urea is to be placed at 6-8 cm deep at the center of 4 consecutive hills of 2 adjacent rows at 10-15 and 20-25 days after transplanting for the wet and dry season, respectively (Bhuiyan, et. at., 1998). In case of machine use, standing water have to be maintained in the field after rice transplanting till the date of USG application to keep the soil soft that helps the smooth operation by opening and closing the furrow properly.

Constraint to Design USG Applicator

Shape of the granule is important to design the metering device. Because of oval shape of the granule with barb that makes a bridge in the tank (**Fig. 2**).

Objectives

- To Place the USG/UMG mechanically between rows in the rice field effectively, easily and rapidly
- To evaluate the performance of the developed applicator

Materials and Method

- MS sheet, flat bar, angle bar, shaft bar, GI pipe, Nuts and Bolts and Granular urea
- Design the applicator using AutoCAD Program and a Prototype will be fabricated in the FMPHT divisional research workshop.

Design Considerations of the Applicator

The applicator was designed using the following design considerations.

- Line to line and plant to plant spacing should be 20 cm
- Depth of placing should be 6-8 cm

Fig. 1 Available size of USG/UMG granules

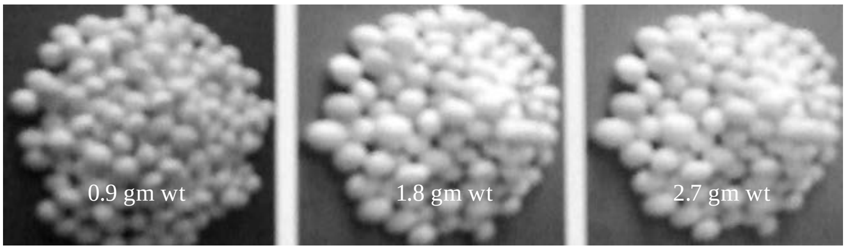
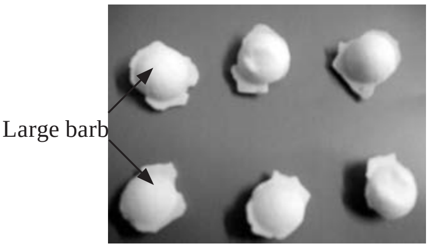


Fig. 2 USG granules with barb



- The applicator should be simple and easy both in operation and maintenance
- Application capacity should be accepted by the farmers
- During operation, it should be trouble free.

Details Designed of Usg Applicator

Final Version

Applicator was designed based on the above design considerations. During design, all components of the applicator were modified with trial and error method. The design details were described as follows:

Width of the Applicator

The applicator was designed for double row operation in the field considering 20 cm line to line spacing; thus, distance between two skids was 40 cm (center to center). By single pass of the applicator, 80 cm effective width was covered (**Fig. 3**).

Metering Device

Cup type metering device was utilized to collect USG/UMG from tank and dispense to the output channel. Five cups were used in each round plate considering the diameter of the drive wheel. Diameter and depth of the holes of the cup were 1.9 cm and 0.6 cm, respectively, based on size and diameter of the granules (**Fig. 4**). Every cup was assembled in the metering plate at 5 degree inclined towards the forward direction for easy collection of UMG from the tank. The metering device was connected directly to the drive wheel.

Drive Wheel

Designed diameter of the drive wheel was 63.69 cm considering the 200 cm periphery of the drive wheel. So, by one rotation, it covered 200 cm horizontal distance (**Fig. 8**). The metering device of the applicator also completed one rotation with one rotation of the drive wheel because of direct coupling. Five cups were assembled into the metering plate. As a result, 5 granules were collected from tank and dispensed in 200 cm distance with one rotation of the metering device that was 40 cm between granule to granule (**Fig. 5**).

Lugs of the Drive Wheel

Lugs were used in the drive wheel to develop traction during field operation. The amount of traction was directly related with the length and width of the lug, soil condition and weight of the applicator. Optimum size (width = 4.25 cm and height = 5.0 cm) was determined by trial and error basis considering the different soil conditiosn and weight of the applicator (**Fig. 6**). A total of 20 lugs were used for smooth operation of the applicator in the fields.

USG/UMG Granules Tank

Granules holding tanks of the applicator were designed to supply the granules to the cups of the metering device properly considering the angle of repose of the USG granules. Angle of repose of the USG granules (2.7 gm size) was 30 degrees. The angle of inclination and length of the sliding side, height and width of the tank was 46 degrees, 22 cm, 18 cm and 15 cm respectively. (**Fig. 7**).

Skid and Furrow Opener

Penetration of the applicator was protected due to use of skid and helps to skidding. 25 degree skidding angle was used in the apex of the skid (**Fig. 8**). The size of the skid was designed based on cone penetration resistance of the soil. Length

Fig. 3 Arrangement of the two skids and driving wheel with line spacing

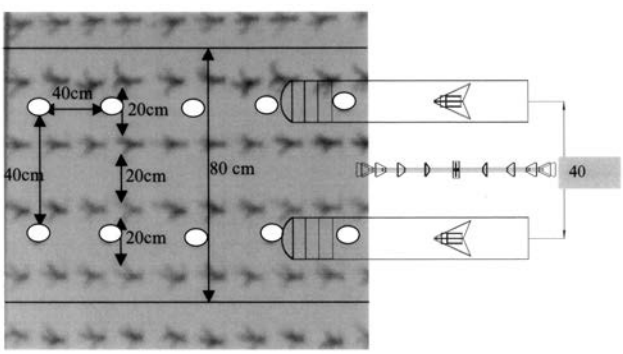


Fig. 6 Front view of an individual lug

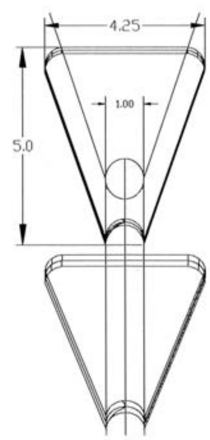


Fig. 4 Metering device with cups and plate arrangement

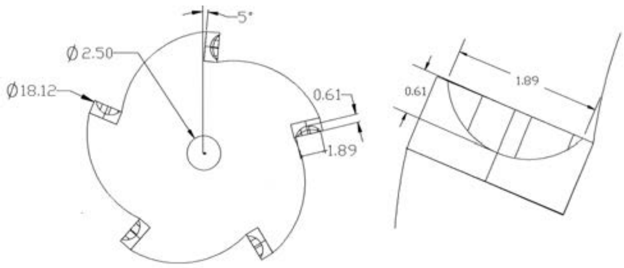
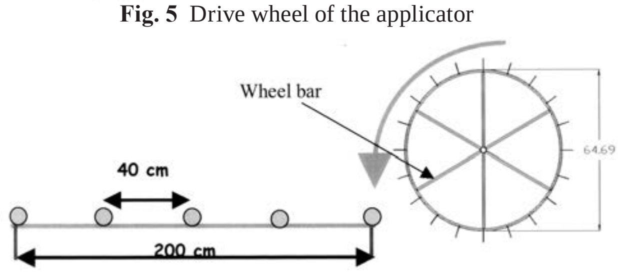


Fig. 5 Drive wheel of the applicator



and width of the skid was critically selected 72.00 and 12 cm respectively. Furrow opener of the applicator was connected at the bottom of the skid maintaining the sliding angle 26 degree. Height (6.0 cm) and length (12.0 cm) of the sliding side of the furrow opener was designed in such way that the granules dispensed easily to the field without clogging and protected muddy soil from entering into the opener (**Fig. 8**).

Output Channel

Output channel of the applicator was connected to granule tank and furrow opener that conveyed the collected granules to the field (**Fig. 9**). The lower part of the channel was connected to a skid with a rectangular holder at 20 degrees incline.

Covering Mechanism

Simple technique was exercised to cover the furrow as well as dispensed granules. Additional plate as per designed shown in the figure was assembled as covering device at the rear of the skid. Depth of the covering device was maintained 4.5 cm by inclining in three stages which was shorter than the depth of USG placement into the soil (**Fig. 10**). As a result, the placed granules were not disturbed by the covering device.

Granules Protecting Mechanism

Spring and cantilever type arrangement was applied to protect the granules dispensing from tank in between gaps of the two cups (**Fig. 11**). When one cup collected granules and moved forward with the rotation of the drive wheel then the door was opened before reaching the next cup of the metering device. This mechanism protected the granules with the apex of the plate. When a cup was entered into the granule tank, the lever was moved downward with the pressure of the cup and again backed to the original position after forward motion of the cup. A soft spring was utilized to avoid the heavy friction between cups and lever.

Handle Holder

Simple cantilever type handle holder was designed for the handle on the skid at 20 cm from end of the skid. There were five options to change the height of the handle as suited by the height of the operator.

Total height of the holder from bottom of the skid, spaced between two levers, width of the lever, hole diameter and distance between two holes made use of 12.5, 2.0, 2.0, 0.75 and 2.00 cm, respectively, (**Figs. 12** and **13**).

Complete View of the Applicator

The complete view of the applicator that was designed using AutoCAD engineering tools mentioned below as side projection (**Fig. 14**).

Fabrication of the Applicator

As per design of the applicator, it was fabricated in the FMPHT re-

Fig. 7 Side and isometric view of the granules tank

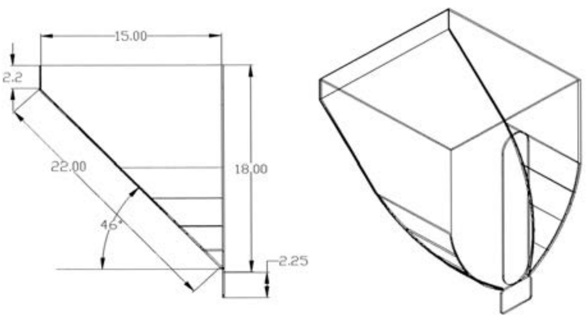


Fig. 8 Side view of the skid and furrow opener

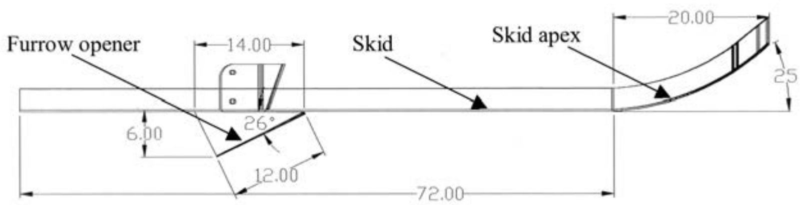


Fig. 9 Side and front view of the output channel of the applicator

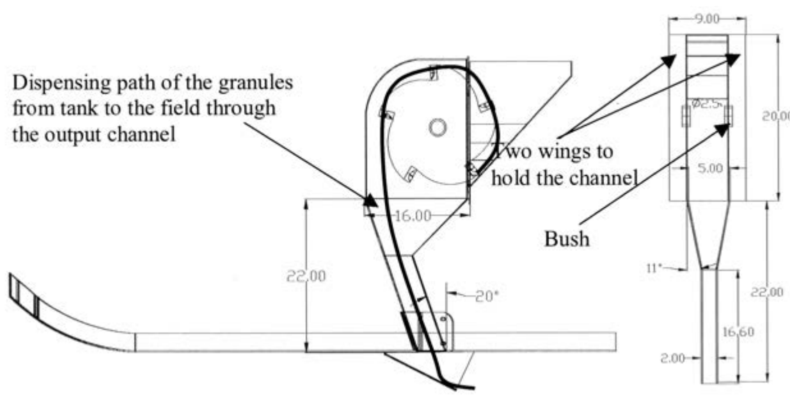
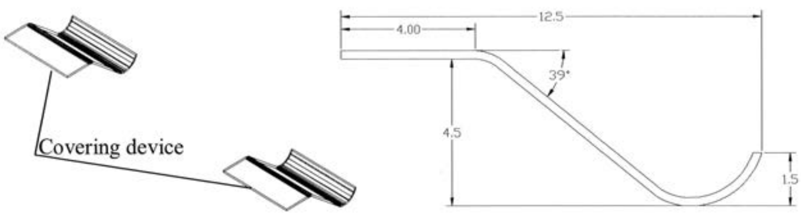


Fig. 10 Isometric and side view of the covering device



search workshop by senior mechanics and technicians. The complete view of the applicator is shown in **Fig. 15**.

Observation Trials

The fabricated applicator was tested using urea mega granules (2.7 gm) theoretically and practically in the research workshop and BRRI research field to collect the following data:

• USG/UMG dispensing efficiency (%)
• Depth of placement (cm)
• Distance between placed granules in the field (cm)
• Walking speed (km/hr)
• Field capacity (ha/hr)

Operational Procedure

• Handle height adjustment is important for efficient operation in the field. It varies with operator height.
• It should be operated by pushing force. Pulling creates blockage of granule dispensing channel by mud.
• During field operation, minimum standing water (0.5-1.0 cm) should be maintained for smooth operation.
• Standing water must be maintained in the field after rice transplanting till the date of USG application to keep the soil soft that helps the smooth operation by opening and closing the furrow properly.

Usg/Umg Dispensing Efficiency

USG/UMG dispensing efficiency was measured in the laboratory. During tests, the applicator was setup at the upper position in such way that the drive wheel moved easily. Two third portion of the tank was filled with granules. The drive wheel was rotated 20 times continuously at normal speed and then the dispensed granules were collected from the bottom of the output channel. Dispensing efficiency was calculated by counting the number of dispensed granule. In laboratory test conditions, dispensing efficiency was 98 percent. Average dispensing efficiency was 98.8 percent during test. The result of the laboratory test is given in **Table 1**.

Capacity of the Applicator

Design Capacity

Capacity of the applicator depend on the walking speed, land condition, soil type, operator strength and skill, uniformity of the granule, bonding freeness and strength of the granule. Design capacity of the applicator was calculated during laboratory test considering the different walking speed. Considering 2, 1.75

Fig. 11 Granules protecting mechanism

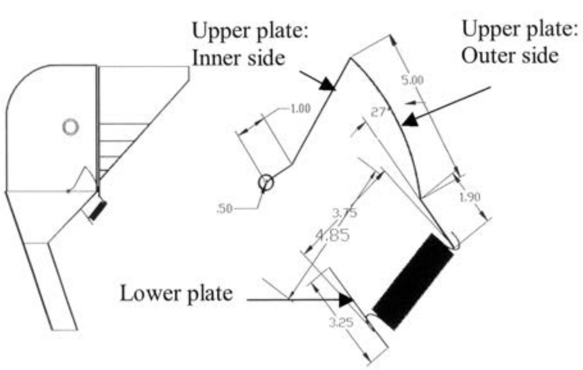


Fig. 12 Front view of the handle holder

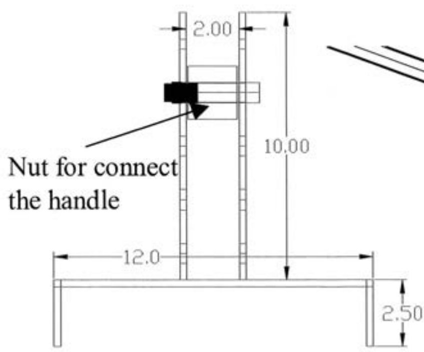


Fig. 13 Side view of the handle holder

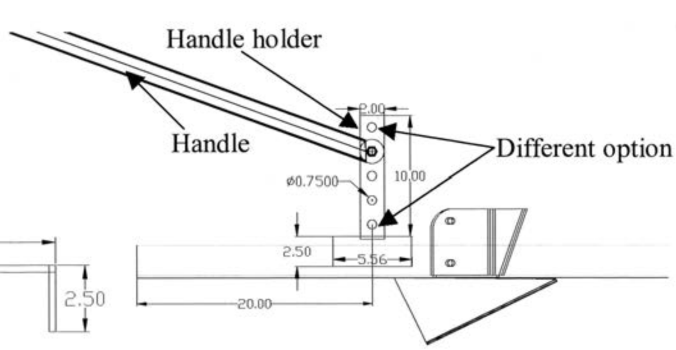


Fig. 14 Complete side view of the applicator

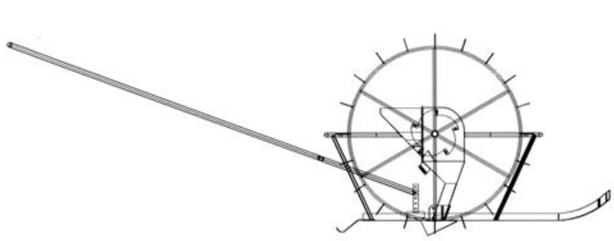
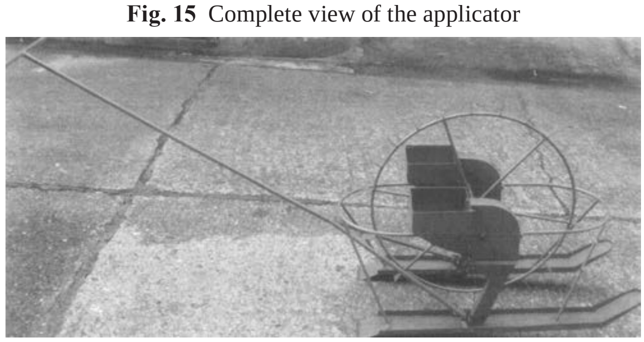


Fig. 15 Complete view of the applicator



and 1.5 km/h operating speed, design capacity was 39.52, 34.55 and 29.64 decimal per hour, respectively.

Field Capacity (In Fallow Land)

Field capacity of the applicator was measured in the BRRI research field trial basis in the fallow land during 2009 by three different labors. Time was recorded including losses and total distance passed. During tests, average capacity was 32 decimal/h (**Table 2**).

Gap Between Dispensed Granules

Distance between granules was 40 cm during design. It might be varied in the field during operation due to more penetration of the drive wheel. Because of more penetration, periphery of the wheel was reduced. As a result distance between granules would be also reduced. Distance between granules was 39.5 cm in the field (**Table 3**).

Depth of Granule Placement

It is important to place the granule at desired depth for efficient use of nitrogen uptake. The depth of placement varied with soil condition and penetration of the applicator during operation. A different depth of granule placement was found during operation (**Table 4**). Average depth of granules placement was 6.63 cm.

Cost Analysis

The cost analysis of the USG applicator is given in **Table 5**. The price of the applicator varied with the quality of the materials. The working life of the applicator was considered 5 years.

Conclusion

A manually operated USG applicator was designed considering line to line and plant to plant spacing of 20 cm and fabricated in the FMPHT divisional research workshop for double row operation in rice field. The field capacity of the applicator was 31 decimal per hour whereas manual application capacity was 4-5 decimal per hour based on labor skill. The applicator was suitable to place the USG/UMG at 6-8 cm depth in line transplanted rice field. Farmers will able to save 6-7 man-days per hector as well as urea fertilizer. One can take it as a business for the demand period. For the purpose of adopting USG/UMG application in farmers' field, this technology needs to be disseminated to the end users.

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Table 1 Results of the laboratory tests

Number of rotation	Number of UMG dispense	% of dispense
20	98	98
20	99	99
20	97	97
20	97	97
20	99	99
20	100	100
	Average	98.33

Table 2 Results of field operation in fallow land

Total time, min	Distance passed, m	Speed, km/hr	Capacity, de-cimal/ hr
10	260	1.56	30.82
13	351	1.62	32.01
9	251	1.67	32.99

N.B: Constant effective width=0.8m

Table 3 Results of gap measurement between dispensed granules during field trails

Number of reading	Highest length, cm	Lowest length, cm	Average length, cm
4	40	38	39.75
4	40	39	39.5
4	42	39	39.75
4	40	37	39.0
		Average	39.5

Table 4 Results of depth measurement of the placed granules during field operation

Number of reading	Highest depth cm	Lowest depth cm	Average depth cm	Remarks
4	8	5	6.5	Because of different penetration of the skid, depth of placement varied
4	7	6	6.5	
4	8	6	7.25	
4	7	6	6.25	
			Average	6.63

Table 5 Cost analysis of the machine

Description	Amount
Cost of the applicator (Tk)	5,000
Working life of the applicator (5 yrs)	5
Capacity (ha/yr, considering 20 working days per season)	60
Interest on investment, depreciation and others cost	2,000
Working time (hr/yr)	480
Wages of one labor (Tk/yr)	15,000
Total cost (Tk/yr)	17,000
Traditional cost in Tk to apply granule in 60 ha area (Considering 8 man-day per hector and Tk 250/man-day).	120,000
Actual profit (Tk/ yr)	103,000
Payback period, man-day	4
Benefit-cost ratio	6 : 1

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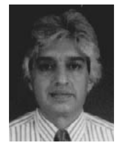
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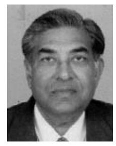
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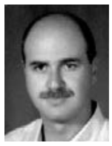
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