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VOL.34, NO.4, AUTUMN 2003

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EDITORIAL

AMA's Farm Mechanization Mission

As indicated in AMA's Summer Issue of 2003, the Shin-Norinsha Co., Ltd. that publishes AMA through the Farm Machinery Industrial Research Corporation, is jubilantly celebrating its 70th anniversary of founding this year. And during this celebration, the Shin-Norinsha Co., Ltd. is recipient of many congratulatory messages: from far and near; AMA's co-operating editors; and readers from many countries.

Historically, the advent of the popular small farm machineries in Japan traces its roots from the 1930s suggesting, in fact, that farming in the country then was not much different from the experience of underdeveloped countries depending much from human and animal power. The few nondescript farm machineries that already existed then fabricated only simple gadgets such as kerosene-fed engines, power threshers, paddy huskers/millers and various farm implements for use with farm power.

In 1933, the Shin-Norinsha Co., Ltd. initiated the publication of a special newspaper that must have influenced both the government and enterprising shop owners to introduce technologies and modernize their operations and product designs. In time, friendly competitive rivalries developed among the shop owners that brought about the organization of occasional shows that display new machineries. Adjudged winners for the most excellent entries were awarded prizes in annual testimonials.

In the interim, advanced Western countries achieved successes in the manufacture of large machineries intended for equally large farms. In comparison, Japan hedged on the manufacture of small ones for obvious reason and guided by the concept of "minor-type-mechanization-technology". And now, the idea of "inner communications" for the system and promotion on farm mechanization that guided the Shin-Norinsha Co., Ltd. 70 years ago also guides the writer to enable AMA to be useful in contributing the reform of agriculture in the 21st century.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
November 2003

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Dibble Precision Seeder for Coated Rice Seeds

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Abstract

A dibble precision seeder with a photoelectric close-loop control was designed according to the requirements of agronomic technology for industrialized rice seedling nursery using coated rice seeds. A single-chip microprocessor (SCM) monitor of the seeder can control the metering process. Only one seed can be fed per metering unit each time, which increases seeding accuracy. Testing results show that the seeder can reach high accuracy of 98.6% with over seeding rate 1.4% and 0 missing seeds. Coated rice seeds used for industrialized rice seedling nursery are favorable for mechanical seeding and can simplify agronomic technology for a seedling nursery.

Introduction

Rice is one of the main crops in China. Planting area (31.3 million ha) and production (198.5 million ton) account for 30% and 40% of the total of crops, respectively. More than 60% of the Chinese depend on rice as their staple food. China is now spreading the technology of industrialized rice seedling nursery as the method of traditional sowing of seeds is no longer practical for industrialized rice seedling nursery. The traditional nursery management requires soaking the seeds at quite high moisture content of 30%wb or so, which is unfavorable to mechanical seeding as the rice seeds could be damaged.

Industrialized rice seedling nursery using coated rice seeds is a creative agronomic technology. Coated rice seeds can be directly dibble-drilled in the form of hills on plastic trays. The trays are then delivered to nursery seedling green house in which good quality seedlings can be grown (Qiu Bin, 2000). Coated rice seeds of low moisture content (13%wb or so, standard safe storage level in China) are beneficial to dibble precision seeding.

Dibble precision seeding is one of the key links in industrialized rice seedling nurseries. The quality of seeding affects the growth of the seedlings and hence the production of rice. The demands of seeding accuracy for hybrid rice seeds are: rate of hills with 1 or 2 seeds per hill or more than 85% and rate of missing hills in less than 4% (Yuan Zhaohe, 1998). Seeding precision shows an increasing trend owing to high quality of seedlings in the hills of single seeds (Qiu Bin, 2000). However, the precision seeder used at present cannot achieve these high accuracy demands. The precision seeder discussed in this paper is a photoelectric closed-loop controlled one with electromagnetic vibrating metering units which can increase seeding accuracy significantly.

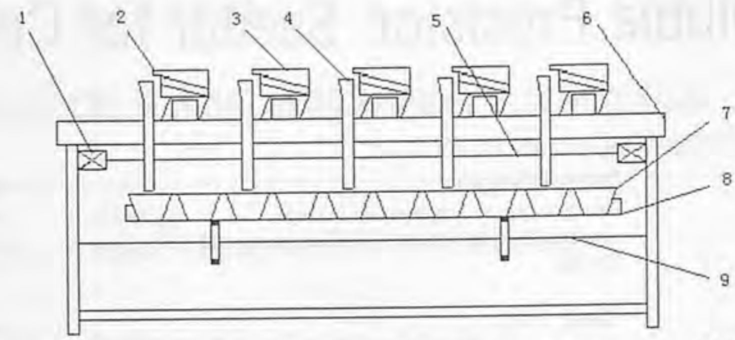
Structure of Precision Seeder

Structure and Seeding Method

The precision seeder is composed of a photoelectric sensor; electromagnetic vibrating metering unit; horizontal shift mechanism; frame; belt conveyer mechanism; plastic tray; and supporting tray (**Fig. 1**).

The electromagnetic vibrating metering unit leads the rice seeds to move uniformly and continuously up on the spiral seed rail in one line and directs them into seed tube. The seeds then fall into hills of the plastic tray. Near the exit of the metering unit is installed the photoelectric sensor which can sense the passage of seeds, resulting in an electrical pulse each time a seed passes. The monitor of seeder can control feeding process of each metering unit.

Five metering units with similar structures are installed on the precision seeder. The plastic trays for testing are 434 type, 434 hills per tray and 10 hills per row. The electromagnetic vibrating metering units need to drill two times for the 10 hills (1 seed per hill) per row since only 5 metering units are available on the seeder. Thus, there is a horizontal shift mechanism driven by the electromagnet. The seed tubes, fixed together with shift mechanism, shift together from one side to another. The supporting tray which supports the plastic tray is pulled by belt conveyer mechanism. To eliminate reciprocal influences of vibrating devices, it requires that the plate on which the springs of the metering devices are installed is 8 mm thick.



Legend: 1.Electromagnet of horizontal shift mechanism 2.Photoelectric sensor 3.Metering unit 4.Seed tube 5.Horizontal shift mechanism 6.Frame 7.Plastic tray 8.Supporting tray 9.Belt conveyer mechanism

Fig. 1 Schematic diagram of the precision seeder.

Electromagnetic Vibrating Metering Unit

The structure of the metering unit is shown in **Fig. 2**. Near the exit of the metering plate is installed a photoelectric sensor. The ends of the vibrating plate springs are fixed at the bottom of metering plate and on the up-plate of frame 3, respectively. The iron corn coil is installed on the frame with a gap of 1 mm at the bottom of the metering plate. The coil of iron corn is supplied from a unidirectional current after half-wave rectification of 110V AC at 50 Hz and provides the desired operating pulse electromotive force (emf) that vibrates the metering device. Rice seeds in the metering plate, subjected forces of gravity, friction and inertia, move uniformly up on the spiral seed rail in one line, and then fall into the hills of the plastic tray through the seed tube. The SCM monitor can control the metering process.

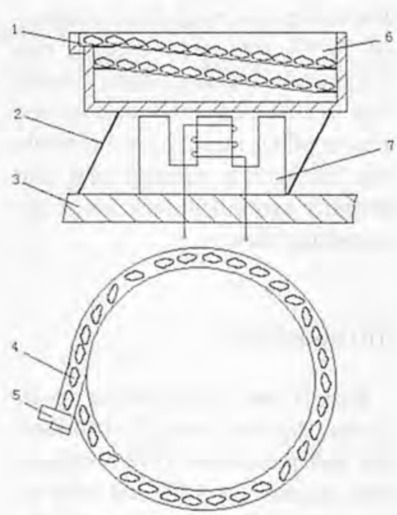
The metering device of the electromagnetic vibrating type is suitable for rice seeds precision seeding, without damage to the seeds.

Hardware Circuit Design

The hardware circuit of this precision seeding system consists of main parts as follows: infrared emitting circuit, infrared collecting circuit of photoelectric sensor, and circuit of SCM monitor. The photoelectric sensors with their infrared emitting circuit and infrared collecting circuit are used to detect the metering process and arrival signals of plastic tray and hill of the tray. The SCM monitor collects outputs of each sensor, analyses them, and then controls the different parts of the seeder to move harmoniously according to actual work conditions. This means that the belt conveyer mechanism cannot step ahead until each hill of a row is metered a seed. Through such closed-loop control, the precision seeder can reach high seeding accuracy.

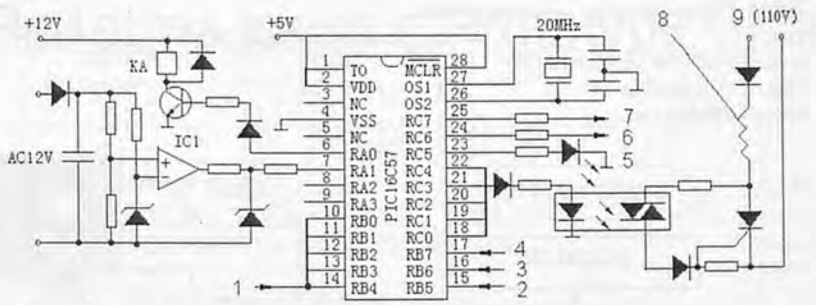
The circuit of the SCM monitor consists of PIC16C57 SCM and its peripheries as shown in **Fig. 3**. The circuits of infrared emitting and collecting are shown in **Figs. 4** and **5**.

The PIC16C57 SCM is used according to control demands of the precision seeder and performance and price of the SCM. It is a one-time programmable and can keep program and data safe. Photoelectric isolation technology is used to prevent the SCM monitor from being interrupted from strong current. The IC1 can detect the voltage of input power and adjust it to normal level through relay KA, which can keep output of a transformer (not shown in **Fig. 3**) stable 110V and input of iron core coil of metering unit. The SCM can accept signals from metering units (RB0~RB4), arrival signals of plastic tray and hills of the tray (RB5, RB6), and signal of seed tube's original location (RB7), respectively. After processing, the SCM can produce signals to control motions of the belt conveyer mechanism (RC7), horizontal shift mechanism (RC6), and metering units (RC0~RC4). At the same time, working conditions of the seeder can be displayed through RC5.



Legend: 1.Exit of seeds 2.Vibrating plate springs (3 in all) 3.Frame 4.Rice seeds 5.Photoelectric sensor 6.Metering plate 7.Iron core coil

Fig.2 Schematic diagram of electromagnetic vibrating metering unit.



Legend: 1.Signals from sensors of metering units 2.Signal of original location of seed tube 3.Signal of plastic tray 4.Signal of hill of tray 5.System condition indicating light 6.Horizontal shift mechanism 7.Belt conveyer mechanism 8.Coil of electromagnetic metering unit 9.Output of a transformer (110V)

Fig.3 Circuit of SCM monitor.

Program Design

The main program of the SCM monitor, as shown in **Fig. 6**, is programmed to control motions of the belt conveyer mechanism, horizontal shift mechanism and metering units. First, it initializes the program, moves horizontal shift mechanism to its original location, and conveys supporting tray with plastic tray until the SCM monitor detects arrival signals of the plastic tray and hill of the tray ("Ready tray and hill?"), then calls the seeding sub-program that controls the seeding process of metering units. With seeding processes of the 5 units finished, they move the horizontal shift mechanism to another location. After that, it call seeding sub-program again, and then return the main program to convey the supporting tray. The following seeding processes are handled in essentially the same way.

Seeding sub-program, as shown in **Fig. 7**, is a key part of software design. The SCM monitor detects the arrival signals of the plastic tray and hill of the tray. First, the SCM clears the flag bits, and the metering units vibrate simultaneously and start to meter the seeds. Then, the monitor detects each unit if it "has metered a seed?" If "YES", it sets corresponding flag bit, then stops the metering process. If "NO", it continues the process. After that, the SCM monitor detects if "all metering device units have finished metering process?" If "NO", it continues metering that has not finished. If "YES", the sub-program stops and returns.

From the seeding process of the seeder system above, we know that the SCM monitor can control the motions of the metering units and other parts of the seeder. This seeder system can reach 0% rate of missing theoretically and solve the problem of high percentage of missing and over seeding. At the same time, each part of the seeder can work harmoniously together via closed-loop control system which results in high accuracy of the seeder.

Testing and Result Analysis

Material and method

In order to determine the performance of the precision seeder an experiment testing was carried out. The rice seeds tested, II you838 (coated) with moisture content 13%wb, 1000 grain weight 25.4g and mean dimension 7.81 mm × 2.84 mm × 2.17 mm, were treated according to the requirements of industrialized rice seedling nursery.

The testing was carried out indoors. The plastic trays for testing were the 434 type (434 hills each tray) from southwest of China. Before testing, the hills of plastic tray were put into 2/3 of bed soil. Seeding process can be done automatically except loading and unloading trays. Six times of testing were carried out, each time more than 100 trays. The seeding results of 10 trays were collected at random each time. Because the precision seeder was designed for the purpose of dibble precision seeding of industrialized rice seedling nursery, the terminology was as follows: the rate of missing hills is the percentage of hills without seeds accounting for total hills of a tray, namely 434; the rate of hills with a single seed is the percentage of 1 seed per

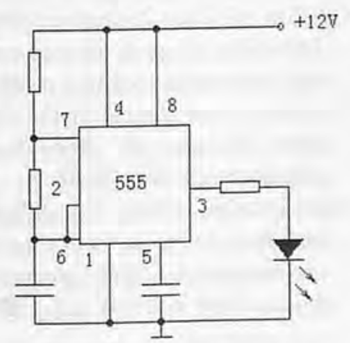


Fig.4 Circuit of infrared emitting.

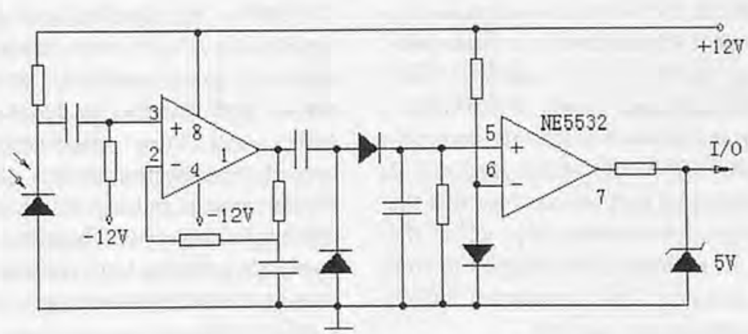


Fig.5 Circuit of infrared collecting.

hill accounting for the total hills of a tray; and the rate of over seeding is the percentage of 2 seeds or more than 2 per hill accounting for the total hills of a tray.

Result and discussion

The test results are presented in **Table1**. The rate of hills with single seed was 98.6%, the rate of over seeding was 1.4% (all 2 seeds per hill), and the rate of missing is 0. The high seeding accuracy completely meets demands of agronomic technology. The seeder can solve problems of low seeding accuracy and the low rate of qualified hills for industrialized rice seedling nursery.

Industrialized rice seedling nursery using coated rice seeds makes rice seeds able to be directly dibble-drilled and delivered into the seedling nursery greenhouse in which good quality seedlings can be cultivated. This simplifies the agronomic technology of seedling nursery. When sowed, coated rice seeds are at quite low moisture content (13%wb or so), with characteristics of good mobility, smooth surface and not easy to adhere together. All these characteristics benefit the metering process of the seeder system, and can result in no damage to rice seeds. However, non-coated rice seeds after soaking accelerates germination, which is unfavorable for machinery seeding and may cause rice seeds damage.

The test results show that although the adoption of closed-loop control system results in high seeding accuracy, over seeding cases still appeared. Seeds in the metering units move uniformly and continuously on the spiral seed rail, 2 seeds near exit are so close that the latter one cannot stop when the SCM monitor gives a signal to stop a metering unit sometimes, which results in over seeding.

Table. 1 Test Results of Precision Seeder

Item	Mean	Standard deviation	Variance coefficient (%)
Rate of hills with single seed (%)	98.6	0.426	0.432
Rate of over seeding (%)	1.4	0.426	30.429
Rate of missing (%)	0	-	-

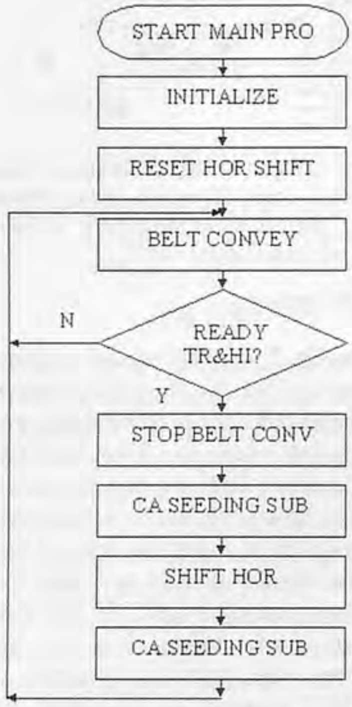


Fig. 6 Flow chart of main program.

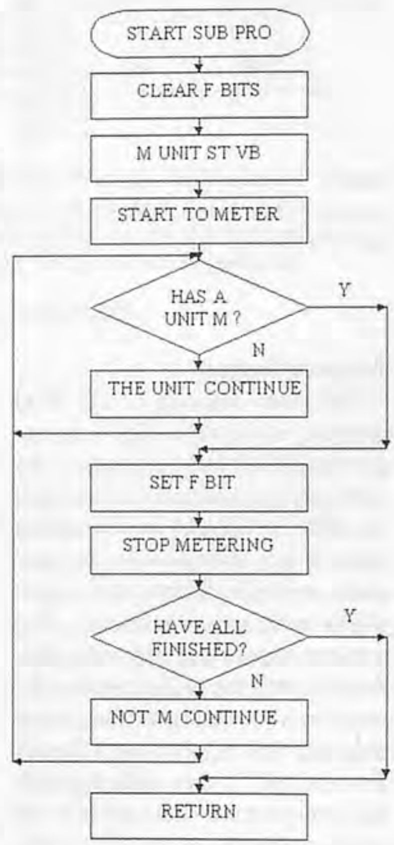


Fig. 7 Flow chart of Sub-program.

Conclusion

The precision seeder with a photoelectric closed-loop control is based on coated rice seeds for industrialized rice seedling nursery. From the engineering point of view, it is a good measure to improve traditional agronomic technology to benefit agricultural machineries. When sowed, coated rice seeds are at quite low moisture content (13%wb or so, standard safe storage level in China), with characteristics of good mobility, smooth surface and not easy to adhere together. All these characteristics benefit the metering process of the seeder system, and can result in no damage to rice seeds. Therefore, the seeder can reach a high seeding accuracy rate of 98.6% or rate of over seeding 1.4%, and zero missing.

The metering units of the seeder are electromagnetic vibrating type with characteristics of simple structure, no damage to seeds, and no transmission mechanism. It has some application prospects for precision rice seeding.

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Performance of a Prototype Okra Planter

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Abstract

A tractor-drawn, three-row machine for planting of soaked okra seeds on the ridges was developed at IARI, Pusa, New Delhi. The machine has modular hopper and an inclined plate type metering unit. A suitable ridger-furrow opener system was provided to place the seeds on ridges at desired depth. The power transmission to the metering unit is through a ground wheel by chain-sprockets system. The machine has provision for varying row spacing and depth of seed placement. It can plant one hectare of land in 5 hours. The field performance of the machine was compared with ridge making by tractor-drawn ridger and manual planting. The planter resulted in a saving of 77 man-hours per hectare and 76 per cent in the cost of operation. The crop parameters and yield were comparable in the case of machine planting and manual planting.

Introduction

India is the largest producer of vegetables in the world, next only to China with an annual production of 72.83 million tonnes from 5.63 million ha. (Negi and Mitra, 1999). This quantity represents 12.22 percent of the world's total vegetable production. The country is bestowed with varied agro-climatic conditions, making cultivation of wide range of vegetables possible in one or other regions throughout the year, which cover about 3.4 per cent of gross cropped area. Okra or 'lady's finger', commonly known as *bhindi* in India, is one of the important fruit vegetables that represents nearly 7.35 per cent of the total area planted to vegetable crops and 5.87 per cent share in total vegetable production. India is the largest producer of okra in the world with an annual production of 3.24 million tonnes. Okra is especially valued for its tender and delicious fruits in different parts of the country. Also, to a limited extent, it finds its use in canned, dehydrated or frozen forms. It has been reported to have an average nutritive value (ANV) of 3.21, which is higher than tomato, egg plant and most cucurbits except bitter gourd (Grubben, 1977).

It has been recommended that sowing soaked okra seeds on ridges ensures proper germination and reduces water requirement during summer and helps in drainage during rainy season (Mishra, 1998). Planting okra seeds is a need-based operation in crop production as it aids to maximize yield. For crops, where tillering does not take place, space planting is recommended for higher yield (Chancellor, 1969; Giannini *et al.*, 1967). Traditionally, okra is sown directly in line by hand dropping of seed using funnel and tube behind the animal drawn plough or by hand dibbling. On commercial scale seed drills are in use. Although a large number of planters have been developed in India and are commercially available for cotton, maize, groundnut, soybean etc. (Pandey *et al.*, 1997), very limited information is available on mechanical planting of okra. Keeping this in view a tractor-drawn okra planter was developed to meet the requirement of the farmers.

Materials and Methods

A three-row, tractor-drawn okra planter was developed at the Agricultural Engineering Division, IARI, Pusa, New Delhi. The planter consisted of modular hoppers, inclined plate type metering units and suitable ridger-furrow opener system. The drive to the seed plate was provided from the ground wheel by chain and sprockets system. Different components were mounted over the main frame made from 6mm thick mild steel square section of 50×50 mm dimensions. The specifications of okra planter are presented in **Table 1**. The modular

Table 1. Specifications of Okra Planter

Component	Specifications
Overall length	1,690 mm
Overall width	1,540 mm
Overall height	1,235 mm
Number of rows	3
Seed metering	Inclined plate type
Hopper capacity	3,500 cm^3 (each)
Plant spacing	Row spacing 45 cm Plant spacing 30 cm
Ridge size	15 cm height
Power transmission	Chain and sprockets; bevel gear
Speed ratio	1.78:1.00 (ground wheel: seed plate)
Power requirement	35 H.P. tractor
Capacity	0.18-0.22 ha/h
Weight	220 kg (empty)
Cost	Approximately Rs. 10,500

hoppers were made of 2mm thick mild steel with a volumetric capacity of 3,500 cm^3. A sliding plate was provided to maintain the depth of seed layer in pick up chamber irrespective of the filling of main chamber. The seed plate, made of cast aluminium was mounted over a set of bevel gear. It had 8 L-shaped cells, with a length of 8 mm and height and width 5 mm each, at its periphery. The ridger bottoms were provided with adjustable wings of mould board shape to make uniform ridges before planting of okra seed at one pass of the machine. The seed tube was made of 16 mm mild steel square cross section forged at bottom in the form of a runner type furrow opener. The details of the planter are shown in **Figs. 1** to 3. The side view and rear view of the complete planter are shown in **Figs. 4** and **5**, respectively.

Performance Evaluation

The performance of the planter was evaluated in the laboratory for different hopper filled conditions. The okra seeds were soaked for 12 hours and the surface moisture was removed by gunny bags. Laboratory test included row-to-row variation in seed metering, uniformity in seed delivery and mechanical damage.

The field experiment was conducted in sandy-loam soil. The major characteristics of the soil are given in **Table 2**. The experimental field was prepared into fine tilth by twice harrowing followed by leveling operation. The test field was sub-divided into four plots of size 36×18 m. The hoppers were filled with soaked okra seeds. The planter was operated in straight rows. The field evaluation included draft, field capacity, field efficiency, field machine index, labour requirement and cost of operation. The cost of operation for machine planting (**Fig. 6**) and manual planting-tractor drawn ridge systems (**Fig. 7**) were compared.

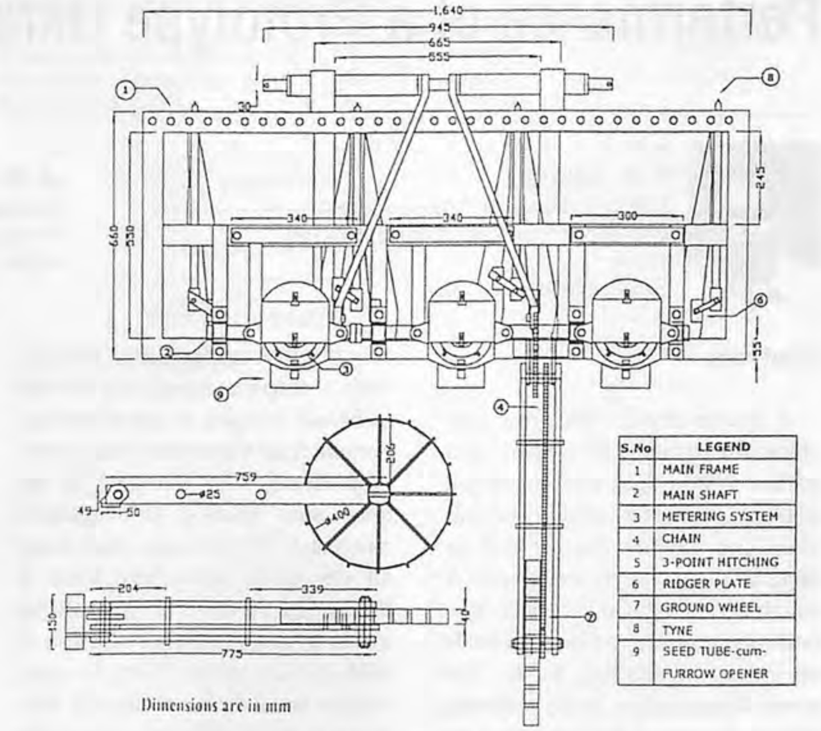

Fig. 1 Okra planter, plan view.

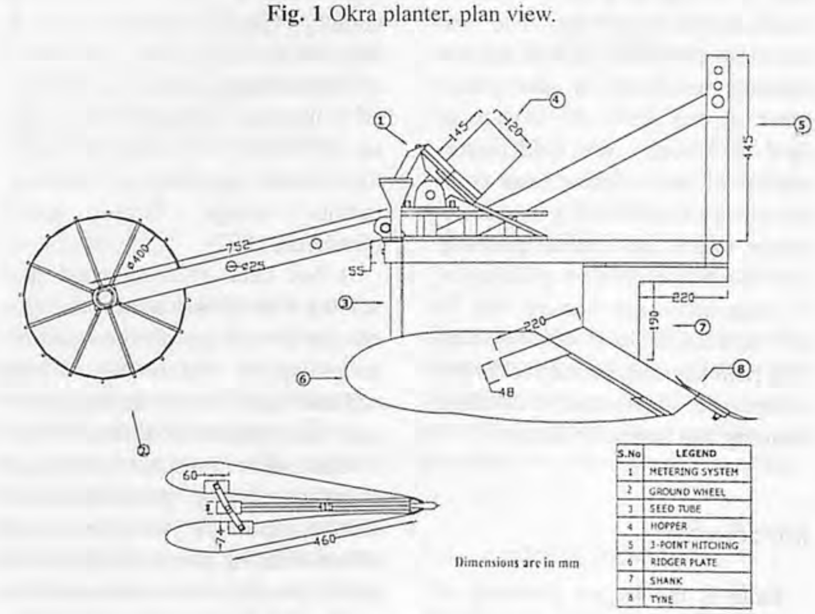

Fig. 2 Okra planter, side view.

The breakeven point gives an idea of the optimum annual use of the machine in hours, so that profit is ensured. The breakeven point of the planter was calculated using the formula (Kumar and Nehru, 1994):

$$F.C. + V.C.(X) = B(X)$$

Where,

X: Annual usage, h
B: Benefit, Rs/h
F.C.: Fixed cost, Rs/Yr
V.C.: Variable cost, Rs/h

The pay back period was calculated as the ratio of initial investment to net benefits per year.

Table 2. Characteristics of the Experimental Field Soil

I. Type: Sandy loam to loam

II. Particle size distribution

Depth, cm	Coarse sand, %	Fine sand, %	Coarse silt, %	Fine silt, %	Clay, %
0-21	0.95	49.00	24.05	11.50	12.75
21-52	0.50	54.35	22.70	8.50	12.25
52-93	0.60	53.75	20.50	9.63	13.00

III. pH, bulk density and moisture retention

Depth, cm	pH value	Bulk density, g cm^{-3}	Moisture retention, per cent		
			1/10 bar	1/3 bar	15 bar
0-21	8.1	1.41	30.75	21.08	7.80
21-52	8.2	1.41	26.28	17.82	6.77
52-93	8.4	1.41	26.45	18.00	6.64

Source: Soil survey and land use planning of IARI farms, Report No. 375 (ICAR).

Results and Discussion

From the laboratory calibration, the maximum deviation of seed discharge of any row from the average was observed to be less than 2 per cent as shown in **Table 3**. The results indicated that variation of seed discharged from the average of three rows was statistically non-significant for all the three hopper fill conditions. This was due to the partition of hopper by sliding plate. The depth of seed layer was identical for all the hopper capacity in the pickup chamber, hence no difference was observed for different hopper capacity. The seeding uniformity was also evaluated by using the sand-bed test. An average of 7.8 seeds were placed per meter length. The maximum deviation of seed of any of the rows from the average was 3.85 per cent. A null-hypothesis, using 't' test indicated that the variation of seed dropped from the mean among the three rows was non-significant **Table 4**. Hence it could be concluded that the prototype planter performed satisfactorily in metering soaked okra seeds.

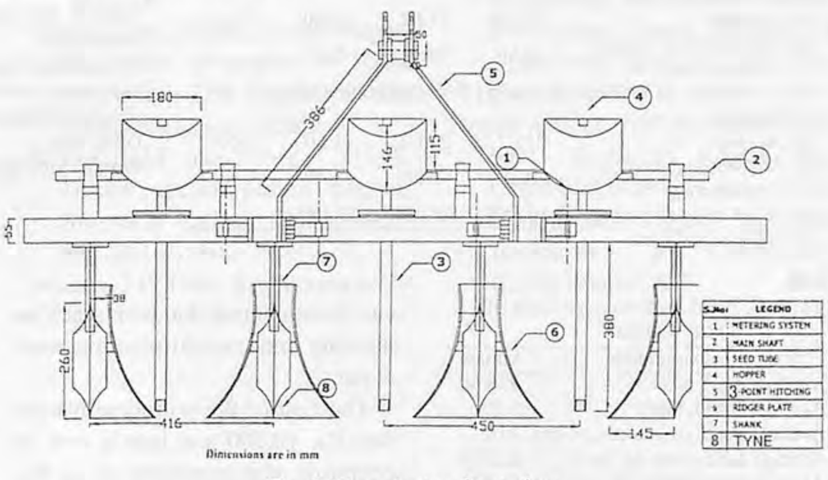

Fig. 3 Okra planter, front view.

The field test was done at the experimental farm of the Agricultural Engineering Division, IARI, Pusa, New Delhi. The performance data of the planter is presented in **Table 5**. The average draft requirement of 536 kgf was recorded for the planter. Hence, a medium size tractor (35hp) could easily operate the planter. An average field capacity of 0.2033 ha/h was obtained for continuous operation of the okra planter at an average speed of 2.27 km/h. A field efficiency of 66.51 percent was observed which was in the prescribed range of 65-75 percent for row crop planter (Kepner *et al.*, 1987). The major loss in efficiency was due to the turns at headland and adjustment of planter position prior to operation so that the ridges formed in the previous pass were not disturbed. No break down, repairs, and adjustment of components during the operation was observed. The average depth of placement of seed of 10 observations randomly selected was 4cm. The field machine index was recorded at an average of 77.38 per cent. The rectangular size of the test plot and contributed to minimum turning time at the head land.

The average spacing between hills were 17.8 cm in the range of

Fig. 4 Okra planter, side view.

Fig. 5 Okra planter, rear view.

Table 3. Seed Distribution in Row with Different Hopper Capacity

Hopper capacity	Average number of seeds discharged in 25 revolution of ground wheel			
	Row 1	Row 2	Row 3	Average
Half hopper				
(i) Average	212.4	216.0	208.6	212.3
(ii) Maximum deviation from average, %	+0.05	+1.74	-1.79	
(iii)'t' on basis of average	0.04 (NS)	1.90 (NS)	1.86 (NS)	
Three-fourths hopper				
(i) Average	207.6	213.2	210.0	210.3
(ii) Maximum deviation from average, %	-0.66	+0.71	-0.07	
(iii)'t' on basis of average	0.35 (NS)	0.40 (NS)	0.05 (NS)	
Full hopper				
(i) Average	215.2	213.2	219.0	215.0
(ii) Maximum deviation from average, %	-0.28	-1.20	+1.48	
(iii)'t' on basis of average	0.16 (NS)	0.79 (NS)	1.26 (NS)	

NS : Not significant.

Table 4. Sand Bed Test for Seeding Uniformity

Parameter	Number of seed per meter length of bed			
	Row 1	Row 2	Row 3	Average
Mean	7.5	7.8	8.1	7.8
Maximum deviation from average, %	-3.85	+0.43	+3.85	-
't' based on average	0.35 (NS)	0.04(NS)	0.32(NS)	-

NS : Not significant.

Table 6. Machine Planting versus Manual Planting

Parameters	Machine planting	Manual planting
Average plant spacing, cm	27.60	26.80
Number of plants per m^2	7.99	8.32
Number of plants per meter	3.60	3.70
Yield, q/ha	73.85	74.08
Average yield per plant, g	108.00	102.00

Table 5. Field Performance Data of Okra Planter

Performance parameters	Values
Average draft, kgf	536.00
Average speed, km/h	2.27
Average depth of placement, cm	4.00
Average field capacity, ha/h	0.2033
Average field efficiency, percent	66.51
Average field machine index, percent	77.43
Labour requirement, man-h/ha	5.53

Note: Soil moisture content 14.05% and soil bulk density 1.13 g cm^{-3}.

0-35 cm. However, after germination the average plant spacing was observed to be 27.6 cm as against the recommended plant spacing of 30 cm. This difference was due to the non-emergence of some seeds in the field. The number of plants over meter length was 3.6 against the theoretical 3.3 plants over that length. The comparison of crop parameters between machine planting and manual planting is presented in **Table 6**. From the crop response it can be concluded that both machine planting and manual planting were at par.

The cost of the prototype planter was Rs. 10,500 and hourly cost of operation was computed to be Rs. 153. The man-h requirement for planting one hectare of land was 5.53. The cost of planting by planter was Rs. 810 per hectare compared with Rs. 1,410 required for manual planting of okra seeds. The cost of manual planting was 76 per cent higher than the machine planting and required 76.6 man-hours more than the machine. The breakeven point was 67.83 hours per year and a payback period for 2.75 years.

Conclusions

On the basis of the results obtained from the laboratory calibration and field trials of the okra planter, the following conclusions can be drawn:

The deviations of seed discharge among the rows from average for half hopper, three-fourths hopper and full hopper were within the range of 7% and statistically insignificant. No difference in metering was observed with different hopper capacity due to the constant depth of seed layer in pickup chamber maintained by sliding plate. In the sand bed test the variation in seeds dropped from the mean among the three rows was non-significant. The maximum deviation of seed discharge for any of the rows from the average was 3.85 per cent.

The effective field capacity of the planter was 0.2ha/h with a field efficiency of 66.5 per cent. Thus, it can be operated by a 35 hp tractor.

There was a saving of 77 man-hours per hectare and 76 per cent in the cost of operation by using the

Fig. 6 Okra planter in operation.

Fig. 7 Manual planting of okra seed.

planter. Only one use of 68 hours per year will benefit the owner and within three years with recommended use will pay back the initial investment on the planter. Hence the use of planter for okra seed planting was justified.

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(Continued from page19)

Influence of Different Planting Methods on Wheat Production after Harvest of Rice

Conclusions

Sowing methods played a significant role in enhancing the wheat yield attributes and yield without deteriorating the soil environment. We can also maintain the fertility status of the soil for longer periods. There were considerable savings in time requirement, operational cost, fuel consumption and energy requirement as compared to the conventional sowing. The strip till drilling produced significantly higher grain yield (6.29 t/ha) followed by conventional tillage (5.93 t/ha), zero till drilling (5.91 t/ha) and bed planting (5.85 t/ha). The strip till drilling was the best sowing method for increasing the productivity of wheat with minimum cost of cultivation as it provides favorable physical environment by placing the seed and fertilizers at the proper place which provides proper nutritional environments to the plants.

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Influence of Different Planting Methods on Wheat Production after Harvest of Rice

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Abstract

A field experiment was conducted to reduce the time, energy and cost of operation zero till drill, strip till drill and raised bed planter were practiced for sowing of wheat in combine harvested rice field. The effective field capacities of the zero till drills and of strip till drills and bed planter were 0.41, 0.40 and 0.35 ha/h, respectively. The zero till and strip till drilling were time saving (75.2 and 74.2%), labour saving (64.3 and 64.3%), fuel saving (79.1 and 77.9%), cost saving (65.9 and 68.3%) and also energy saving (79.2 and 78.1%) as compared to conventional sowing of wheat. The strip till drilling produced significantly higher grain yield (6.29 t/ha) followed by conventional tillage (5.93 t/ha), zero till drilling (5.91 t/ha) and bed planting (5.85 t/ha).

Introduction

Rice-wheat crop rotation is very common in India. The wheat production is adversely affected if the crop is not sown in time. Delayed sowing and poor quality seedbed affect germination and ultimately the yield. The energy input, time and cost of seedbed preparation for wheat sowing in combine harvested paddy fields is high. Also, with greater intensity of tillage, the repeated movement of traffic on soil causes mechanical compaction and deterioration of soil structure (Oni and Adeot, 1986). Generally, 4-12 or even more operations of harrow and/or cultivator are needed for seedbed preparation in combine harvested rice fields in clay soils which involve both time and money of the farmers. To reduce the time, energy and cost of seedbed preparation, zero till and strip till drills have been specially designed which can sow wheat directly after the harvest of rice without any field preparation. For areas with scarcity of water, bed planting reduces the cost of cultivation by reducing the need for seed, fertilizer and irrigation water. Thus keeping in view the present study was undertaken to observe the effect of different planting methods on the production of wheat.

Materials and Methods

A field experiment was conducted at the research farm of PDCSR, Modipuram during 2000-2001 in sandy loam soil. Zero till drilling, strip till drilling, bed planting and conventional tillage sowing of wheat (UP-2338) were practiced after the harvest of the rice crop with three replications in split plot design. The zero till drill with knife type furrow openers was used for placing seed and fertilizer at row-to-row distance of 180 mm directly without any field preparation. The strip till drill prepares 9 strips each of 10 cm width for simultaneously placing the seed and fertilizer at appropriate depths at row-to-row distance of 180 mm. In the strip till drilling the sowing was also done directly without any field preparation. The bed planter made beds of 600 mm with the provision of sowing three rows of wheat with row spacing of 120 mm on each bed. In conventional sowing and bed planting 2 harrowing, 1 cultivating and one planking operations were performed before sowing. The texture of the soil was sandy loam. In fertilizer scheduling, half dose of nitrogen (60 kg N/ha) and full dose of P and K were applied at the time of sowing. The remaining half dose of N was top-dressed at first irrigation and maximum tillering stage. The soil of experiment was slightly alkaline in reaction (pH-8.21, EC(ds/m)-0.30, O.C(%)-0.50, available P_2O_5(kg/ha)- 21.96, available K_2O(kg/ha)-161.28).

Results and Discussion

The results indicated that the effective field capacity of the zero till

Table 1. Field Performance Parameters of Wheat Sowing Machines

Item	Zero till drill	Strip till drill	Bed planter
Effective working width, mm	1,620	1,620	1,500
Row spacing , mm	180	180	120
Depth of sowing, mm	40	45	45
Operating speed, km/hr	3.45	3.38	3.24
No. of operation (including seedbed preparation)	1	1	5
Effective field capacity, ha/h	0.41	0.40	0.35
Field Efficiency, %	73.2	72.7	72.0

drill was 0.41 ha/h and the cost of sowing and energy requirement were $ 9.3 per ha and 431 MJ/ha, respectively. In the case of strip till drilling the effective field capacity of the machine was 0.40 ha/h with the cost of sowing $11.45 per ha and energy requirement 455 MJ/ha. The effective field capacity of the bed planter was 0.35 ha/h. The cost of sowing, including the bed preparation was $27.5 per ha and energy requirement was 2074 MJ/ha (**Table 1**). The zero till and strip till drilling were time saving (75.2 and 74.2%), labour saving (64.3 and 64.3%), fuel saving (79.1 and 77.9%), cost saving (65.9 and 68.3%) and also energy saving (79.2 and 78.1%) as compared to the conventional sowing of wheat (**Table 2**).

The results reveal that maximum yield attributes and yield were obtained with strip till drill followed by zero till drilling except grain yield in which conventional sowing gave slightly higher grain yield as compared to zero till drilling. The strip till drilling produced significantly higher grain yield (6.29 t/ha) than other treatments and lowest (5.85 t/ha) in bed planting. (**Table 3**). The strip till drilling also produced maximum straw yield (9.07 t/ha) followed by zero till drilling (8.57 t/ha) with minimum (8.45t/ha) in bed planting (**Table 3**). The low yields under zero till drilling were primarily associated with low germination percentage, inadequate plan population per unit area and relatively higher weed infestation. The lowest yields obtained in bed planting may be due to covering less area under sowing. Whereas, in conventional sowing higher weed infestation and inadequate plant population were the main cause of low yield as compared to strip till drilling. The strip till drilling also recorded the highest benefit : cost ratio (3.84) followed by zero till drilling (3.29), bed planting (3.58) and conventional sowing (3.24).

The yield attributes like number of ears/ m^2, grains / ear and grain weight / ear were significantly higher with strip till drilling as compared to other sowing methods. These attributes were minimum in bed planting. However, strip till drilling being at par with zero till drilling, significantly increased the test weight over conventional sowing and bed planting. The higher values for yield attributing characters under strip till drilling were mainly due to the side placement of fertilizers in root zone increasing the availability of nutrients for better and vigorous growth and development of wheat.

There was no significant effect of the different tillage treatments on physio-chemical properties of the soil but improved aggregate condition (mean weight diameter (mm) Org.C, and moisture content of soil were noticed under the zero tillage which was due to slow decomposition of residue. Low pH and slightly higher EC under zero tillage was attributed to the secretion of organic acids from the decomposing residue in the surface layer as the residues were left on the surface.

(Continued on page 17)

Table 2. Time, Cost, Fuel Consumption and Energy Requirement under Different Planting Methods of Wheat

Item	Zero till drilling	Strip till drilling	Conventional sowing/bed planting*
Time required of operation, h/ha	2.4	2.5	9.7
Fuel consumption, L/ha	7.6	8.01	36.3
Labour requirement, human-h/ha	5	5	14
Cost of sowing, $./ha	9.3	11.43	27.5
Energy requirement, MJ/ha	431	455	2,074
Time saving as compared to conventional sowing, %	75.2	74.2	--
Fuel saving as compared to conventional sowing, %	79.1	77.9	--
Labourer saving as compared to conventional sowing, %	64.3	64.3	--
Cost of operation saving as compared to conventional sowing, %	65.9	58.3	--
Energy saving as compared to conventional sowing, %	79.2	78.1	--

* *Including seedbed preparation.*

Table 3. Yield Attributes, Yield and Benefit Cost Ratio of Wheat as Affected by Different Sowing Methods

Treatments	Ears/m^2 (no.)	Grains/ ear (no.)	Grain weight / ear(g)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	B:C ratio
Zero till drilling	427.0	41.45	1.66	44.96	5.91	8.57	3.59
Strip till drilling	492.0	47.20	1.95	45.54	6.29	9.07	3.84
Bed planting	412.0	40.90	1.58	43.56	5.85	8.45	3.58
Conventional sowing	425.0	41.10	1.60	43.86	5.93	8.50	3.24
CD (5%)	12.48	0.70	0.08	1.31	0.17	0.05	-

Modification of the Injection Planter for the Tropics

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Abstract

The initial design of the injection planter did not function satisfactorily in most of the tropical soils due to soil attachment.

The planter was re-designed in such a way that only a few parts come in contact with the soil. Those parts are cleaned by a scraper incorporated into the design.

When tested on sandy and sandy loam soils, there was no soil attachment that would impair its functioning. Seed droppings were, in most cases, one per hole. There was no seed breakage. The equipment can plant maize, cowpea, soybean and *mucuna*. For 0.75m crop row spacing, its rate of work is 0.13ha/h.

Introduction

The original concept of the existing rolling injection planters which has been used in the tropics was conceived by George Banbury, a Briton, in 1977 (Garman, 1981). When this type of planter was introduced to the tropical farmers in the seventies, the farmers accepted the tools wholeheartedly. They expected the planter to be a do-it-all in the area of seed planting, with respect to maize, cowpea, soybean, *mucuna*, but to mention a few. Many farmers invested on this machine – the single row hand pushed, 2-row animal drawn, 3-row walking-type machine, 4-row tractor-mounted and 6-row tractor-mounted types.

As time went on, many farmers began to express dissatisfaction with the performance of this planter on tropical soils. Their major complaints were: (i) soil accumulation on the planter soil openers and body; (ii) inability of the planter to release seeds into the soil when it is required to do so; and (iii) having to wait for hours after rains, depending on the rain intensity, before the planter could be used, especially on tilled soils. Many farmers who acquired this piece of equipment gradually lost interest in it and eventually dropped it. The local farmers resorted to the traditional method of planting with sticks or cutlasses. This has a negative influence on the timeliness of seed sowing; and it has been reported (Rowland, 1993) that any delay in sowing beyond the optimum time results in drastic reduction in yield.

It is not that the concept of the originator of this tool is not feasible. Rather the fact is that the soil in which his work was tested is quite different from the tropical soils. Most of the tropical soils are not friable and as such stick to the bodies of planters, making soil penetration by planter openers either difficult or impossible. In other cases the openers were blocked by soil, making it impossible for seeds to be released into the soil. The rolling injection planter is, in fact, a vital tool for all levels of farmers. It is basically a no-till planter and makes it very suitable for the majority of the tropical farmers who, in most cases, practice the no-till system. However, the planter can also be conveniently used on tilled soils. The use of a functional model of this tool encourages row cropping which aids mechanization. This is coupled with savings in time, achievement of timeliness, and reduction of drudgery.

Because of the importance of this tool, the present work has looked at a re-design to suit the tropical environment. The areas of concentration were:

(i) Minimizing the parts that come in contact with the soil;
(ii)Making all the parts that come in contact with the soil amenable to scrapping; and
(iii)Incorporating a scraper.

These ensure that any soil attached to the tool is significantly reduced.

The Improved Design

The improved injection planter is shown in **Fig. 1**. Basically the tool is pushed to roll on soil surface through the handle (1). Seeds which are contained in the hopper (2) are injected into the soil through the soil openers (5). The openers are in pairs. There are six pairs. The press wheel (16) which follows behind firms the soil. The wheel is mounted on a hub (15). The hub is sleeved into a spindle attached to the float link (14). The link allows the press wheel to float through the contour of soil surface.

In the former design, the soil openers were positioned with their widths placed across the direction of the planter forward movement. By this design, it was not possible to incorporate any scrapper to clean these openers. In the current design, the openers are positioned with their widths placed along the direction of travel of the planter. This is to ensure that the openers lend themselves to scrapping action. At each pair of openers, one is fixed while the other can swing open from the rear (the side closer to the operator), up to an angle of 90° to the direction of travel. It is closed back after the seed has been released through the action of the return spring (4).

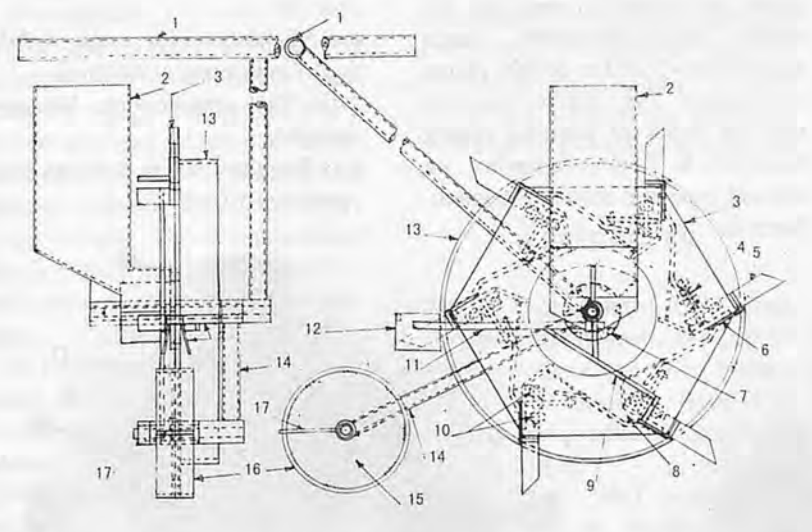
As the planter rolls on the ground, it gets to a point when the opener arm (6) collides with the opener actuator (9), and remains in that position. This causes the swinging out of the movable opener which is installed in hinges (10). As this is done, the compression spring (4), which acts as a return spring, is loaded and the openers remain open as long as the opener arm remains hooked with the opener actuator.

The next action is the release of seed(s). Kepner et al. (1980) reported that the devices for metering single seeds usually have cells on a moving member or an arrangement to pick up single seeds and lift them out of a mass. Of the two systems, the former was employed, in the form of suitable seed roller. Seed(s) which have been metered by the seed roller (7) and dropped into the waiting room (8) are now dropped into the soil. When the opener arm (6) moves past the actuator (9), the already loaded return spring now causes the closure of the openers. This takes place when the openers must have traversed the soil, dropped the seeds, moved completely out of the soil, and moved some further distance (which acts as a factor of safety). The traversing of this further distance ensures that no soil or trash is trapped between the openers when the compression spring acts to close the soil openers. The depth wheel (13) controls the planting depth. Large wheels are inserted for shallower depths and vice versa for deeper depths. The depth wheel is made of a flat bar, 51mm wide, and it performs another function of preventing the planter from sinking, should the soil be tilled.

A scraper system (12) is mounted on a scrapper arm (11) and it cleans both the openers and the depth wheel. Another scraper (17) cleans the press wheel. The shape of the body (3) of the planter is hexagonal, the same as for the former design because when units of such a shape is cut from a standard metal plate, there is very little material losses. The pictorial views of the improved injection planter are shown in **Figs. 2** and **3**.

Table 1. Parameters of Test Field

Field	Type of soil (m^2)	Land preparation	Area of field	Dimensions of field (m)
A	Sandy	Ploughed	1,275	50× 25.5
B	Sandy-loam	Ploughed	1,500	50× 30
C	Sandy	No-till	1,275	50× 25.5
D	Sandy-loam	No-till	1,500	50× 30



1-Handle, 2-Hopper, 3-Planter body, 4-Return spring, 5-Soil opener, 6-Opener arm, 7-Seed roller, 8-Seed waiting room, 9-Opener actuator, 10-Hinge, 11-Seraper arm, 12-Scraper, 13-Depth wheel, 14-Float link, 15-Hub, 16-Press wheel, 17-Press wheel scraper.

Fig. 1 Graphic view of the injection planter.

Performance Tests And Discussion

The injection planter was tested according to the Regional Network for Agricultural Machinery (RNAM, 1983) Test Codes and Procedures. The planter was tested both on plain ground and on the field. The procedures follow:

Test Conditions

(A) Condition of field: The parameters of the test field are given in **Table 1**.

(B) Condition of seeds:

Table 2. Frequencies of Seed Droppings on Plain Soil

Seeds per hole	0	1	2	3	4	5	6
Frequencies	4	88	4	4	0	0	0

(i) Name of seed: Maize
(ii) Variety of seed: TZSR-Y
(iii) Viability of seed: 98%

(C) Condition of planter and operator:
(i) Source of power: Manual
(ii) Adjustment: In each case the planter was adjusted to drop one or two seeds per hole, but mostly one seed per hole. Planting depth was fixed at 5.0cm.
(iii) Travelling speed: 3km/h (Average speed of man on the farm)
(iv) Skill of operator: The operator is used to the conventional rolling injection planter.

Laboratory Performance Tests

(i) Name of seed: Maize
(ii) Variety of seed: TZSR – Y
(iii) Weight of seed delivered/10 revolutions of planter: 0.014kg
(iv) Travelling distance: 15m
(v) No. of rows/0.1275 ha: 35
(vi) Row spacing: 0.75m.
(vii) Delivery rate/ha: 12.81kg
(viii) Percentage of seeds damaged by the metering device: 0
(ix) Pattern of seeds deposited: Precision seeding.

According to Purseglove (1988), an average seed rate of 9 – 16kg/ha is normally used for maize. The above laboratory test is, therefore, in agreement with the normal rate. For row spacing of 0.60m, this would give a rate of 15.87kg/ha.

The seed roller used for the performance test was tested by running the planter on a plain soil and the seeds injected into the soil from one hundred consecutive injections were carefully dug out. The frequencies of the various seed droppings are shown in **Table 2**.

The above rates could be varied by inserting a suitable seed roller. No seed damage was recorded.

Field Performance Tests

(A) Performance and Accuracy:

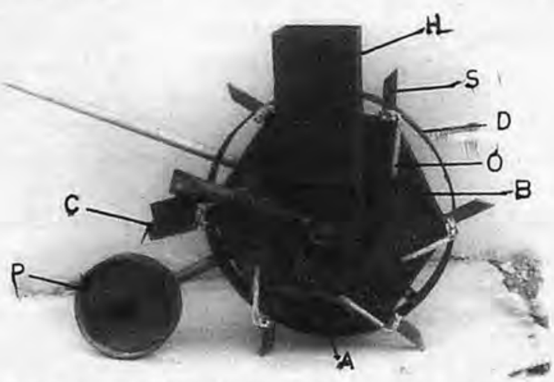
By the RNAM test codes, the size of the field should not be less than 30m×50m. The tests which were conducted for tilled and untilled plots were carried out for 0.75m row spacing. The results are shown under Fields A and C. The calculated equivalents, using the data for 0.75m row spacing, are shown under Fields B and D for 0.60m row spacing. The results are presented in **Table 3**.

Bishop et al. (1983) reported that in areas with the highest potential, such as irrigated areas, maize stand levels range from 60,000 to 74,000 plants per hectare; in areas that are mostly rainfall-dependent, stands range from 45,000 to 60,000 plants per hectare. They further reported that the depth of planting ranges from 2.5 to 7.5cm, depending on the soil type and moisture content. Norman et al. (1995) stated that high growth rates are usually achieved in the tropics at populations of about 50,000 plants per hectare. The population realized in this work, when row spacing was 0.60m, is in agreement with those in the literature. When row spacing is 0.75m, this population would be realized if the missing stands are supplied, probably with a jab planter; or by using seeds of higher viability. However, the population as it is can also be allowed in some areas of tropical farming.

Slippage and sinking of machine were found to be negligible for the ploughed plots (A and B), and absent for unploughed plots (C and D). The ease of handling and operating is just like that of the conventional rolling injection planter.

(B) Work Rate and Labour Requirement:
(i) Actual average travelling speed: 3km/h
(ii) Actual operating time: 8h/ha
(iii) Time spent for turning at headlands: 0.75h
(iv) Time spent for adjustment of machine: 0.50h
(v) Time spent for machine trouble: 0h
(vi) *Time spent for resting: 1.25h
(vii) Work capacity: 0.13ha/h
(viii) Fuel consumption: Not applicable
(ix) Required no. of workers and man-hour: 1 and 8

Fig. 2 Pictorial view of the injection planter.



S-Soil opener, D-Depth whieel, O-Opener arm, B-Body, A-Opener actuator, P-Preswheel, C-Scraper, H-Hopper.

Fig. 3 An enlarged view of the planter.

*Not included in the RNAM test codes.

RNAM Test Codes Criteria for Evaluating the Acceptability of a Seeding Equipment

(i) Crops for which the equipment is suitable: Maize, Cowpea, Mucuna, Soybean, Sorghum – all depending on the type of seed roller inserted.

(ii) Type of soil: Loam, sandy, sandy-loam, clayey.

(iii) Method of land preparation: no-till, minimum tillage, conventional tillage.

(iv) Accuracy and uniformity of operation: Drops seeds uniformly.

(v) Ease of operation and machine maintenance: Like the conventional rolling injection planter. The planter should be cleaned after use. No attempt to roll the planter backward should be made.

(vi) Working capacity of machine (ha/h): 0.13.

(vii) Source of power: Human muscle.

(viii) Labour requirement: An operator at a time

(ix) Operating cost: The wage for the operator.

The Test Codes reported that planters which can handle more than one type of seed are more preferred to those which can handle only one type of seed. The injection planter in question plants up to five types of seeds. This is coupled with the fact that it can be used in different types of soils and soil conditions.

It is interesting to note that the seeds used in the performance tests were not graded. They were purchased from a local market in Abeokuta, Nigeria. This makes it more suitable for the local farmers of the tropics, since majority of them do not know what it means to grade seeds for planting.

Table 3. Results of Field Tests

Field	Row spacings, m	Distance between stands, m	*No. of seeds planted/ha (S)	*No. of plants established/ha (P)	Ratio of (P) to (S)	Planting depth, m	**Missing stands/ha
A	0.75	0.25	45,098	44,196	49:50	0.50	1,804
B	0.60	0.25	55,857	54,740	49:50	0.50	2,234
C	0.75	0.25	45,098	41,451	23:25	0.50	1,804
D	0.60	0.25	55,857	51,340	23:25	0.50	2,234

* Both the population of seeds planted and established per hectare were calculated from the plot areas used for the test, namely, 5750 seeds planted, 5635 plants established per 0.1275ha (25.5m×50m) for the tilled plot of 0.75m row spacing; 5750 seeds planted, 5285 plants established per 0.1275ha for the no-till plot of 0.75m row spacing; and so on.
** The rate of missing stands was calculated from the average number of zero droppings when the metering device was tested on plain soil surface. This information would be wrong if taken from the plot, as there are missing hills due to seeds which did not germinate.

Conclusions

The injection planter has been modified to suit the tropical condition. The parts that come in contact with the soil have been made fewer, when compared with the original design. These parts have been made amenable to scraping action and a scraper has been incorporated into the design to clean the parts as the planter works.

When tested in both sandy and sandy-loam soils, the level of soil adherence to the equipment did not impede its functioning. It has a capacity of 0.13ha/h, when crop row spacing is 0.75m.

Units of the planter could be attached to tool bars to obtain a 2-row planter which can be pulled by a work bull; a 3-row type made into a walking-type machine; a 4-row, 5-row, and 6-row types which can be drawn by a 4-wheel farm tractor.

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Comparative Performance of Manually-operated Fertilizer Broadcasters

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Abstract

Three commercially available manually-operated fertilizer broadcasters were tested. The overlapped spread pattern distribution that resulted in least coefficient of variation was found to depend on speed ratio, drop ratio, drop shape and orientation of drop. These parameters contributed towards space requirements to be observed while making left and right hand turns.

Introduction

The spread pattern of commercially available manually-operated single disc fertilizer broadcasters is usually skewed towards right of the line of travel. The skewness, it was shown (2) is a function of drop ratio (Drop radius/radius of the spinner). It was possible to so select a drop ratio that skewness could almost disappear but the resultant overlapped pattern that gave the least coefficient of variation for the recommended doze of fertilizer rate, required different spacings while making left and right hand turns. This recommendation remained a major bottleneck from not only saleability standpoint but also from uniform fertilizer distribution. No manufacturer within the country even today to the authors' knowledge gives recommendations to the users with respect to spacings to be observed while making left or right turns for a pre-selected fertilizer rate. Non-uniform distribution became quite apparent to those users who went on for broadcasting small seeds using such broadcasters. Successive patches of thin and thick density of crop on seedbed made them rethink about the utility of fertilizer broadcaster vis à vis the conventional method of broadcasting by hand. The study was undertaken to meet the following objectives:

i) To compare overlapped patterns of three commercially available fertilizer broadcasters of similar design; and

ii) To bring home the point that drop ratio, drop location and drop shape all combined together are responsible for bringing nearly uniform and even (on either side of line of travel) fertilizer distribution.

Methods and Materials

Three commercially available manually-operated fertilizer broadcasters designated as A, B and C were tested and evaluated at the Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana.

The fertilizer broadcasters one at one time, were mounted on a wooden platform (**Fig. 1**). The wooden platform was fixed on a steel table whose height from the ground could easily be varied. This table and hence the fertilizer broadcaster remained fixed at one place. One hp electric motor was used as a source of power to drive the shaft of broadcaster. A speed reduction unit consisting of suitable step pulleys and V-belts in between the prime mover and the fertilizer broadcaster was mounted so as to achieve the final desired rpm.

An array of longitudinal G.I. channels by overlapping L sections width-wise (**Fig. 1**), was made. Each L-section was 30 × 15 cm and was made out of 250 × 45 cm G.I. sheet. The maximum rebound height of particles was less than 15cm and therefore 15 cm height of L-section ensured the particles to remain in their respective channels. The width of channels could easily be varied by altering the amount of overlap. However, a width of 25 cm was maintained in this study. The height of the spinner from the horizontal plane formed by the top edges of L-sections was maintained at 80 cm.

The fertilizer broadcasters and arrays of channels were positioned in such a fashion that all the particles that were ejected by the spinner were trapped by the receptacles. The broadcasters were run for 60 seconds. The fertilizer received in each receptacle was weighed. Three replications were taken for computing the final effective swath width.

Results and Discussion

Three commercial locally avail-

Table 1. Comparative Performance of Three Fertilizer Boradcasters at Fertilizer Rate Setting Close to 100 kg/ha

Manufacturer	Least CV	L (cm)	R (cm)	Effective Swath (cm)	Speed ratio	Drop Ratio	Drop shape (on the spinner) w.r.t. line of travel (LOT)	Fins Shape
A	9.05	25	450	236	1:7.92	117.5:28		
B	8.26	175	450	313	1:9.12	117.5:22		
C	9.59	200	175	188	1:8.36	125:32		

able fertilizer broadcasters used were designated as A,B and C. The fertilizer free swath width remained more towards the right of line of travel in comparison to left in all the broadcasters.

Speed Ratio

The overall free swath width (**Fig. 2**) remained maximum on either side of line of travel in the case of B, **Table A2**, due to high speed ratio (between the hand drive shaft and spinner) of 1:9.12 (**Table 1**). High speed ratio also helped to increase the effective swath width and hence field capacity of man-machine system. Besides, it improved the spacing required to be observed while taking left (L) turn in comparison to A. A lower value of speed ratio (not reported) was found to increase sharply the coefficient of variation (CV). A speed ratio of 1:10, therefore, is recommended for design.

Intensity of Distribution

Intensity of distribution within 1 m on either side of line of travel was more towards left in comparison to right only in the case of C (**Table A3**) primarily because of shape and, of course, orientation of drop area. A factor that was responsible for equating the space requirement to be observed on either side for the final overlapped patterns. As a matter of fact, the space required to be observed turned out to be more towards L (=200 cm) rather than R (=175 cm) (**Table 1**) - an indication that L and R can be made equal even for a single disc fertilizer broadcaster.

Drop Ratio, Shape and Orientation

The intensity of spread distribution is quite sensitive to drop ratio, shape and orientation of the drop area with respect to line of travel. The location of the drop was in all the broadcasters, towards rear of the centre of the spinner. The drop shape of A tended towards a point-drop, that of B towards a circumferential slit while that of C towards a radial slit (**Table 1**). A radial slit had a definite advantage in making the final distribution even. The reason could be attributed to widely varying elemental drop ratios coupled with (in real conditions) varying masses and locations.

Fins

There were six fins in all the cases. The shape though differs yet their effect on the pattern was not isolated. On the spinner, all of them

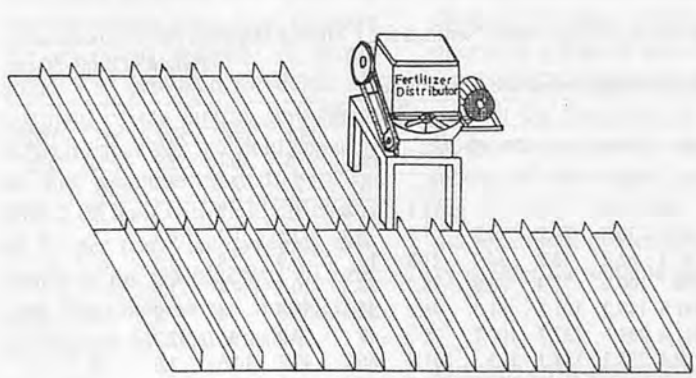

Fig. 1 Experimental set-up for evaluating the spread patterns of stationary fertilizer distributor.

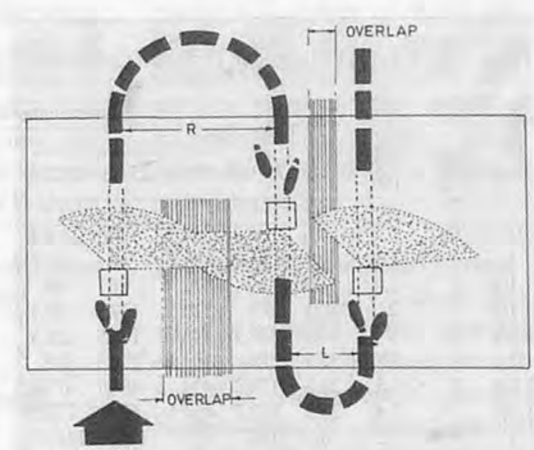

Fig. 2 Overlap spacings for right (R) and left (L) turns.

were mounted in an upright manner.

Summary and Conclusions

From the even spread pattern distribution standpoint, C broadcaster came much closer to the users' requirement. Speed ratio needs to be enhanced to 1:10 in order to increase field capacity as well as reduce non-uniformity in spread, especially when working at lower speeds (rpm). Since drop ratio, drop shape and orientation with respect to line of travel are sensitive parameters - a "standard" is a must.

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APPENDIX - A

Mass in Gms. Collected in the Channels.

Table A1. Mass Collected(g) in Different Collection Channels at Various Notch Settings for 'A' Broadcaster

Notch setting	Lateral Interval (cm) from the central line of the spinner																		
	Left (cm)							LINE OF TRAVEL	Right (cm)										
	150-175	125-150	100-125	75-100	50-75	25-50	0-25		0-25	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275
	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10	11
1/4	-	.07	.15	1.0	3.1	9.3	16.2		26.5	27.3	30.6	32.7	38.8	33.7	24.2	18.3	5.2	1.03	0.023
1/2	.04	2.6	15.0	39.8	68	101.8	114.5		144.3	150.5	155.8	175.8	191	182.9	166	149	59.8	13	2
3/4	0.9	8.1	93.3	228.1	294.8	298	333.4		391	372.3	339.8	341.3	365.4	388.6	381.8	356	90.7	8.2	0.8
Full	0.2	4.2	65.2	324.7	547.6	647	740.2		709.2	604.7	604.7	461.7	474.8	486.5	548.7	537.6	136	8.2	0.8

Table A2. Mass Collected(g) in Different Collection Channels at Various Notch Settings for 'B' Broadcaster

Notch setting	Lateral Interval (cm) from the central line of the spinner																				
	Left (cm)								LINE OF TRAVEL	Right (cm)											
	175-200	150-175	125-150	100-125	75-100	50-75	25-50	0-25		0-25	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275	275-300
1/4	-	-	-	0.1	.65	1.65	3.75	2.58		2.65	5.03	7.43	9.15	12.28	10.95	11.13	9.75	6.35	3.08	1.1	-
1/2	-	.03	.33	.9	3.03	10.45	22.25	27.5		37.33	40.83	42.93	51.15	61.75	61.95	72.65	61.13	35.73	13.3	3.05	0.4
3/4	-	.2	1.4	9.6	19.29	30.27	65.66	63.95		70.82	76.14	85.14	89.96	105.9	100.8	112.03	108.21	68.28	19.08	4.11	.39
Full	.33	3.58	18.1	41.27	60.2	80.47	103.77	100.9		108.77	113.17	119.85	119.34	129.42	131	133.25	131.68	85.3	31.07	6.02	.63

Table A3. Mass (g) Collected in Different Collection Channels at Various Notch Settings for 1 Minute Duration for 'C' Broadcaster

Height of drop: 80 cm

Notch setting	Lateral Interval (cm) from the central line of the spinner																		
	Left (cm)							LINE OF TRAVEL	Right (cm)										
	150-175	125-150	100-125	75-100	50-75	25-50	0-25		0-25	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-225	225-250	250-275
	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	9	10	11
1/2	.08	.2	.6	1.7	4.7	4.1	6.4		6.8	2.9	2.9	2	1.1	.8	1	.8	.3	.3	.2
1	-	1.6	9.3	31.2	36.3	39.8	44.9		42.6	30.8	20.2	14.8	7.8	5.3	2.5	1.3	0.7	-	-
1 1/4	.5	2.4	23	62	79.3	86	90		87.2	62.8	52.7	34.7	21.8	12	6.3	2.8	1.3	-	-
1 1/2	-	2	30.1	101	120.5	137.5	148.4		140	100.2	77.9	62.8	38.7	24.3	10.3	4.8	1.6	-	-
1 3/4	.2	6	46.1	147.5	213	198.9	228.5		191.8	149.2	101.3	81.3	46.1	32.3	133.3	4	.9	.2	.1
2	-	2.3	35.3	186	267.3	290.3	355		311.6	209	132.7	102.7	75	57	27.2	11	2.2	-	-
2 1/4	.3	1.5	21.8	176.3	434	488.7	617.4		529.4	285.3	184.3	133	101.8	66.7	42.2	14.6	2.6	.9	.1
2 1/2	-	2.4	26.3	182.7	450.3	628	772.5		644.8	305.3	211.5	151.8	110.7	85.2	49.8	20.3	4.8	1.7	-
3	-	1.2	8.5	118.3	557	1189	1445.7		954.4	422.7	280	206.7	161.7	139.7	83.8	36	7.5	1	.3
3 1/2	-	.6	3.3	59	489.3	1489.7	2727.2		1599.5	482.3	307.7	243	212.5	171.3	129	60.3	15.3	2.5	.9
4	-	.3	1.5	19	306	2270	4899.3		2370	513	338.1	278.3	236	198	159.7	84.7	24.8	2.1	.4

Design and Development of Power-operated Rotary Weeder for Wetland Paddy

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Abstract

The introduction of efficient weeding aids and equipments for weed control seems highly necessary to minimize the time consumption, labour requirement and cost. As a consequence, a prototype power-operated rotary weeder for weeding in wetland rice cultivation was designed, developed and fabricated at the Faculty of Agricultural Engineering workshop, IGAU, Raipur, India during the year 1999-2000 and tested in the experimental field. A 0.5-hp petrol driven engine was used for power weeder with a reduction gearbox. The power transmission from engine to traction wheel and to the cutting unit was provided by means of a belt, pulley and chain, sprocket. For cutting the 4 L-shaped standard blades were used on the hub, and in turn fitted on rotary shaft. Two big traction wheels were used to make the operation smooth. A guage wheel was provided for depth adjustment of the cutting unit. With 200-mm spacing, the field capacity of the machine varied between 0.04-0.06 ha/h with field efficiency of 71 per cent. The weeding efficiency of the machine was 90.5 per cent. The machine was simple, easy to fabricate by local artesians.

Introduction

In India, weed control is one of the major problems in rice cultivation accounting for a major share in the cost of production. The traditional methods for controlling weed problem are no longer used in commercial rice production. Due to weeds yield reduction in direct seeded upland paddy ranged from 42 to 65 per cent (Sharma et al. 1977). Therefore, an attempt was made to develop a power-operated rotary weeder for intercultural operation under wetland conditions.

For the design and development procedure of the power weeder the power and draft requirement for wetland condition is about ½ to1 hp per row (Datta et al., 1972). Gurusamy (1988 and Tajjuddin et al., 1991) reported that 1.7 hp engine is sufficient to power the engine for weeding with maximum operating depth of 50 mm, walking speed of operators 1.8 km/h and allowing 30 per cent of transmission loss.

With the foregoing in view, this study was undertaken with the objective of developing and evaluating a low-cost, locally manufactured power-operated rotary weeder for wetland paddy.

Design and Development

The developed power weeder consisted of a chassis, prime mover, power transmission system and cutting unit (**Fig. 1**).

The Chassis

The chassis consisted of a main frame and a supporting frame that house the power unit, gearbox, transmission system and cutting unit. The main frame is 1150 × 25 mm long and 185 mm wide. The supporting frame is made of a 35 × 35 × 5 mm mild steel (MS). Strips of MS plat size 115 × 32 mm were welded in between the angle irons of the main frame for better support and extra strength. The vertical supporting frame is made of MS sheet in box type shape, fixed to the main frame, and, in turn, fixed to the engine.

The Prime Mover

The prime mover is a single cylinder, two-stroke, air-cooled petrol engine with a bore of 40.40 mm, stroke 39.00 mm, displacement volume 49.99 cc (0.5 hp) and compression ratio 1:8. The power requirement for wet paddy intercultural operation is about ½ hp to 1 hp per row.

The Power Transmission System

A V-belt pulley, chain and sprocket transmit power from the engine to the ground wheel and cutting unit (rotary blade). Various combinations of chain, sprocket and belt pulley were tested to get a final drive in the range of 15 to 25

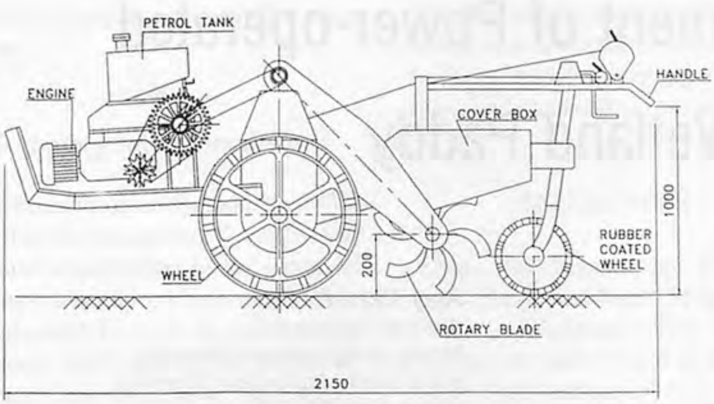

Fig. 1 Schematic diagram of the power-operated rotary weeder.

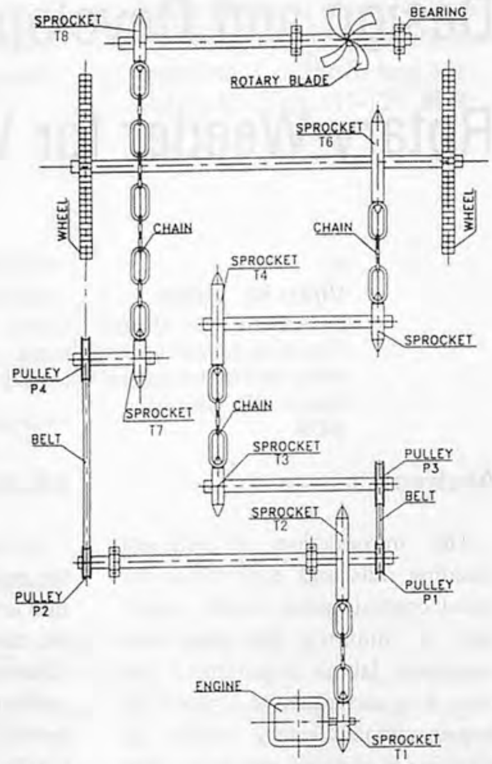

Fig. 2 Block diagram of power transmission system.

rpm and 175 to 200 rpm for ground wheel and cutting unit, respectively. **Fig. 2**. The sprockets with number of teeth were T_1=13, T_2=T_4=T_6=47, T_3=T_5=14 and T_7=T_8=19. The pulley diameters were P_1=P_2= 75 mm, P_3=P_4= 100 mm all of which are governed with the following formula:

$$N_1 = N_2 \times \frac{D_2}{D_1}$$

Where, N_1 = rpm of driven pulley
N_2 = rpm of drive pulley
D_1 = diameter of driven pulley
D_2 = diameter of drive pulley

and

$$N' = N'' \times \frac{T_1}{T_2}$$

Where, N'= rpm of driven sprocket
N"= rpm of drive sprocket
T_1= number of teeth in drive sprocket
T_2= number of teeth in driven sprocket

The final reduction of rpm from the engine (900 rpm) is reduced to 17 rpm at ground wheel 188 rpm at the cutting unit.

The Cutting Unit

Four cutting blades, made of high carbon steel, were fitted on the hub, which was fixed on the rotary shaft. The rotary shaft was made of 48 mm diameter and 100 mm long MS pipe, which was bolted with 25 mm diameter MS rod and supported by ball bearings. The blades are bolted with nuts and bolts with the hub which are, in turn, welded to the shaft at 350 mm spacing. The four blades are fitted on hub in staggered manner.

The Ground Wheel

The two-traction wheels of MS rods of 10 mm diameter were made by using two different diameter rings, outer 457 mm and inner 537 mm. These were placed between the 18 lugs of MS flat dimension 38 ? 38 ? 5 mm which were welded on the rim at 90 mm spacing. The six MS rods of 10 mm diameter and 241 mm long in the outer ring and 203 mm in inner ring were welded as spokes on the central hub. The 100-mm long hub was made up of MS pipe to suit the 25 mm size MS shaft, which is the central axle of the ground wheels.

In order to design the optimum lug spacing of the ground wheel, it was to be assumed that ground wheel should be run at a maximum slip of 30% at which the lug spacing required for a wheel with radius 260 mm, lug sinkage 30 mm and minimum shear spacing 60 mm using the **equation** (Dutta et al.,

Equation

$$L_1 = \frac{2}{(1-i)}\left[r\cos^{-1}\left(\frac{r-h}{r}\right) - r\sqrt{1-\left(\frac{r-H}{r}\right)^2} + \frac{S}{2} \right]$$

Where, H = depth of lug sinkage
S = minimum shear spacing
I = maximum slip
R = wheel radius, by substituting the values in above equation the optimum lug spacing can be calculated as 90 mm.

The specifics of the developed power weeder

1. Type	:	Walking behind type
2. Over all dimensions		
Length	:	2150 mm
Width	:	600 mm
Height	:	1000 mm
3. Weight	:	102 kg
4. Cutting unit		
Type	:	Rotary
No. of blade	:	4
Blade type	:	L-shaped blade
Width of cut	:	135 mm
5. Ground clearance	:	150 mm
6. Wheels	:	Two ground wheel
	:	One gauge wheel at rear end
Diameter	:	450 mm (outer)
	:	530 mm (inner)
Width of wheel	:	50 mm
No. of lugs	:	18
Lug spacing	:	90 mm

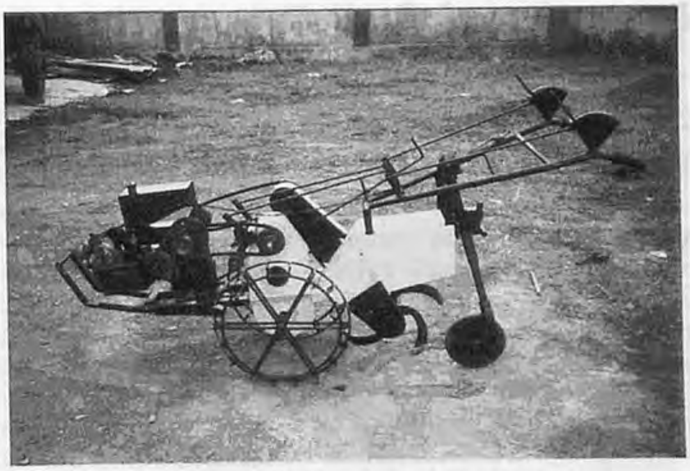

Fig. 3 Side view of the power-operated rotary weeder.

1972).

The Guage Wheel

A guage wheel was attached to the rear end of the mainframe for depth setting of the rotary blades. A 254 × 38 mm rubber coated iron wheel was used for the purpose of rising and lowering so as to alter the depth of cutting and weeding by the rotary blades.

The Ground Wheel Axle Shaft

As cited earlier, the power weeder is operated by a 0.5 hp (49.99 cc) SI engine with an equivalent torque as determined by the Guest's theory and with the help of the Flexure formula for circular section of the shaft. The safe design diameter of the shaft is 25 mm for the ground wheel axle shaft.

The Steering Mechanism

For steering the weeder two handles made of iron pipes were attached to the main frame. Two hand levers are mounted on the handles for engaging or disengaging the power from the engine to ground wheel and rotary blade. An accelerator adjustable lever was fixed on the right side handle for varying the engine speed.

Machine Performance

The machine was tested in the experimental plots of Faculty of Agricultural Engineering for weeding performance. It performed well on a 50 – 70 mm standing water. On hard soil beneath the standing water the machine performance was not satisfactory as the engine became heated up after several intervals due to improper cooling of the engine and over draft required during the weeding operation. The bigger wheel provides better stability and some of the weeds were cut and buried due to the action of lugs.

The performance test of the weeder was compared with hand weeding, single roller paddy weeder (manual) and *Biasi* (Beusnai) operation. The power weeder gave the highest field capacity (0.044 ha/h) and field efficiency (71 per cent). The performance index (0.066) also greater than that of the other weeding methods. The weeding efficiency was 90.5 per cent. The operational cost was Rs. 882.00 per ha.

Future Line of Work

The developed machine demonstrated a low cost weeding operation. Further research like testing of the machine can be done by replacing the petrol engine with kerosene engine of similar power, further tests for optimum ground clearance and different rpm of the cutting unit.

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A study of Soil Properties Relevant to the Design of Yam Harvesters in the Benue Flood Plain of Nigeria

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NIGERIA

Abstract

The soil properties relevant to the design of potential tractor-mounted yam (*Dioscorea species*) harvesting machines in the Benue flood plain of Nigeria was investigated. The yam cultivars *Anacha* and *Gbangu* of D.rotunda species grown on mounds were used in the study. The soil was 54.6% sand, 27.7% silt and 17.7% clay. At harvest, the soil had a bulk density of 1.5g/cm^3, total porosity of 42.5% and moisture content of 5.8%, angle of shearing resistance of 25.6° and cohesion of 2.75kN/m^2. It had a clod number of 65 for 30-45mm, 18 for 45-55mm and 9.5 for 55-75mm. The width and nose angle of the harvester shares should not be less than 97cm and range between 26° and 90°, respectively. Harvester shares should be designed to cut the mound at the ground level. To facilitate the mechanisation of yam harvesting, the mounds should be cultivated in rows.

Introduction

Yams (*Dioscorea spp*) are the most important food crops in West Africa, except for cereals (Coursey, 1967; Onwueme, 1978). The crop is a staple food for millions of people in this region, providing an important source of carbohydrate and more protein on a dry-weight basis than is commonly assumed (IITA, 1992). Over 90% of global yam production come from this region (Onwueme and Sinha, 1991). Yam accounts for 4.1% of the world's total output of root and tuber crops (IITA, 1995). In sub-Saharan Africa, yam accounts for 26.9% of the total root crop production (Gabremeskel and Oyewole, 1987; Onwueme and Sinha, 1991). Nigeria alone accounts for 59% of the world yam acreage and 68% of the world production (Onwueme and Sinha, 1991). Nigeria produces about 15 million tonnes of yam annually from 1.4 million hectares (Ene and Okoli, 1985) ranking second (total output and area covered) among the root and tuber crops (CBN, 1995).

In recent years, yam has become expensive and relatively unaffordable by many Nigerians. The production of this all - important basic staple food crop in Nigeria has not been quite satisfactory. Production has not kept pace with population and demand exceeds supply. Consumers are turning more and more to the less expensive cassava (*Manihot esculenta*) even though they prefer yam. The average yield and output have declined from 8.96MT/ha between 1966 and 1975 to 7.54MT/ha between 1991 and 1996 and in the study area most commonly referred to as the yam state the production declined from 23.47 to 13.69MT/ha within the same period (FMNR, 1991).

Improvements in yam production have been fraught with difficulties and numerous problems. Principal among these is its high costs, which is a consequence of the heavy labour requirement at planting and harvest, the need for staking, and sizeable expenditure on seed yams. The present day methods of production require the performance of a very large number of tasks: clearing, planting, weeding, staking, harvesting, barn preparation, etc. Most of these tasks are performed by hand or hand tools, and may continue to be so for years to come. Some of these tasks are specialised and tend to defy mechanisation, of which harvesting is one (Onwueme, 1978). Yams are planted in mounds and they grow vertically downwards towards the ground level and are sometimes branched. Harvesting the tubers requires the destruction of the mound by removing the soil to which it is held and binded to. Harvesting by hand with hoes and cutlasses is very laborious, tedious and slow with a manual labour requirement of about 45 man days per tonne of the harvested crop or 0.10 hectares of area planted (Coursey, 1967). Any strategy aimed at halting the apparent decline in yam production must include new technologies that enable the farmers to reduce the cost of production. Mechanisation of the various aspects of yam production is one such strategy. Various attempts have been made to mechanise yam planting and harvesting but progress towards harvesting has been relatively slow. Tuber crop mechanisation has generally been confined to processing. Several factors concerning yam growth and production continue to pose serious problems when attempting to mechanise its harvesting. Apart from the serious difficulties arising from the tuber growth pattern, many yam cultivars produce branching tubers, which are more difficult and more delicate to lift while harvesting. A further complication is that the yams are grown on mounds.

An understanding of soil properties and how they affect the harvesting of yam tubers is a requirement for the development of a harvesting machine. This is because the soil properties directly or indirectly affect the passage of harvesters into the soil as well as the wear rate of the harvester shares. Therefore, the development of a yam-harvesting machine must essentially proceed from the local conditions in the area of production (Kaul and Egbo, 1985). The objective of this study was to determine the soil properties relevant to the design of potential tractor - mounted yam harvesting machines in the Benue flood plain of Nigeria.

Materials and Methods

The yam cultivars *Anacha* and *Gbangu* of D.rotundata species commonly grown in the study area were used in this study. Soil samples were collected from mounds on farms in Apir, Nigeria. Apir is located at latitude 6°30′- 8°15′. Soil properties investigated were porosity (bulk and particle densities), particle and clod size, moisture content and strength (shearing and penetration resistance). Yam tuber size, tuber growth pattern, mound size, mound density and inter-mound spacing were also investigated. The mean of the samples analysed was taken as the value for the soil properties and the parameters investigated.

Soils were sampled from yam mounds at harvest from four plots on a farm. Samples were taken with an auger from a depth of 50cm from five mounds per plot in W-shaped position across the plots. The samples were bulked in order to obtain representative samples because of the high degree of spatial variability of soils. The samples were then put into polythene bags, labelled and taken to the laboratory for analysis. In each of the plots, undisturbed core samples were air-dried for 24 hours, crushed in a mortar and sieved to remove materials greater than 2mm (gravel) and analysed for moisture content, particle density and size.

Bulk density was determined as described by Blake and Hartge (1986a) and the particle density determined by the pycnometer method as described by Blake and Hartge (1986b) and Agbenin (1995). Total porosity was determined as described by Danielson and Sutherland (1986). Particle size distribution was determined by the hydrometer method as described by Gee and Bauder (1986). The clod size distribution was determined as described by Campbell (1982). The moisture content of the soil was determined as described by Agbenin (1995). Soil shear strength and angle of shearing resistance was determined using a direct box apparatus as described by Otukoya (1971). The maximum shear stress versus maximum normal stress graph for the samples were plotted and the method of least square was used to fit straight lines for the shear strength (**Fig. 1**). The penetration resistance of the soil was determined from a cone penetrometer. The maximum length and diameter of forty tubers of the two cultivars were measured using venier calipers, measuring tape and weighing on a scale. Measurements of the height and basal diameter of 15 mounds from three farms were taken using measuring tape and pegs. Inter–mound spacing of 30 mounds each from three selected farms was determined by measuring the centre-to-centre distance of two adjacent mounds using measuring tape and pegs. The intra-mound spacing of 30 mounds was determined by measuring the ground distance between one mound to the other.

Result and Discussion

Table 1 is a summary of the measured parameters for crop and mound. The cv. *Anacha* has a

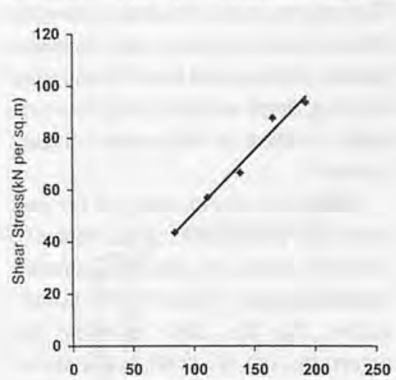

Fig. 1 Maximum shear stress and maximum normal stress for soil..

Table 1. Summary of Measured Parameters for Crop and Mound

Parameter	Item
Species	D.rotundata
Cultivars	*Gbangu* and *Anacha*
Yam tuber size	
cv.Anacha	
length	39.5cm
diameter	18.2cm
weight	2.6kg
cv.Gbangu	
length	33.2cm
diameter	14.4cm
weight	3.4kg
Mound size	
height	46cm
basal diameter	97cm
Inter-mound spacing	99cm
Intra-mound spacing	96cm

Table 2. Summary of Soil Physical Properties

Soil property	Item
Particle size (%)	
sand	54.7
silt	27.7
clay	17.7
Texture	sandy loam
Porosity (%)	42.5
Bulk density (g/cm^3)	1.5
Particle density (g/cm^3)	2.6
Moisture content (%)	5.8
Clod size (weight/number)	
30-45mm	2.5/63
45-55mm	1.7/18
55-75mm	2.0/9.5
Angle of shearing resistance	25.6°
Penetration resistance (kN)	3.01(0.92MPa)
Cohesion (kN/m^2)	2.75

length of 39.5cm, diameter of 18.2cm and weight of 2.6kg. The cv. *Gbangu* has a length of 33.2cm, diameter of 14.4cm and weight of 3.4kg. The tubers developed vertically inside the mound from the top to the bottom without branching. A cross-section of the mound showed that the tubers were contained in a roughly cylindrical area with most of the tubers at the centre. **Fig. 2** is the diagram of mounds showing yam tuber growth pattern. The growth pattern for cv. *Anacha* was such that its head was 5.8cm from the top of the mound leaving a vertical distance of 7.0cm between the tuber and the ground level. The cv. *Gbangu* had its head 5.2cm from the top of the mound leaving a vertical distance of 7.4cm between the tuber and the ground level. The tuber growth pattern enables the design of gauge wheels for harvesters. The tuber growth pattern for the two cultivars indicate that harvester shares be designed to cut the mound at the ground level in order to minimise bruises to the tubers during harvest.

Table 2 is a summary of the soil physical properties. Bulk density, porosity, moisture content, penetration resistance and textural classification of the soil enables the determination of draft requirement and drawbar pull of harvesters. The soil was 54.6% sand, 27.7% silt and 17.7% clay. The textural classification of the soil ranged from sandy loam to sandy clay loam. Soil properties dictate the nature of soil reactions (Culpin, 1981). The particle size assists in determining or deciding on the type of tillage tool for harvesters with respect to wear property and scouring ability. It is pertinent in the design of the cutting (rake) angle of harvester shares. The drawbar pull for harvesters working this soil is expected to be medium because the soil is largely light and will offer low resistance (Johnson, 1979).

The bulk density of the soil was 1.5 g/cm^3 and a porosity of 42.5% similar to values reported by Michael (1978) and Johnson (1979) for sandy loam soils. The bulk density is an indicator of the degree of compaction of the soil. According to Johnson (1979) drawbar pull is medium for soils with bulk densities of 1.2 to 1.8g/cm^3 and porosity of 30 to 55%. The low bulk density indicates a less compact soil, hence the drawbar pull for harvesters will be medium.

The clod size number for 30-45mm, 45-55mm and 55-75mm was 65, 18 and 9.5, respectively. The occurrence of clods may be associated with the clay and silt content, a useful prediction of likely clod problem at harvest. However, a clod problem is likely to be slight in the field because clods are an important problem in heavier soils but not on light soils (Campbell, 1982). Clod size has a direct bearing on the separation problem at harvest since harvesting root crops involve separation of the tubers from the clods. The clod size is relevant to the design of harvester components capable of improving the separation of tubers from the soil. The maximum clod size range was 55-75mm. Therefore, harvester components for clod separation will have to be spaced at not more than 55mm apart.

The low moisture content of 5.8% makes the soil hard and cohesive with a high degree of consistency. The soil is expected to be hard for the penetration of most tillage tools especially since the clay content (17.7%) is fairly high (Kaul and Egbo, 1985). This means high draft requirement for harvesters. This will also cause a greater wear rate on harvester shares and will be relevant in the design of the cutting (rake) angle of harvester shares.

The shear strength of soils depends on the internal friction of the soil and is proportional to the mutual cohesion of its particles at a given state of the soil (Bosoi et al., 1988). The soil angle of shearing resistance was 25.6° and a cohesion of 2.75 kN/m^2. The shear value or coefficient of internal resistance of soils is generally accepted as a ma-

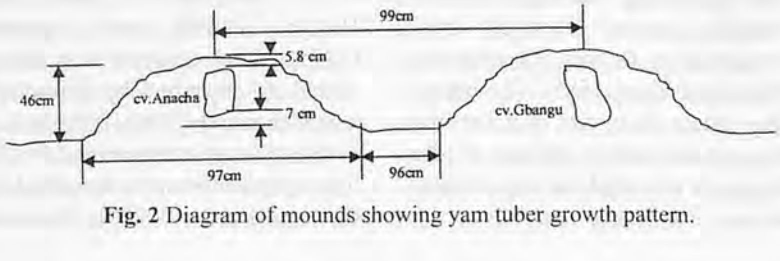

Fig. 2 Diagram of mounds showing yam tuber growth pattern.

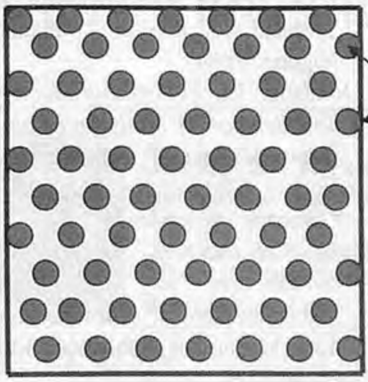

Fig. 3 Field layout of a typical yam farm.

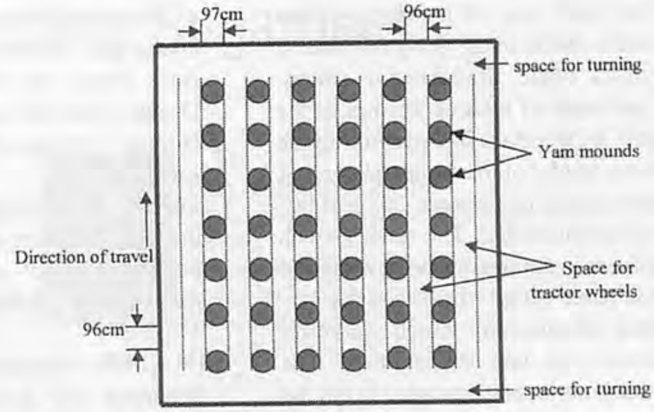

Fig. 4 Recommended field layout for the mechanisation of yam

jor dynamic property in soil-machine interactions (Singh, 1989). The angle of shearing resistance compares closely with the value 25°30′ - 35° reported for sandy loam soils by Bosoi *et al.* (1988) but was less than the 3.5kN/m^2 for light loose sandy loam soils and 12.5kN/m^2 for hard clay soils as reported by Berhane (1973). Also, the cohesion of this soil did not agree with the values of 6.9 kN/m^2 – 52.7 kN/m^2 usually obtained for more than 90% of agricultural soils (Onwuji, 1983). This may have been because the soils were sampled on mounds. The angle of internal friction of the soil is relevant to the design of nose angle of harvester shares. The nose angle of harvester shares is expected to be greater than the angle of internal friction of the soil but not more than 90° (Bosoi, 1988). Therefore, the nose angle of harvester shares for this area is recommended to range between 26° to 90°.

The mound size enables the determination of the width of harvester shares. Campbell (1982) recommended that shares be designed to cover the entire mound and maintain correct digging depth. The basal diameter of the mounds at harvest is 97cm. Therefore, the width of harvester shares should not be less than 97cm. Planting of yams on mounds is by far the most common practice in traditional agriculture, and in the West Africa yam zone is almost universal (Coursey, 1969). As evident, the difficulties in engineering the mechanisation of yam harvesting are unique. Effective mechanisation of yam harvesting will rely on yam cultivars, which are amenable to mechanisation as well as the alteration of prevailing cultural practices and preferences. Adaptation of existing root, tuber harvesters will not suffice for yam harvesting. A special harvester must be designed to take into consideration the unique characteristics of the crop.

Fig. 3 is the field layout of a typical yam farm, which has no provision for mechanisation. In this layout, a tractor or farm machinery cannot go through the farm without destroying the mounds and the tubers because of the way the mounds were cultivated. According to Odigboh and Ahmed (1989) this layout appears to be the major constraint affecting the mechanisation of yam production. At harvest, the mounds have a basal diameter of 97cm and a height of 46cm with a spacing of about 99cm from the centre of one mound to the other and a ground spacing of about 96cm from the base one mound to the other. The mound density was 5,706 per hectare. The thickness of a tractor rear wheel is 44cm and the distance between the wheels is 138 cm. These specifications showed that if the mounds are cultivated in rows (**Fig. 4**), the tractor propelling the harvester can pass through the yam farm with a mound to be harvested between its wheels (**Fig. 5**). The advantage of this layout is that the mounds are not destroyed and the cultural practice of growing yams on mounds is not altered.

Conclusion

The soil of the Benue flood plains, Nigeria is light and not compact requiring medium draft and drawbar pull for potential yam harvesters. The problem of separation of tubers from the soil is expected to be slight. The low moisture content of the soil at harvest will affect

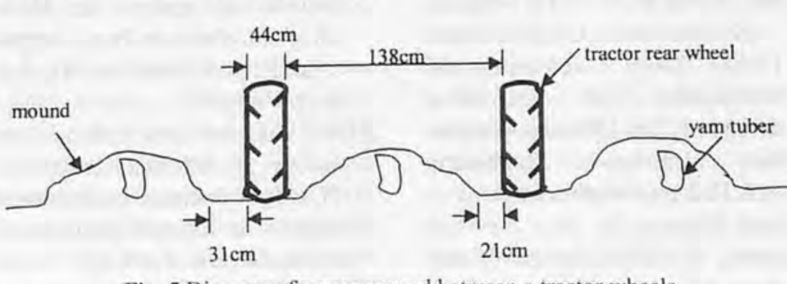

Fig. 5 Diagram of a yam mound between a tractor wheels.

the wear rate of harvester shares and is useful in the design of cutting (rake) angle of harvester shares. The angle of internal friction of the soil is important in determining the nose angle of harvester shares. A nose angle of between 26° and 90° is recommended. The tuber growth pattern is applicable in the design of harvester gauge wheels and the vertical distance at which harvester shares cut into the mounds. The harvester is recommended to cut the mounds at the ground level. The basal diameter of the mound is relevant to the design of the width of harvester shares. A share width of not less than 97cm is recommended. It is also recommended that to enhance the mechanisation of yam, the mounds be cultivated in rows to enable the passage of tractor propelled harvesters through the farms.

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Stable Lifters for Harvesting Sugarbeet

by

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Abstract

Lifters constitute an important functional unit of the sugarbeet digger. A study was conducted to observe the effect on lifting and conveying efficiencies of different types of stable lifters used in tractor-operated sugarbeet digger in sandy loam soil. Results indicated that a fork lifter performed better than a share lifter with positive angle of incidence followed by share lifter with negative angle of incidence.

Introduction

Sugarbeet (*Beta vulgaris L.*) plant is one of the most efficient converter of solar energy into stored energy. It provides more than 45% of world sugar requirement and is grown in 45 countries of the world (Singh, 1999). It is mainly grown in Northern parts of India.

This rabi crop is sown in September-October and harvested in April and May. Harvesting of sugarbeet in Northern India coincides with that of wheat harvesting and other parallel crops. Traditionally sugarbeet is harvested with the use of manual spade, which requires about 325 man hours per hectare (Thakur et al., 1980).

Due to harvesting of parallel crops there is scarcity of labour, which reduces the rate of harvesting. These results in storage of harvested crop for a longer period at higher temperature rendering the beets unfit for processing. It also interrupts the regular supply of sugarbeet to sugar mills. The cost of harvesting by manual method is about 13 per cent of the value of the crop with overall harvesting losses of 4 to 5 per cent. (Thakur et al., 1980).

Tillers and, some times furrower, are also used for digging the beets. In both cases the per cent damage is high and recovery is poor. In addition to this the furrower leaves the ground undulated which needs a separate operation for land leveling. A number of sugarbeet diggers are in use in developed countries but their suitability is still questioned in India because of costs, field conditions, adaptability etc. This emphasizes the need to study a suitable technology for mechanized harvesting of sugarbeet.

Sugarbeet harvesting mainly includes topping, lifting and gathering of roots from the soil. Lifters constitute an important functional unit of the sugarbeet digger. It is that part of the machine which first enters into the soil, looses it, lifts and cleans the dug roots with minimum damage. The stable lifters have advantage over vibrating lifters considering their suitability for light and medium soils, design, cost etc. (Kanafojski and Karwowski, 1976). Keeping this in view a study was undertaken to observe the effect of different types of stable lifters on harvesting of sugarbeet.

Machine Considerations

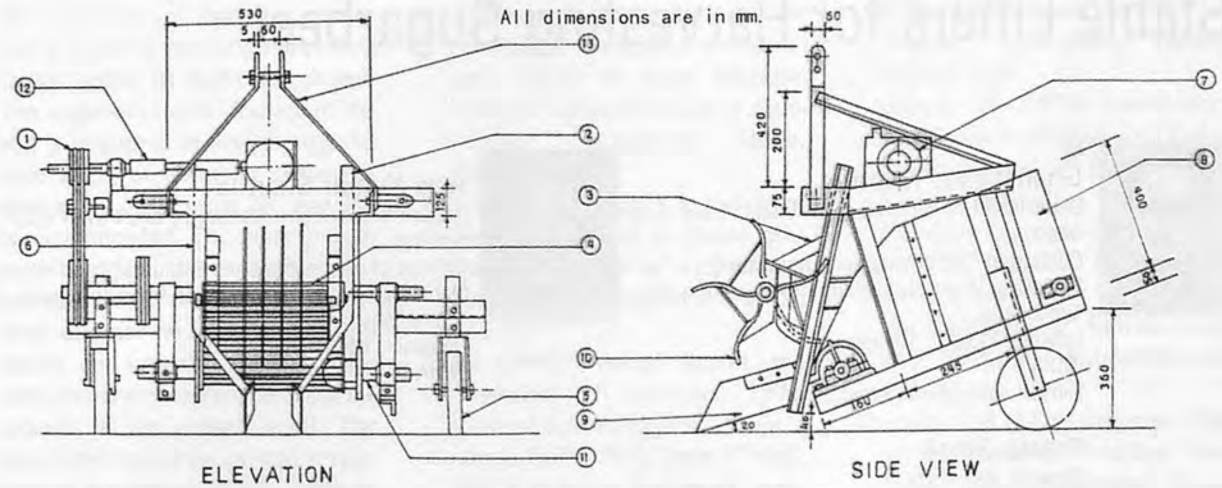
The main components of sugarbeet digger are the lifter, thrower, cleaning and separating unit, and transmission system (**Fig 1**).

Lifters

The function of lifter is not only to lift the roots but also to clean them from soil. Stable lifters include fork lifters, share lifters with positive or negative angle of incidence (**Fig. 2**). The various parameters of the lifters considered in the study are presented in **Table 1**.

Throwers

The task of the thrower is to prevent lifted roots from falling on the ground and conveying them to the cleaning and separating unit. Three throwers with 20 equally spaced spikes were used to throw beets on the conveyor (**Fig. 1**). As thrower



S.N.	Name of the parts	Material	Size	Qty.
1	Transmission		Single belt 10 ϕ 15 ϕ Double belt 20 ϕ 10 ϕ	2 1 2 1
2	Share arm	M.S.channel	40 × 30	2
3	Thrower arm	M.S.angle	40 × 40 × 4.5	2
4	Conveyor chain	M.S.rod	10 ϕ	2
5	Ground wheel	M.S.	250 ϕ	2
6	Main frame	M.S.angle	50 × 50 × 5	1
7	Gear box	Standard	Standard	1
8	Side wall	M.S.sheet	18 gauge	2
9	Share	M.S.flat	6mm thick	2
10	Thrower	M.S.rod	10.0	4
11	Front shaft	M.S.	30 ϕ	1
12	Gear box shaft	M.S.	30 ϕ	1
13	Three point hitch	M.S.flat	50 × 10	1

Fig. 1 Tractor-operated sugarbeet digger.

Table 1. Different Parameters of Lifters Used in Study

Particulars	Symbol	Type of lifter: Fork	Share lifter with positive angle of incidence	Share lifter with negative angle of incidence
Angle of opening of shares in vertical plane (A-A)	α	-	60°	60°
Angle of opening of pins of shares	β	30°	30°	30°
Lifters inclination to the surface	γ	20°	20°	20°
Angle of incidence	δ	-	65°	40°
Openings of the pins of lifters at the inlet	c	160mm	160mm	160mm
Length of the pins	L	440mm	400mm	480mm

speed should be five times of forward travel speed of 3 km/h (Kanafojski and Karwowski, 1976) the rotational speed of thrower was kept at 202 rpm.

Cleaning and Separating Unit

This is the unit of digger which separates the soil and leaf remnants from the roots. A single rod endless chain of 500-mm width at an angle of 30° with the horizontal was used as elevator (**Fig.1**). The pitch between the rods was 60mm taking into account the minimum size of the roots. The linear speed of elevator was kept at 1.2 times of the forward speed of travel (Kanafojski and Karwowski, 1976).

Power Transmission

A gearbox, set of V groove pulleys and sprockets were used to obtain the desired operational speeds of the different units from tractor PTO (Fig. 3).

Transporting Wheels

Two transport wheels of 250mm diameter were provided for sup-

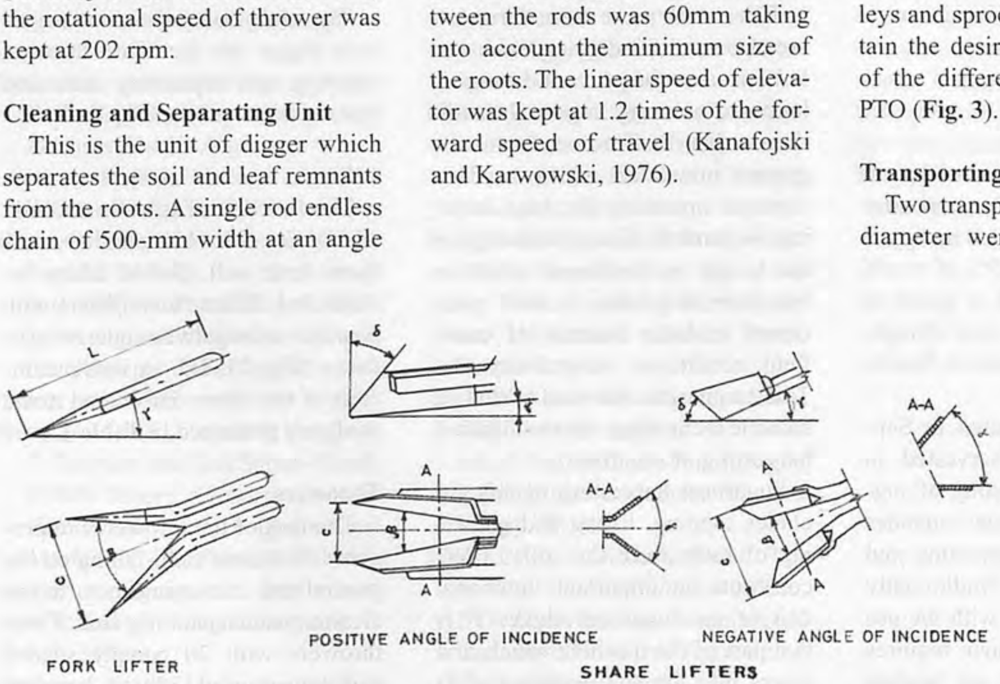


Fig. 2 Stable lifters used in the study.

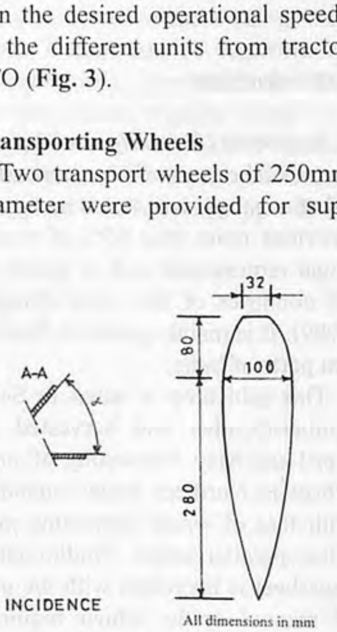


Fig. 4 Wooden model of sugarbeet.

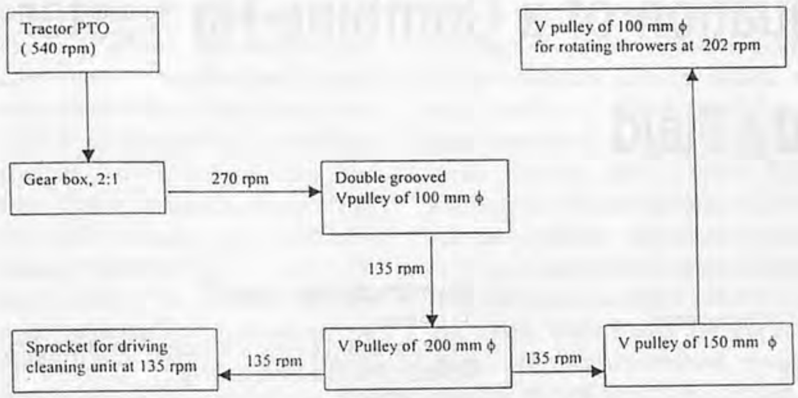


Fig. 3 Schematic diagram of power transmission.

Fig. 5 Sugarbeet models in field.

porting and transporting the digger during operation (**Fig. 1**). The angle of inclination of conveyor was also adjusted with these wheels.

Experimental Techniques

Due to non-availability of the crop, wooden models representing the average dimensions and weight of the actual good-topped crop (**Fig. 4**) of the sugarbeet were used in the experiments. These models were placed in the ridge (500mm wide and 250mm high) at a distance of 250mm (**Fig. 5**) in sandy loam soil at 9-11% moisture content (w.b.). These sugarbeet models were dug using different types of lifters at working depth of 350mm and forward speed of 3km/h (Thakur et al., 1980) using a 35 hp tractor. Replicated trials were conducted and the number of beets dug and conveyed by the conveyor were collected and counted manually for calculating the lifting and conveying efficiencies of the machine as follow:

$$\eta_d = \frac{B_r - B_d}{B_r} \times 100 \qquad \ldots (1)$$

$$\eta_c = \frac{B_d - B_c}{B_d} \times 100 \qquad \ldots (2)$$

where

η_d = lifting efficiency, %;

η_c = conveying efficiency, %;

B_r = number of beets in the ridge;

B_d = number of beets dug out; and

B_c = number of beets conveyed.

Results and Discussion

The performance of various lifters is shown in Fig.6. The fork type lifter gave the maximum lifting efficiency (91%) followed by the share lifter with positive angle of incidence (84.4%) and share lifter with negative angle of incidence (77.7%). This may be due to broad profile of the furrow in its upper part in comparison with the shares of positive and negative angle of incidence, thereby lifting the whole soil patches of soil together with roots resulting in higher lifting efficiencies with fork type lifters. The shares with positive angle of incidence, more intensively pile and crush soil in front of them than those with negative angle of incidence and cut the soil in which the root is situated resulting in higher lifting efficiency than the share with negative angle of incidence.

A similar trend was observed for conveying efficiency also. This may be attributed to the amount of soil mass moving with the roots dug by the stable lifters. The high momentum gained by the soil–root mass with the same forward speed because of greater mass may result in pushing the dug material directly on conveyor chain thus avoiding the side dropping of roots resulting in higher conveying efficiencies. Similar findings have been also reported by other researchers that the shape of the digging tool effects the digging of root crops (Srivastava and Yadav, 1979, Vatsa et al., 1993).

(Continued on page 44)

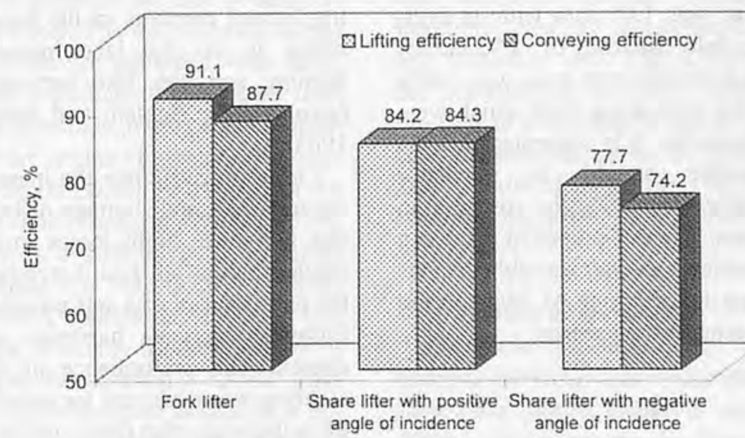


Fig. 6 Comparative performance of lifters.

Performance Evaluation of a Combine Harvester in Malaysian Paddy Field

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Abstract

A study was carried out to investigate the performance and grain losses of a combine harvester in the course of mechanization of rice harvesting to overcome the increasing high cost and shortage of labor and to reduce grain losses. A New Holland (Clayson 1545) European self-propelled conventional all-crop combine harvester was used in a commercial farm where MR211 rice variety was being grown. The average field capacity of the machine was 1.05 ha/h with an average field efficiency of 72%, and the machine loss over grain was 1.68% of the total grain yield which were reasonable. It is suggested that the machine should be regularly checked to reduce the costly grain losses. The self-propelled European combine harvester was able to overcome the shortage of labor during peak harvesting season.

Introduction

Rice is a main crop in Malaysia where it is grown in 1/7 of the total cropped area (Anon, 2000) and up to 40% of total labor is employed in the harvesting and threshing operations (Carruthers, 1985). Recently, rice harvesting became a problem due to shortage of labor and, consequently, the increase of wages in the country. With the advent of industrialization, there has been a migration of labor from the agriculture sector to the industrial sector leaving limited numbers in the former sector to do the labor-intensive farming activities like harvesting (Ayob, 1979; Hussain and Ismail, 1983).

I order to overcome the increasing high cost and shortage of labor and to reduce grain losses in the mechanization of rice harvesting, the performance of a self-propelled European combine harvester was chosen. The performance of this combine was evaluated for suitability in the Malaysian field conditions where tests were conducted in three paddy plots. At the same time, the grain loss was evaluated. The specific objective was to determine the field capacity, field efficiency and grain losses of a combine harvester.

Review of Literature

Field Performance

The rate of work of a combine depends on the size, rate of travel and yield of grain. The capacity of a small grain and soybean combine of 4.2 m cutter bar is 15-20 ha day^{-1}. For the soft soil, it reduces to 10 ha day^{-1} (or 1.2 ha h^{-1}) for the same combine where per day working hours is 8 h (Smith and Wilkes, 1976). Field performance estimates for many machines utilized on U.S. farms are summarized in the ASAE Agricultural Engineers Yearbook (ASAE, 1997). Hassan and Larson (1978) reported the combine capacitive performance data gathered in time studies of sorghum harvesting. They recorded the activities using time study board and stop watches on: harvesting, turning, emptying tank, travel to and from trailer, cleaning, minor maintenance and adjustment of machine and operator personal time. These data were used to compute effective field capacities and field efficiencies. The time studies revealed average effective field capacity and field efficiency were 1.42 ha h^{-1} and 72%, respectively. The average forward speed and machine width were 4.04 km h^{-1} and 5.69 m, respectively. Foud et al. (1990) studied the performance of a self-propelled German harvester on rice harvesting in Egypt. The specifications of rice harvesting Deutz-Fahr (M 980) combine harvester with 54 kW diesel engine were 3 m of cutting width, 1030 mm wide and 560 mm diameter of peg type drum and operated at 800 rpm. The drum-concave clearance was adjusted to 15 mm in front and 7 mm in the rear according to the instructions. They found the grain loss was 178-380 kg ha^{-1} for Ryhe variety rice where grain losses increased with increasing forward speed (0.8-2.9 km h^{-1}). The field efficiency increased from 54 to 82% with a reduced forward speed from 2.9 to 0.8 km h^{-1} where time losses were counted for turning, grain unloading and removal of straw clogging for the same variety of rice in the field soil moisture content of 30-32.7% during harvesting.

Sources of Grain Losses

The sources of total grain losses on the combine harvester are: preharvest losses, header losses, threshing losses, straw walker losses and shoe losses (Culpin, 1986; Smith and Wilkes, 1976). To reduce grain losses, the operator must know the source of losses and how to measure losses. If the grain losses are not acceptable, the operator must reduce them by adjusting the components, which are causing the costly losses. The losses from improperly adjusted combines can be quite significant. It was reported that in 1985, wheat farmers in Oklahoma lost $37 million in grain due to combine cleaner losses, a large portion of which could have been prevented by proper adjustments (Downs et al., 1985). Researchers at Oklahoma State visited various combine operations in the field and checked the grain losses from different machines (Downs et al., 1985). They found that the average for machine-related losses was 5% of total yield. Most experts agree that the correct adjustment and operation should give losses between 1 and 3% of the total yield (FMO, 1987).

In spite of the potentially large economic rewards, it has been estimated that only 10% of the combine operators regularly check the adjustment of their machine (Newton et al., 1986). Reasons for this neglect are the time required, the difficulty of performing the task, and in some cases, a basic lack of knowledge about how to perform the task. It is much easier to understand this neglect after one has spent several successive 14 h workdays in a combine cab. Typical of the many attempts to solve the problems are: ground speed controls, cleaning fan speed controls, and threshing cylinder speed controls.

Rice Combine Harvester

The main difference in regular grain combine and rice combine is the wheel. The main wheels of rice combine are equipped with large, deep, mud lugs to give better traction in muddy, poorly drained field. So, the engine of greater horsepower (hp) is chosen to travel over the rice field (Smith and Wilkes, 1976). Rice is a difficult grain to thresh because it is hard to strip from the straw. A spike-tooth threshing cylinder is usually used because of its aggressive threshing action. Rice should be threshed as soon as it ripens to avoid crackage by the sun if allowed to stand in the field too long. Rice may often be down or lodged following storms which makes harvesting more difficult. For rice harvesting, the cylinder speed varies from 700 to 1050 rpm. The concave spacing is about 0.15 cm. The chaffer and sieve openings are 1.58 – 1.90 cm and 0.63 – 0.95 cm, respectively.

Materials and Methods

In this study, the performance of the company's rented combine harvester on paddy harvesting was observed.

Test Site and Test Plots

The field performance of the combine harvester was conducted at plots A3, A4 and A5 under Block A in the study field which was owned by Sulam Sumber Sdn. Bhd. The field was located at the southern part of Peninsular Malaysia. The study was conducted during the harvesting of paddy (variety MR211) on the second week of July 2000. Almost similar plots were selected for the determination of the field capacity of the machine.

Rice Combine Harvester

The used rice combine harvester was a self-propelled machine (New Holland CLASON 1545) consisting of eight major units: prime mover, undercarriage, transmission and steering, reaping, feeding, threshing, cleaning and separating and unloading unit. **Fig. 1** shows the rice combine harvester used in the studied plots. **Fig. 2** shows the rice combine harvester in operation. Details of major units of the combine harvester are referred to Roy (2001).

Performance Evaluation

The field performance of the combine harvester was evaluated in three plots (approximately 330m × 70m) by measuring the field capacity, field efficiency and machine

Fig. 1 Combine harvester used in harvesting.

Fig. 2 Combine harvester operation in studied plot.

operation (grain) losses.

Field Capacities and Efficiency

The headland pattern (Hunt, 1995) from boundaries in the center of field operation was used throughout the test. This pattern was followed by the operator due to difficulty of turning at the headland and the cutting width of 4.20m. It was easy for the operator to drive and control the big machine in 330m×70m plots. In straight operation, the operator tried to keep the machine in straight forward with constant ground speed to avoid the complicated movement for the next harvest line. During the test, total time, turning time at each round during raising of header, unloading time, time for rearrange of rice in tank, time for maintenance, refueling, and other idle times were recorded. In the measurement of the combine's forward speed, time was recorded for 55m distance, which was the distance between two successive red-marked poles on the roadside. In the lengthwise, there were red-marked poles every 55m distance in the both sides of each plot. The actual width of cut was recorded at five places of the every plot. During the harvest operation, the failure elements were also observed.

The effective field capacity was determined from measuring all the time elements involved while harvesting. The total time was categorized into productive and non-productive categories. The productive time is the actual time used for harvesting the grains. The non-productive time consisted of the turning time, repair and adjustment time and other time losses (idle times), i.e. the header was raised from the ground and not in cutting-operation on paddy. The area covered divided by the total time is the effective field capacity (EFC):

$$EFC = A/T \text{ .... [1]}$$

$$T = T_t + T_{rm} + T_{turn} + T_{uld} + T_{rful} + T_o \text{ .... [2]}$$

where, A = actual harvested area, ha; T = total harvesting time, sec; T_t = net harvesting time, sec; T_{rm} = time loss for repairs, sec; T_{turn} = time loss for turning, sec; T_{uld} = time loss for unloading grain, sec; T_{rful} = time loss for refueling, sec; T_o = time loss for other activities, sec.

The theoretical field capacity (TFC) is the rate of harvesting that would be obtained if the machine were performing its function 100% of the time at rated forward speed and always covered 100% of its cutting width (Anon, 1983; Bainer et al., 1987). So, TFC (ha h^{-1}) is:

$$TFC = A/T_t = (s \times w)/10 \text{ .... [3]}$$

where, s = rated forward speed, km h^{-1}; w = cutting width, m

The field efficiency (FE) was determined by the ratio of productive time to the total time.

$$FE = EFC/TFC = T_t/T \text{ .... [4]}$$

Machine Operation Losses

The total grain losses are the sum of preharvest losses, header/cutter bar losses, threshing/cylinder losses, and separator/shoe losses. The machine operation loss refers to the summation of header/cutterbar loss, threshing/cylinder loss and shoe/separator loss (FMO, 1987; Hunt, 1995). **Fig. 3** shows the sampling points around the combine harvester. The methods determining the various losses are shown below:

Pre-harvest Loss

Preharvest losses were measured by placing a square frame (1m×1m) in the unharvest area. All the grains lying on the ground were collected within the frame which used to remain below the cutter bar in operation. Usually, the preharvest loss is considered when the grain is on the ground as a result of wind shatter, lodging, down crop or weather conditions (FMO, 1987). A few grains were found within the square frame in the field. Three random sampling were done and the mean value of the numbers of the threshed grains found. The average grain loss per hectare was calculated using the Preharvest and Header Loss rate provided by FMO (1987).

Cutterbar Loss

The cutterbar loss is caused by faulty adjustment and operation of the cutting platform (FMO, 1987). In order to determine the cutter bar/header losses, the frame (1m×1m) was placed on the ground in front of the combine within the harvested

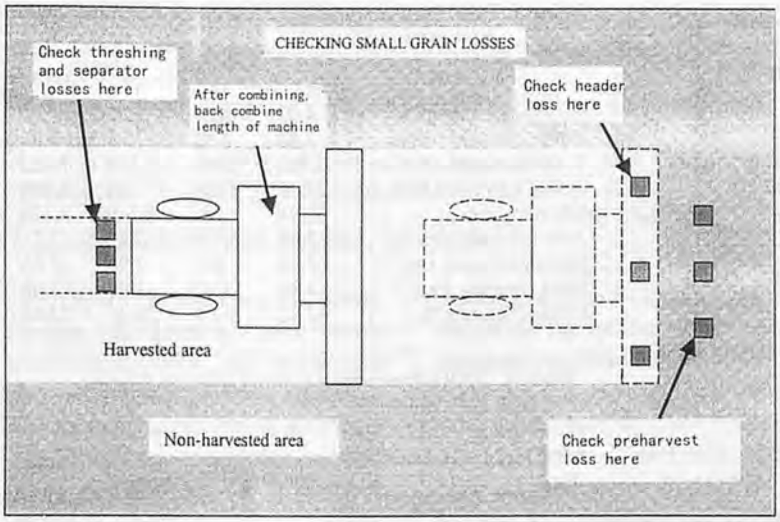

Fig. 3 Checking rice grain losses in paddy field (source: FMO, 1987).

area after backing the length of the machine. Grains found inside the frame were collected and counted. Similarly, grains were also collected from other two places of the studied plot. Grains found from three places were averaged and the preharvest loss checked was subtracted. The loss in kg ha^{-1} was determined using the Preharvest and Header Loss rate provided FMO (1987).

Threshing Loss

The threshing loss is caused by unthreshed grain carried over straw walkers. In the determination of threshing loss, straws containing attached unthreshed grain were collected using the frame (1m×1m) placed at three places directly behind the separator or machine discharge. All straws were arranged together and tightened with labeled plastic bag. In the field office, all bundles were opened and exposed to sun for drying. Then the grains were removed by beating action using a stick. The Machine Loss Chart provided by FMO (1987) for rice was later used to determine the loss per hectare.

Separating Loss

The separating loss is caused by too much material over walker, too much air from fan, too much material over the chaffer and improperly adjusted chaffer and sieve (FMO, 1987). In the determination of separator or shoe losses, the square frame (1m×1m) was placed on the ground directly behind the separator or machine discharge. A sickle was used to cut the straws and plant stubbles found inside the square bar which was removed. The threshed grains lying on the ground were then collected later. Similarly, three samples were collected randomly and were averaged. Grains found in the header-loss and preharvest-loss was then subtracted from the averaged collected grains. The remaining value was given as the number of grain-loss over the separator or shoe. The loss per hectare was calculated using the Machine Loss Chart provided by FMO (1987).

Calibration of Seed Counting

The seed samples for every loss were weighed in the field office since the numbers of seeds were difficult to count in every loss. A seed calibration was done to convert the weight of every sample to the number counting seeds. For seed calibration, four harvested seed samples were transported back to the University campus in Serdang. A 2 mm-sieve was used to remove small particles from these seed samples and air-blast from winnowing machine was then used to remove light materials. The cleaned seeds were then counted by seed-counting machine. The brand of the seed counting machine was Numigral II (tripette and renand from France; 35 kW, 59/60 Hz). From these four samples, a seed calibration chart was prepared (**Fig. 4**) and the weight of every loss (found in field) was converted into number of seeds. Calibration data for seed counting are referred to Roy (2001).

Materials Other than Grain (MOG) Determination

The presence of MOG was determined from the seeds harvested by combine harvester. The seed sample was represented as one from the combine grain-tank. The presence of MOG was due to improper adjustment of sieve-openings and the fan-speed (ASAE, 1997). The sample was sieved to remove small particles lesser than 2mm by sieve and winnowed to remove light materials. The MOG (sieved and winnowed) and clean grain items were then weighed separately to calculate clean grain and MOG in percentage.

Result and Discussion

The information regarding the used combine harvester in the field was collected during field performance done in plots A3, A4 and A5.

Advantages and Disadvantages of Used Combine Harvester

In conversation with the managing director of the company and the machine operator, the advantages and disadvantages of combine in the field were understood. The reasons behind the utilization of com-

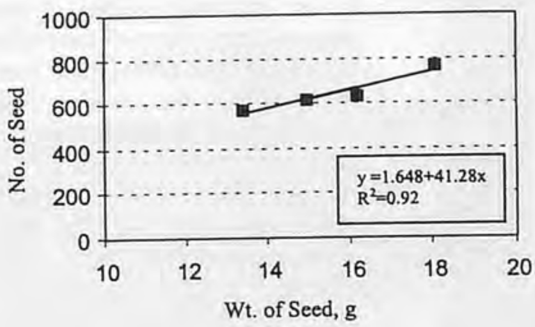

Fig. 4 Seed calibration chart.

Table 1. Field Performance Test of the Rice Combine Harvester in Plots

Parameters	Field No. A3	A4	A5	Average
Average speed, km h^{-1}	4.01	4.04	3.98	4.06
Width of cutter bar, m	3.86	3.91	3.88	3.92
Total harvested time, sec	8,860	6,168	8,273	7,755
Actual harvested time, sec	5,566	4,674	6,524	5,588
Idle time, sec	3294	1,494	1,749	2,179
Area harvested, ha	2.09	2.10	2.43	2.21
Estimated yield, t ha^{-1}	2.54	2.53	2.98	2.68
Field capacity, ha h^{-1}	0.86	1.23	1.06	1.05
Field efficiency, %	62.82	75.78	78.86	72.48

Table 3. MOG Presence in Sample Harvested Grain

Item	Weight, g	Percent	MOG to grain ratio
Clean grain	120.57	94.40	0.06
MOG	7.15	5.60	-
Total	127.73	100.00	-

bine harvester were: shortage of agricultural labor, high wage of labor, high machine capacity, lower grain losses as compared with manual harvesting, cheap in harvest with machine as compared to manual harvest, and convenient in use for large farm and time saving.

On the other hand, the reasons behind the utilization of manual method instead of using the combine harvester were: small land holding size, high transportation cost of machine using truck, machine not suited to flooded field and lodged crop conditions, non-uniform maturity of the crop in the same area, lack of confidence in the machine's performance, non-availability of the machine, and lack of grain drying facilities (area etc.) to handle large quantities of harvested grain by the machine in a very short period. Ayob (1979), and Hussain and Ismail (1983) also reported the same advantages and disadvantages of using combine harvester in other parts of Malaysia.

Breakdowns Occurred during Operation

The following problems were observed during the field operation of the rice combine harvester.

i) Cutting system. The cutterbar or saw-blade was damaged due to frequent cutting of the paddy plants and sometimes rubbed over stones, hard plant stubbles or some other hard substances. The blade was replaced by a new set after harvesting about 15 ha. One set of blade can be used for two successive seasons.

ii) Transmission system. The gearbox was jammed during harvesting which interrupted the harvesting operation. It took a couple of days repairing the gearbox.

Besides the breakdowns of the machine, there was another problem observed during harvesting. The operator needed to level the grain in the grain tank by himself. There was a time loss in operation or, it requires an extra labor. This problem could be overcome by modifying the outlet of the grain-elevator system for uniform distribution of grains over tank.

The annual average repair and maintenance cost for the harvester was RM40,000*. It needed to replace bearings, belts, saw-blade, etc for every two seasons (operator, pers. comm.). The recent value of the new New Holland CLASON 1545 (New Holland, 1996) is about RM140,000 in the local market though this type of machine is now obsolete.

Field Performance of the Used Combine Harvester

The performance of the combine machine depends on its size, rate of travel and yield of grain. The average speed and average effective width of cut of the machine were 4.06 km h^{-1} and 3.92 m, respectively. The average speed and average effective width of cut were determined from five distances (for 55 m) and five positions for each plot. The effective field capacity of the machine varied from 0.86 to 1.23 ha h^{-1} with an average of 1.05 ha h^{-1} as in **Table 1**. The field capacity for plot A3 was higher since the idle time (3,294 s) was high. The higher idle time was due to time taking for the arrangement of the unloading-lorry. During this idle time, the operator did help the lorry driver in arranging the tent over the lorry. During unloading of plots A4 and A5, the unloading lorries were pre-arranged. The other idle times were due to turning, travel to and from lorry, cleaning, minor adjustment and maintenance, grain arrangement on grain tank and operator personal time. The average field efficiency for three plots was 72.48%. However, the average field capacity and field efficiency of the combine were reasonable since many research reports indicated that the effective field capacity varied from 1.06 to 2.11 ha h^{-1} and field efficiency varied from 58.70% to 80.70% using time studies

* US$1 = RM3.80.

Table 2. Grain Losses on Combine Harvester

Items	No. of grains/ m^2						Avg./ m^2	Losses/ m^2	[Losses]	Losses	Remarks (grain loss)
	Sample 1		Sample 2		Sample 3						
	g	no.	g	no.	g	no.	no.	no.		kg ha^{-1}	
Pre-harvest loss, A1	1.56	66	2.06	87	1.69	71	75	75		11.71	31-33 grains/10 m^2= 50 kg ha^{-1}
Cutter bar loss, A2	2.95	123	4.75	198	4.15	173	165	90	[A2-A1]	14.06	31-33 grains/10 m^2= 50 kg ha^{-1}
Threshing loss, A3	13.85	573	8.78	364	9.49	393	444	444		46.25	48 grains/10 m^2= 50 kg ha^{-1}
Separator loss, A4	6.05	251	2.95	123	4.30	179	185	20	[A4-(A1+A2)]	2.08	48 grains/10 m^2= 50 kg ha^{-1}
							Total machine loss		(A2+A3+A4) =	62.39	

N.B. Cutting width = 4.20m; Separator width = 1.30m.

(ASAE, 1977; Foud et al., 1990; Hassan and Larson, 1978; Smith and Wilkes, 1976). In plot A4 and A5, some areas were not cultivated due to unevenness. It was also indicated that some areas were harvested as trial test-runs for 2 rounds in plots A3 and A4 before the day test-data recorded. However, the measured actual harvested areas were 2.09 ha, 2.10 ha and 2.43 ha in plots A3, A4 and A5, respectively. During harvesting, soil moisture content of the field varied from 39.07 to 49.14% (wet basis). The detail data regarding the time study of combine in plots A3, A4 and A5 are referred to Roy (2001).

Machine Operation Losses

The total grain losses in the field consisted of pre-harvest loss, cutterbar loss, threshing loss and separator loss. The machine operation losses are referred to only the summation of cutterbar loss, threshing loss and separator loss. After harvesting, three samples were collected randomly from the field for each loss determination. The pre-harvest loss, cutterbar loss, threshing loss and separator loss were 11.71 kg ha^{-1}, 14.06 kg ha^{-1}, 46.25 kg ha^{-1} and 2.08 kg ha^{-1}, respectively, as shown in **Table 2**. The total machine operation loss was 62.39 kg ha^{-1}. The loss due to threshing was high compared to other losses which might be due to low cylinder speed, too much clearance between cylinder and concaves, and crop too wet (Culpin, 1986; Hall, 1991). In reducing this loss, it is necessary to increase the cylinder speed, reduce the clearance and wait until the crop dries. On the other hand, adjusting the speed of cutter bar and height of the header could reduce the cutter-bar loss further.

According to the local market price at the rate of RM1.80 per kg of rice (Anon, 2000), the loss in monetary value was RM112.30 per ha. Anon (2000) reported the average paddy yield is 3.7 t ha^{-1} for wet paddy cultivation in Malaysia. Then, the average machine related loss is 1.68% of total yield. FMO (1987) reported that the adjusted and operated machine loss should be between 1 and 3% of total yield. So, the measured loss is within the acceptable range.

Presence of MOG in Machine Harvested Paddy

The materials other than grain (MOG) presence in harvested grain was determined using 2 mm-sieve and winnowing machine. It was 5.60% of the total grain weight as shown in **Table 3**. The value MOG of 5.60% i.e., MOG to grain ratio of 0.06 is reasonable since ASAE (1997) reported the acceptable range of MOG to grain ratio is up to 2.4 for rice where grain moisture varied from 15 to 28%. Most of MOG was without kernel whereas others were weed, plant residues and some other small particles. The empty grain might be higher due to variety of plant, availability of minerals in the soil or attack of pest.

Conclusion

The average effective field capacity and field efficiency of the used combine harvester in the field were 1.01 ha h^{-1} and 72%, respectively. In harvesting the paddy with this combine harvester, the average machine operation loss was 62.39 kg ha^{-1}. The machine field capacity, efficiency and machine operation losses were reasonable according to the range of values listed in the ASAE Agricultural Engineers Year Book.

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(*Continued from page 37*)

Stable Lifters for Harvesting Sugarbeet

Conclusions

1. Fork lifters have higher lifting and conveying efficiencies than share lifters.
2. Share lifters with positive angle of incidence performed better than the share lifters with negative angle of incidence.

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Post-harvest Practices of Turmeric in Orissa, India

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INDIA

Abstract

Turmeric is one of the important and ancient spices of India and a traditional item of export. Apart from its use in preparation of tasty curried dishes, it is also used widely in processed food, cotton textiles, medicines and cosmetics. Turmeric is the major cash crop of Kandhamal district, Orissa and it is grown through organic farming for which there is increasing demand in the country and abroad. The present study was undertaken to investigate the various post-harvest practices followed by the farmers so that the major area of research and development for the introduction of improved processing machineries and process technologies can be identified. Cooperative approach in turmeric processing and quality consciousness among the farmers during the post-harvest phase can boost the income of the farmers through export of quality turmeric.

Acknowledgement

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Introduction

Turmeric belongs to the plant group *Curcuma Longa Linn.* It is a commercial crop in the tropics. It is cultivated extensively in India, Sri Lanka, parts of China, Indonesia and Pakistan. India is the largest producer and exporter of turmeric with an annual production of 6.59 lakh tonnes. The main turmeric growing states are Andhra Pradesh, Maharashtra, Orissa, Tamilnadu, Karnataka and West Bengal. The state-wise area of cultivation, productivity and production of turmeric in India is shown in **Table 1**. Turmeric ranked fourth among the spices exported from India as the country earned a foreign exchange of over 75 crore rupees through the export of 24,900 tonnes of turmeric during 1997-98 (**Table 2**). There is considerable demand for good quality organic turmeric from U.S.A., Germany, U.K., Japan and Middle East countries.

The share of Orissa in the country was about 9% of turmeric production of 62.91 thousand tonnes from 26.5 thousand hectares in 1997-98. The Kandhamal district occupies a unique position in the State in turmeric production from organic farming with nearly 57% share both in terms of area and production.

The tribal group have since been are growing turmeric traditionally from ages in Kandhamal district. The entire district is a network of hills and forests and forms a broken plateau of about 518 meters above sea level. Turmeric thrives well in a well-drained sandy or clay loam soil, which is available in the uplands and slopes leading down from

Table 1. Area, Production and Yield of Turmeric, by State

State	A	P	Y
Arunachal Pradesh	0.4	0.4	-
Assam	9.6	6.7	-
Bihar	2.9	3.3	-
Gujrat	0.5	4.4	-
Karnataka	4.9	79.0	16,122
Kerala	3.7	5.6	-
Madhya Pradesh	0.7	0.7	-
Maharashtra	7.2	9.0	-
Meghalaya	1.4	1.8	-
Mizoram	0.2	1.7	-
Orissa	25.8	51.1	1,981
Rajasthan	0.2	0.7	-
Sikkim	0.4	0.1	-
Tamil Nadu	16.9	105.0	6,213
Tripura	1.5	2.9	-
Uttar Pradesh	1.1	1.8	-
West Bengal	11.6	21.8	1,879
Andhra Pradesh	58.0	363.4	6,266
All India	147.0	659.4	4,486

A: Area in thousand hectares
P: Production in thousand tonnes
Y: Yield per hectare in kgs
Source: Directorate of Economics and Statistics, Department of Agriculture and Co-operation, Ministry of Agriculture, Government of India.

Table 2. Export of Turmeric from India

Year	Quantity (Tonnes)	Value (Rs. Lakhs)
1991-92	19,661	3776.22
1992-93	19,726	4885.43
1993-94	25,436	5256.00
1994-95	28,286	4517.96
1995-96	27,376	4607.07
1996-97	21,600	5470.95
1997-98	24,900	7510.00

Source: Indian Food Industry, Jan. – Apr., 1997.

the foot of the hills of the district. The most important ingredient for turmeric cultivation is mulching materials which are abundant in forest tracts.

Methodology

A survey was conducted in the Raikia block of Kandhmal district to study the traditional harvest and post-harvest practices followed by the farmers. Large and small-scale processors were also contacted on the existing practices in processing. Information regarding the methods used for different unit operations and problems encountered are collected through questionnaire sheets to identify the area where post-harvest approach is needed.

Processing at Farm Level

Fig. 1 shows the sequence of processing turmeric at the farm level.

Harvesting

Depending upon the variety, turmeric becomes ready for harvest in 7-9 months after planting which extends from January to March. Withering of plants after maturity indicates the time of harvest. At first, the withered plants are cleaned from the field using sickles. Harvesting is done by manual digging using hand hoe (**Fig. 2**). The clumps are lifted and gathered by hand picking. All the adhering soil is shaken off from the rhizomes. The fingers (rhizomes) are separated from the mother rhizomes and spent ups (previous year seed, locally called *'Nali'*) are gathered in heaps near the processing yard (**Fig. 3**). The fibrous roots are cut off from the mother rhizomes by means of a knife (**Fig. 4**). These mother rhizomes are stored as seed materials. Sometimes the healthy primary fingers are also kept for seed purpose. The spent ups are cut longitudinally into halves or quarters, known as splits which are subsequently cured and dried (**Fig. 5**).

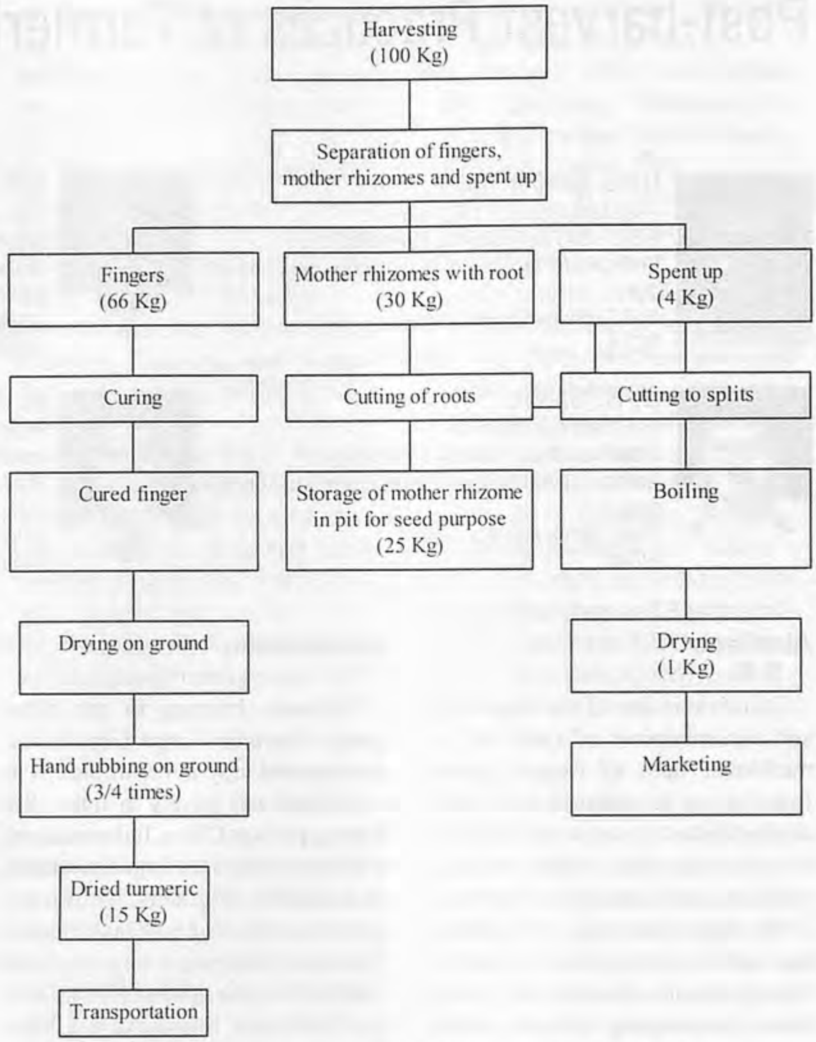

Fig. 1 Flow chart for processing of raw turmeric at farm level.

Curing

The boiling of rhizomes reduces the time of drying, ensures an even distribution of colour in the rhizomes and gives a better quality product by gelatinisation of the starch (Purseglove, 1981). The processing yard near the temporary shed is cleaned for carrying out the post-harvest operation. The oil tins (25cm×25cm×40cm) are generally used by the farmers of the area for curing of turmeric. A *chullah* is made having common burning chamber and 8 to 10 openings for boiling 8-10 tins in a batch at a time.

First, the fresh rhizomes are placed in the tins and submerged with water. The tins with lid/gunny cloth are placed on the live chullah for boiling of rhizomes as shown in **Fig. 6**. After boiling for sometime, froth starts coming out and white fumes appear giving out a typical odour. A rhizome is tested to determine the end point of boiling by pressing it between the thumb and in-

Fig. 2 Havesting of turmeric.

Fig. 3 Spent-ups, fingers and mother rhizomes in the processing yard.

Fig. 4 Cutting of roots from rhizomes.

dex finger. When properly cooked, the rhizomes would be soft. After boiling, the cured rhizomes are transferred on the drying yard and allowed to cool. This operation is a very tedious and time consuming.

Drying

Next day the rhizomes are spread uniformly for sun-drying on the yard (**Fig. 7**). During drying rhizomes are polished by rubbing them on the ground with the palm of the hand so that rootlets and outer skin are removed. Generally, three to four such polishing are given the rhizomes to impart a smooth surface and better colour. Depending on weather condition it takes 10 to 15 days for the rhizomes to become thoroughly dry, i.e., when they become quite hard and brittle and produce a metallic sound on breaking.

Transportation and Marketing

The dried turmeric is transported to the local market for sale using baskets or gunny bags. Some buyers operate marketing centres and storage houses near producing areas who buy turmeric from farmers at low price during harvest season and store it in their godown. The quality and cost of turmeric is judged by its hardness (drying to low moisture content of 10% d.b.) and colour of the core. If not properly dried, the buyers pay low prices for further drying in their own facilities. The dried turmeric is packed in gunny bags and stored in the godown. These middlemen sell the turmeric to processors.

Storage of Mother Rhizomes

After the roots are cut off, the mother rhizomes are stored for seed purposes. Generally, a pit of 30 to 45cm deep is dug from an elevated area under a tree shade to avoid accumulation of rainwater. The seeds are placed in the pit and covered with branches of trees (**Fig. 8**). In the month of May, the seeds are taken out for planting in the field. The labour requirement during post-harvest operations at farmers' level is shown in **Table 3**.

Processing at Processor's Level

Fig. 9 shows the sequence of processing turmeric at the processors' level.

Polishing

In this operation the dried turmeric is cleaned of outer skin, rootlets and remaining particles of soil and transformed from the rough-coated, dirty brown condition into relatively smooth, bright-yellow rhizomes. Polished turmeric fetches higher price than unpolished one by Rs 2 – Rs 3 per kg for its attractive condition.

Farmers in the Kandhamal district usually do not polish the turmeric except rubbing it on the ground by hand during drying. Some middlemen operate polishing units near the turmeric production area. They buy unpolished dried turmeric from farmers and polish it in a motor operated by drum polisher. There is a public polishing unit at the Raikia block in Kandhamal district which requires 1.5 hours for polishing of one batch of four-quintal capacity driven by 8 kW electric motor. After polishing middlemen pack the turmeric in gunny bags and sell to the end processors.

Grading

When turmeric is exported as whole, it should be of uniform size. Turmeric is graded into bulbs, large and small fingers by the reciprocating motion of the sieves. Some pro-

Fig. 5 Cutting of spent-ups into splits.

Fig. 6 Traditional curing of turmeric.

Fig. 7 Drying of cured turmeric in the drying yard.

cessors grade the turmeric before milling by using hand grader which separates small pieces of turmeric and extraneous materials which otherwise affect the quality of the turmeric powder.

Milling

Turmeric powder is mostly consumed domestically for culinary purposes. It is also used in the manufacture of curry powder and spice mixtures, the demand for which is on the increase. Usually turmeric is milled in home scale by means of flour mill with two friction plates. Milling is done in two stages: first the turmeric is broken into small pieces by increasing the gap between friction plates. Then it is finally powdered to the desired fineness by reducing the clearance between plates. In rural areas, for day-to-day consumption of turmeric, people mill their own turmeric in local flour mills (**Fig. 10**).

Special hammer mills of small capacity are also installed in some areas for milling turmeric. The rotor with a hammer in the periphery is rotated inside a casing. The bottom half of the casing is made of sharp iron strips lined together with small gap in between for the passage of the powder, which is collected in the bottom chamber. Hammer mills work better than flourmill in making of turmeric.

In large-scale commercial grinding factories, a pulveriser machine is couples with a blower, cyclone separator and dust collector is used for milling of turmeric. Turmeric powder is cooled (since there is heat generation in friction milling), transported pneumatically through a duct, and collected in the cyclone separator. The air from the cyclone separator is cooled to collect the lost volatile oil.

Fig. 8 Storage of mother rhizomes for seed purpose.

Sieving

After milling the powder is sieved through hand or motor operated by a vibrating sieve of 300 (fine) or 500-micron (coarse) size (**Fig. 11**).

Packaging

The powder is packed with fixed quantity and sealed in polyester-poly film pouches by a manual sealing machine (**Fig. 12**) or automatic packaging machine. Then the packs are placed in cartoons for distribution to end -users.

Factors Affecting Quality in Traditional Processing

Turmeric is valued for its high pigment content giving deep yellow colour, and somewhat bitter content free from soil particles, dirt, animal excreta, mould growth, any added colour and starch in powder. The traditional method of processing turmeric produces inferior quality product. The source of quality deterioration during various processing steps and care that should be taken to maintain quality is explained below:

1. Harvesting should be done after proper maturity in order to obtain the highest yield. During harvesting of turmeric crop, care should be taken so that the rhizomes are not cut or bruised and the whole clump is lifted. The adhering soil must be shaken or rubbed off properly.
2. Before curing, the rhizomes should be well washed with clean water to remove the adhering dirt and soil particles. Instead of recirculating the same water throughout the curing process, clean water should be used after 2 to 3 batches.
3. Drying of rhizomes should be done on cemented floor or on polyethylene sheet to avoid contamination from dust and soil particles. Near the drying yard, provision should be provided to prevent their produce from rain.
4. As polishing increases the cost of rhizomes also increases by Rs 2 – Rs 3 per kg. If farmers polish their turmeric by low cost hand operated drum polisher, they can earn more by the value added products.

Fig. 12 Packageing of turmeric powder.

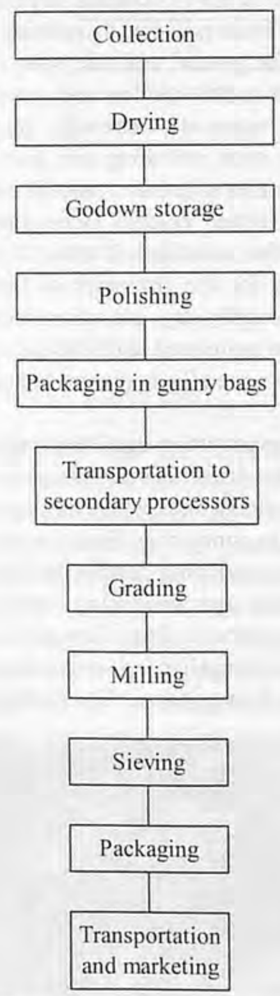

Fig. 9 Flow chart for processing dried turmeric at processors' level.

Table 3. Labour requirement during traditional processing operations for turmeric (Unit: 0.1 ha)

Operations	Man-day work
Harvesting	10
Separation of fingers and rhizomes	3
Preparation of processing site	1
Transportation to processing site	2
Collection of fire wood	2
Curing	12
Drying and hand rubbing	5
Transportation to market	2
Cutting roots from mother rhizomes	5
Storage of mother rhizomes for seed purposes	1
Total	43

Fig. 10 Milling of turmeric in local flour mill.

Fig. 11 Sieving of turmeric powder.

By-product Utilisation

(1)The dried plant and roots are burned in the field and the ashes are mixed in the soil for conditioning.
(2)The upper skin removed during polishing is used as excellent fertilizer.
(3)The spent up is used for manufacturing *'Alata'*, a red colour liquid used for decorating feet and *'kumkum'*, a red colour powder used for decorating the forehead.

Processed Products

Turmeric oleoresin, oils, curcumin, turmeric bits and powder are the by-products from turmeric. Natural pigments and organic turmeric is emerging as novel by-products from turmeric.

Uses

Turmeric is unique, colourful and versatile natural plant product combining the properties of (a) a spice or flavourant; (b) a colourant; brilliant yellow hue; (c) a cosmetic; and (d) a drug useful in a number of diseases. Turmeric is largely consumed as a spice and only limited quantities are utilized for other purposes.

Future Research Needs on Post-harvest Technology of Turmeric

(1)Development of cleaning and curing equipment for turmeric.
(2)Effect of steam cooking and hot air drying on quality of turmeric.
(3)Development of low cost solar dryer for turmeric to reduce drying time.
(4)Drying of sliced raw turmeric to eliminate boiling operation and a study of quality.
(5)Development of home scale polisher and grader for farmers.
(6)Packaging study of turmeric powder.
(7)Development of suitable processing technology for spent up and
(8)Production of oleoresin from turmeric.

Conclusions and Recommendation

Cooperative societies should be formed to look into the processing and marketing aspects of turmeric. Turmeric processing centres should be established in producing areas. It should be equipped with curing vats, cemented drying yard and polishing facilities. Godowns should be made for storage of dried turmeric which can be marketed later, in the lean season. Infestation should be controlled by scientific means. Income of the farmers can be supplemented if hammer mills can be provided in the community processing centres to powder turmeric. After milling, the powder should be packed on low cost efficient packs for marketing. There is a vast scope for proper utilisation of turmeric for preparation of by-products. Post-harvest technology of turmeric should be scientifically explored to get quality product. Low cost processing equipment such as washer, polisher, and grader should be developed for different unit operations to make the work easy. It can help to improve the economic status of farmers by selling their quality turmeric at high price. With the global demand for organic turmeric, Orissa can lead the export market as the turmeric is grown by organic farming. Quality consciousness among farmers during the post-harvest phase can boost their income from the export of quality product.

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Design, Construction and Performance Analysis of Two Hay Chopping Machines

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Abstract

Two different hay chopping machines were designed and constructed to improve feed intake and digestibility of hay by ruminants. Taking into account defects of local threshers in chopping hay, design studies were focused on two principles of chopping. They are: (1) Impact cutting in special suction channel; and (2) Cutting with a countershear. First prototype machine, named suction type chopper with rotary blades, has two functional units. A disk which has changeable cutting blades and a radial blower under the disk. Hay was chopped by disk blades effect of impact cutting while it was passing through blower suction. The second prototype machine has also two functional units that are feeding rollers and chopping unit. In fact, this machine is adapted from the chopping unit of precision-cut forage harvesters considering dry material features.

Introduction

Animal production depends highly on feed costs. It was reported that feed costs had included 60-70% of total costs. According to some investigations conducted in Eastern Anatolia this rate has reached to 70% (Boyar, 1999; Sahin 1999). Fodder from alfalfa, sainfoin, vetch, meadow, etc. is stored as hay because Turkey's climatic condition is suitable to drying fodder. In addition, chopped straw has been used as complementary source of fodder due to lack of quality fodder (Soya et al., 1999).

Diets of cattle and sheep are based on fodder, hence the importance of high-quality and moderate-quality hay with regard to both production and haymaking techniques is stressed. Roughage, also called fodder, increases the period of passing through rumen hence the degree of digestibility increases and as they ensure physical satiation in ruminants. When health and physiology of ruminants are taken into account, adequately chopped roughage should be kept in rations (Owen, 1991; Kiliç, 1997). Most farmers who have cattle or sheep enterprises rely greatly on haymaking for winter feeding. Hay chopping is of great relevance where mixed diets are used. Having dense material by this process, work efficiency increases following processes such as storing, conveying and feeding. It was reported that chopping hay into 10mm even length is invaluable in the aim of achieving a uniform blend which was not amenable to selective eating by the cattle (Owen, 1991). It is well known that the fine fraction of over processing of hay can have a deleterious effect on its nutritive value to cattle. Finely ground material passes through the rumen quickly and, therefore, its digestibility is usually low.

Fine fraction that can be named "dust fraction" may cause flocculate which has harmful effect in rumen. Dust fraction in feed also causes deleterious effects in respiration system of ruminants. In some studies, optimum chopping length was investigated. For example, Chenost and Demarquilly reported that chopping fresh *Festuca arundinacea* (2 to 4cm pieces) increased the voluntary intake of sheep by 6 to 9% (Minson, 1990). For these reasons, hay must be chopped to adequate size without causing dust. Also, nutritional value of leaves, especially in legumes, is higher than the stems (Srivastava et al., 1994).

Local threshers, specific to Turkey's condition, were developed to thresh wheat, barley, lentil, chick pea, etc. and two major aims are to acquire grain and chopped straw. In other words, reason for designing local thresher is to chopped straw acquisition to be used as fodder (Evcim, 1983). Since there are no alternatives to local threshers for

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chopping hay, these machines have also been used to chop hay. However, chopping hay in the threshing unit of the machine was a result of over processing of the material. Hence leaves and fine stems with more nutritive parts of hay have been wasted with threshing process. Therefore, local threshers are not suitable to chop hay and chopping machines affordable to Turkish farmers are needed (Yumak et al., 2000).

The major objective of this study is to develop a low-cost hay chopping machine suitable for conditions in Turkey. For this purpose, disadvantages of local threshers in chopping hay, expectations of breeders and veterinary considerations were taken into account. Two different prototype hay chopping machines were constructed after design studies were completed. The prototype machines were small- scale so that they could be tested regarding to factors determined in advance.

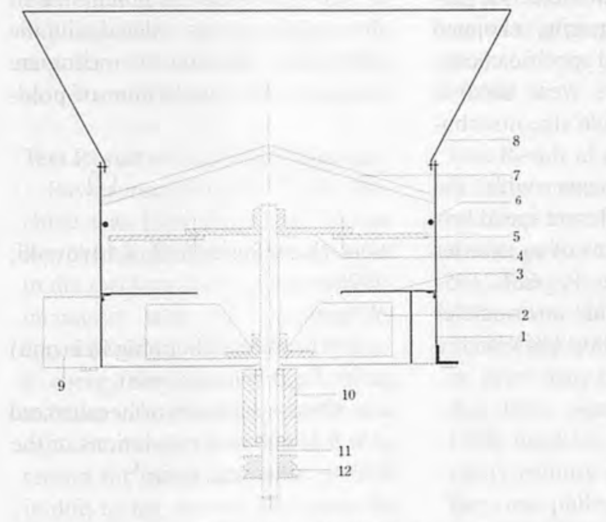
Procedure and Equipment

At the beginning of design studies farmers' expectations and their available practices of chopping-cutting hay were taken into account (Yumak et al., 1999). The principal design considerations and data needed were reached based on the previous studies (Kanafojski and Karwowski, 1976; Rider and Barr, 1976; Culpin, 1992; Yildiz, 1996). To prevent producing dust in chopping hay, cutting principles were preferred in place of threshing.

Functional and constructional features of prototype hay chopping machines designed and then constructed were described here.

Suction Type Hay Chopper with Rotary Blades (SCRB)

This machine has two functional units that are: (1) Radial blower; and (2) Rotary disk that has changeable 2-4 of blades. The rotary disk and the blower fan were mounted together on a vertical shaft (**Fig. 1**). The disk was so posi-



1- Cylindrical body, 2- Radial fan, 3- Metal sheet with a suction opening, 4- Disk, 5- Blades, 6- Ring, 7- Fixed tripod, 8- Conical inlet, 9- Outlet, 10- Bearing assemble, 11- Shaft, 12- V Belt pulley

Fig. 1 Schematic view of the SCRB machine.

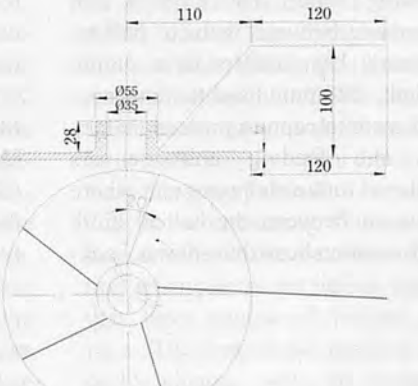


Fig. 2 Radial fan details of the SCRB machine.

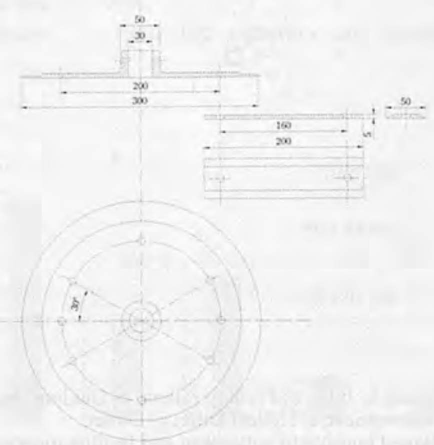
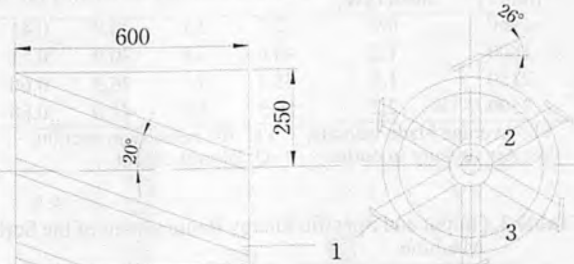


Fig. 3 Disk and blade details of the SCRB machine.



1- Helical knife mounted on helical guide, 2- Knife guide holder, 3- Ring support

Fig. 4 Constructional features of cylindrical rotor (cutterhead) in the CHK machine tioned that its blades run suction channel of the blower. In this way, when hay is fed into the conical inlet, it is pulled down with effect of air suction plus gravity and it is cut at that time. Chopped hay is passed through the fan then blown out tangentially from the outlet section. Details of the radial fan are shown in **Fig. 2**. The diameter of the disk was chosen to be 300mm to ensure enough air suction and peripheral speed. Details of the disk and a blade are given in **Fig. 3**.

Hay Chopper with Helical Knives (CHK)

This machine, adapted from a precision- cut forage harvester, consists of a feeding unit and a chopping unit (cutterhead). The feeding unit consists of a pair of counter-rotating roller that have 37mm clearance between them to pull by pressing hay. Rollers have 55mm length, 140mm diameter and special teeth to capture pressed material. The feeding unit delivers material to the chopping unit where it is cut between the helical knife and countershear then blows backward. The construction of cylindrical rotor which has six helical knives is shown in **Fig. 4**. Helices angle and rake angle were designed based on previous studies (Jekendra and Singh, 1991; Chattopadhyay and Pandey, 1999). The gap between the rotor's knife and the countershear can be adjustable. Both rotor's knives and the countershear were made of chromium steel. The side view of the CHK machine is shown in **Fig. 5**.

Alfalfa and sainfoin were chopped to determine the performance of the prototype hay chopping machines. After the preliminary tests, a factorial test pattern with three replications was undertaken. The parameters of performance were capacity, chopped size distribution and specific energy requirement. Sieves were used to determine the particle size distribution of the samples.

In the experiments with the SCRB machine, different speed levels were set by means of an inverter (Siemens-Simovert P, 6SE2105-3AA01). A digital anemometer (Airflow LCA 6000, UK) and a Prandtl tube were used for measuring air velocity. Since the dynamic pressure of air had been measured, air velocity was then calculated using following equation (Genceli, 1998):

$$v = C\sqrt{\frac{2(P_t - P)}{\rho}} = C\sqrt{\frac{2P_d}{\rho}} \quad ...(1)$$

Where:

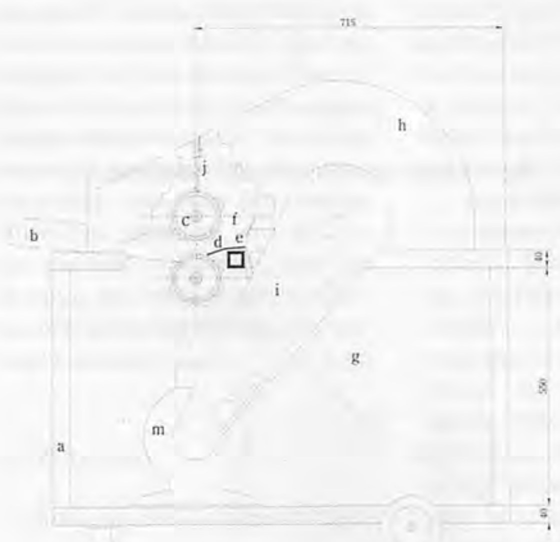
v = Air velocity (m/s),
P_t = Total air pressure (Pa),
P = Static pressure (Pa),
P_d = Dynamic pressure (Pa),
ρ = Air density (kg/m^3)
C = Coefficient of correction (For Prandtl tube, $C \cong 1$)

The theoretical chopping size of the material was calculated with the following equation to compare chopping size distribution of products (Kanafojski and Karwowski, 1976).

$$l = \frac{6.10^4.v}{z.n} \quad .....(2)$$

Where:

l = Theoretical chopping size (mm)
v = Feed velocity (m/s)
z = Number of knives of the cutterhead
n = Number of revolutions of the cutterhead (min^{-1})



a- Frame, b- Inlet, c- Feeding rollers, d- Guiding sheet, e- Countershear, f- Helical knife, g- Outlet, h- Hinged housing of cutterhead and feeding rollers, i- V-Belt housing, j- Baffle, m- Electric motor

Fig. 5 Side view of the CHK machine.

Results and Discussion

Table 1. Working Characteristics of the Scrb Machine

Drive speed (min^{-1})	Power requirement (kW)	Vb (m/s)	Vs (m/s)	Vo (m/s)	Q (m^3/s)
1450	0.9	32.7	2.1	24.9	0.41
1800	1.2	40.6	2.6	30.9	0.51
2150	1.5	48.4	3.1	36.3	0.60
2500	2.2	56.3	3.5	41.0	0.68

Vb: Average blade velocity, Vs: Air velocity in suction, Vo: Air velocity in outlet, Q: Blower output

Table 2. Output and Specific Energy Requirement of the Scrb Machine

Drive speed (min^{-1})	Output (kg/h)		Specific energy requirement (kWh/t)	
	Alfalfa	Sainfoin	Alfalfa	Sainfoin
1450	110	120	8.36	10.8
1800	150	135	10.33	13.11
2150	165	160	11.27	13.12
2500	180	190	17.22	16.32

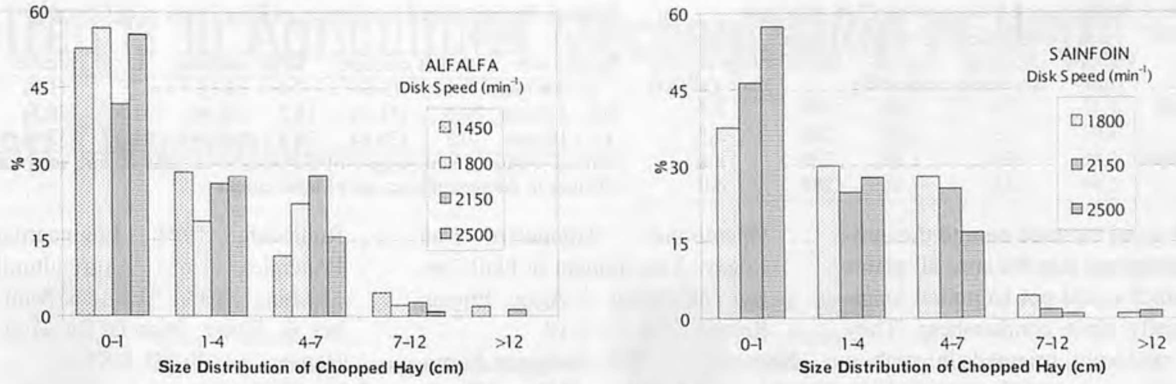


Fig. 6 Chopped size distribution of product by SCRB machine.

The performance of prototype hay chopping machines were found encouraging and the farmers were highly interested in these machines. Data have shown that fine parts of hay, especially leaves, were not in dust form. Test results of the machines are presented.

Test Result of the SCRB Machine

Power requirement of the machine was high due to the blower fan. Although there is no material in the machine power, consumption increased with the increase of speed (**Table 1**). Output and specific energy requirement (SER) of the machine in chopping alfalfa and sainfoin are given in **Table 2**. The reason for increasing value of SER is due to the blower fan since the disk of blades and fan were driven by the same shaft.

When the size distribution of chopped product is examined, fine fractions are much more than that of coarse in both alfalfa and sainfoin (**Fig. 6**). But, leaves of plant could be distinguished in samples of chopped hay. This means that leaves and fine parts of hay were not over-processed and, hence, dust formation in product was small (**Table 4**).

Test Result of the CHK Machine

Performance values of the CHK machine are summarized in **Table 3**. The power requirement and specific energy requirement of this machine were half of or less than the SCRB machine. The main reason, as previously mentioned, is the fact that there was no blower in the CHK machine. Feeding rollers can easily capture bunches of hay then they are pulled into the chopping unit. The rollers can also press the material like wafer and deliver to the countershear. Since pressed hay acts as continuous material, shearing process was enhanced.

When the chopped size distribution of product is examined, fine fractions are much more than that of coarse in both alfalfa and sainfoin as in the SCRB machine. However, it is noticed that coarse fraction have increased a little (**Fig. 7**). When the particles of chopped alfalfa smaller than 10mm was examined, dust fraction (0-1.4mm) of the product from the SCRB and the CHK machines were determined to be considerably less than that of the local thresher (**Table 4**).

It is an interesting finding that the cutterhead also has blower action arising from the helical knives that have angles of helices and rake. The cutterhead housing and outlet channel were so designed that air flow was directed to the outlet. Therefore, chopped hay can be blown out from the outlet section.

On the contrary of expected,

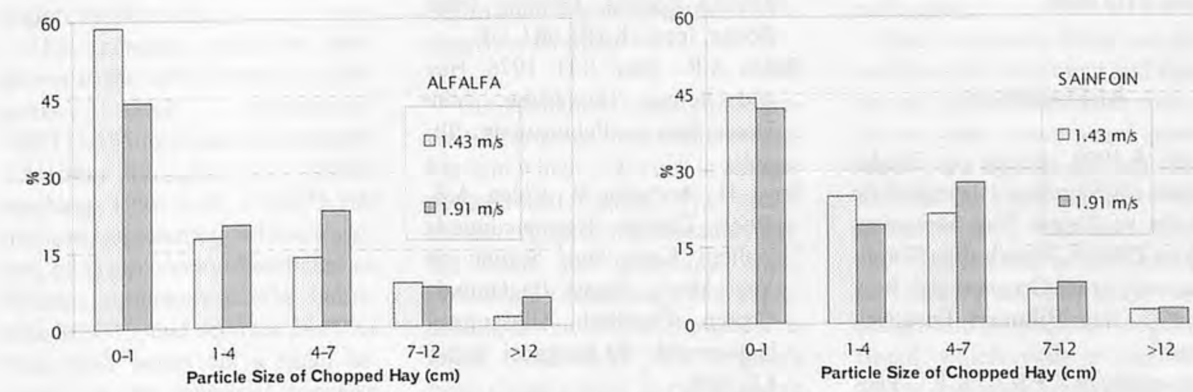


Fig. 7 Size distribution of chopped products by CHK machine.

Table 3. Performance Values of the CHK Machine

Feed	Feed velocity (m/s)	Theoretical chopping size (m/s)	Power requirement (kW)	Output (kg/h)	Specific energy requirement (kWh/t)
Alfalfa	1.43	24	1.40	260	5.4
	1.91	33	1.06	200	5.3
Sainfoin	1.43	24	1.18	220	5.4
	1.91	33	1.37	280	4.9

Table 4. Particle Size Distribution of Fine Fraction of Chopped Alfalfa

Particle size	SCRB machine		CHK machine		Local Thresher	
0 - 0.6 mm	9.1	(5.0)	7.5	(4.3)	17.2	(11.2)
0.6 - 1.4 mm	20.6	(11.3)	18.2	(10.4)	31.5	(20.5)
1.4 - 10 mm	70.3	(38.6)	74.3	(42.5)	51.3	(33.4)

Values represent percentages of fractions in weight of fine samples (Values in the parentheses are of total samples).

there is no increase around theoretical chopping size because all plants in bunch could not be pulled longitudinally onto countershear. They are randomly oriented in such a way that some of them are crosswise, some of them are parallel and majority are diagonal at different angles according to cutting line.

Conclusion and Recommendations

The prototype hay chopping machines designed and constructed in this study were determined to be capable of chopping hay without making dust of leaves and fine parts. Dust fraction in chopped hay could be minimized using these machines. However, it was not possible to produce completely dust-free chopped hay because of the friction among particles of processed materials. Both SCRB and CHK machines can be suggested as an alternative to conventional local threshers for chopping hay. Further studies should be carried out to improve the prototype machines. AC electric motors were used to drive the machines but they can also be equipped with a system driven by tractor PTO shaft.

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Trends in Agricultural Mechanization in Brazil – an Overview


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Introduction

Brazil has a territory of roughly 8.5 Mkm^2, representing 20.8% of the American Continent as well as 47.0% of Latin America. Over 41% are flat lands, 58.5% are altiplans, and less than 0.5% are mountains. Brazilian climate is predominantly tropical, being partially equatorial, semi- arid and subtropical in some regions. The annual average temperature is 22 ℃ and rain precipitation is 1,300 mm. The total Brazilian population is about 165 million inhabitants, with an average population density of 19 inhabitants per km^2. Approximately 76% and 45 % of the country population live in urban and in the Southern region, respectively.

The economic activities have grown in the last 10 years. In 1980 gross GNP represented US$173,153 millions and increased 3.5 times throughout the period, reaching 1998 with US$775,700 millions, representing different sectors of the economy distributed as follows: agriculture 6.84%, industries 38.43%, and services 54.80%. This trend points out a small increase on the industrial business and a large decrease in the agricultural activities (ALVES et al., 1999). Nowadays the Brazilian economy contributes around 60% of the total South America gross domestic product which represents around US$1,316.6 millions (IPEA, 2000).

The size of the country as well as the uneven distribution of land with agricultural potential in some regions make the concentration of large farms in frontier lands where there are problems regarding the agricultural products storage and distribution for different markets. This paper presents a prospective overview of the agricultural mechanization in Brazil.

Today's Agricultural Production Profile

The Brazilian agricultural production is spread over available arable land which is divided in 5 major geographical regions. The Southeastern region produces mainly coffee beans and sugarcane. Dairy production is also important, representing around 50% of the total Brazilian production. The region's main characteristic is the intensive industrial processing of the agricultural production partly using labor employment at farm level. The Northern region is located mostly in the Amazon rain forest. Agricultural production is mainly subsistence level, even though there are changes in some areas where beef cattle has been introduced as well as soybean, corn and bean crops. With dry and hot climate, Northeast Brazil has been developing tropical fruits crops in areas where irrigation is available such as melon, grape, pineapple and cashew. This area is known for intensive agriculture. In some sub-regions, irrigated corn and soybean have been grown with success. With large cultivated area, the States of Pernambuco and Alagoas have a significant sugarcane production.

Many regions in Brazil are in the process of development and expansion of agricultural lands, but one of the great concerns of government is the agricultural use for the 127 million ha of the arable lands in the so-called *"cerrados"(savannas)*. These lands extend over part of Center-West, Northern, Northeastern and Southeastern regions of Brazil, which relate to one of the fewest available lands in the world for increasing food production. The current annual agricultural production of *cerrados* corresponds to 25% of the Brazilian production, which can be considered very important for the economy.

The cost of equipment allied to the unstable economy problems in the country and the cut in agricultural subsidies, made it very difficult for farmers to invest in purchasing new equipment. On the other hand, the process of elimination of small farming units due to the lack of economical power for purchasing new technology is proportional to the industrial and urban expansion. The urban employment is a factor that may regulate this. However, the whole process is not properly managed by governmental policies leading to high unemployment rates and the consequent crisis and social conflicts.

In other areas where crops like sugarcane dominates, the small farm units are already gone or rented. Without capital for investment in updated machinery, it is nearly impossible for small farmers to remain in business, and this has already caused a major process in land ownership concentration. In crops such as coffee, mechanization has not been yet the interfering factor in the change in land distribution. However, the harvesting technology for both coffee and sugarcane production is in large expansion process. This means that a large number of labor force employed in the fields will soon be out of work, adding to the already large rate of urban unemployment. In addition, due to environmental enforcement laws the burning of sugarcane prior to harvest has been restricted and, the only option is replacing the human labor force by machine harvesters.

Agricultural machinery in Brazil is mainly owned by either the farmers or cooperatives so that the contractors do not have an important role in the agricultural business as in other countries.

Interactions of Agricultural Production and Brazilian Economy

According to IBGE (1998) total Brazilian production of grains reached 82.5 million tons in 1999, increasing 9.83% compared to the 1998 production. The Southeast, South and Center West regions which contributed 90% of the total, presented an increase of 7.18 %, while the regions North and Northeast, reflecting 10% of national production, increased around 44%. **Fig. 1** summarizes the total Brazilian grain production in 1999, by each geographic region. **Fig. 2** shows the evolution on crop production through the late years.

The South and Southeast regions represent over 50% of the crop production of the country. It is in those regions that agriculture is more mechanized. In the beginning of the 90s in the whole country, there were 6 million of rural enterprises of 380 million ha, where 60 million farms have approximately 750,000 tractors or about 80 ha per each tractor (Alves et al, 1999). Among the rural business in both South and Southeast regions, there have been immigrant entrepreneurs that carried out an important segment of the small scale agricultural business. However, the pressure today is more towards eliminating the small agricultural business which lies compressed, at least in some transition areas, between the *modern* and *old fashion* agricultural trends.

According to Mantovani et al. (2000), in 1990 Brazil exported 3,744 million dollars of sugar, 10,996 million dollars of raw coffee and around 1,644 million dollars of soybeans. Even though fluctuations on the external market involving the orange prices influences the national production, this is the sector that developed most in the past years. In 1990 the exports of orange juice was of 6,180 million dollars. On the other hand, Brazil imported some of the fertilizers used in agricultural production. During the last five years the percentage of production *versus* consumption increased, representing a deficit of 5.1% of nitrogen, 3.2% of phosphate and 8.8% of potassium which was supplied by imports.

Over all, the Brazilian labor force in agriculture is very significant representing 60%, while animal traction is 31% and mechanized agriculture is only 14%. Southern and Southeastern of Brazil detains

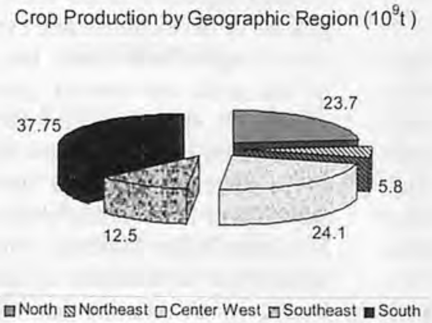

Fig. 1 Brazilian crop production in each geographic region (IBGE, 1998).

Fig. 2 Brazilian crop production evolution, 1980 to 1999 (adapted from SBEA, 2000).

around 28% of the mechanized land. **Table 1** shows the percent evolution of the country land with agricultural potential, indicating the growth in the agricultural production indexes relating to the intensive use of mechanization, proportional to the labor force migration from rural areas between 1970 and 1995 (Manitova et al., 2000).

Several investments were made in order to increase the use of tractors in Brazil. However, the lack of real agricultural governmental subsidies made it very difficult for the small farmer to invest in infrastructure. The size of the country as well as the uneven distribution of land with agricultural potential in some regions made the concentration of large farms in frontier lands where there are concentrated problems of storage and distribution for the market.

The implement industry was also affected by the same crisis that merged with the tractor market. Lately this industry has been involved in a direction change through no-tillage planters production, and that is strongly pushing the prices up mainly for industry that has a good no-tillage planter to offer the market. A well designed implement has been associated with air seed meters and that has been possible by joint ventures with foreign companies that provide such technology.

From 1970 to 1975, the mechanization level of Brazil, ha/wheel tractors, improved 57%, and 35% from 1975 to 1980 (**Table 2**). The data also show a non-growth period from 1980 to 1990, and a 17% decrease up to now, with a mechanization level of 116 ha/wheel tractors, in 1998. Comparing these number it can be seen that even though improving the existing problems the country index are far away from the developed countries' results that have as Brazil, large production areas.

Trends in Precision Farming

The conflict between the *old* and *modern* techniques is evident in some farming activities. A small farmer with up to 50 ha corn and dry beans farming, just feasible in a mechanized system, hardly survives in an economy that is in transition to the so called *developed world.* A crop like soybean is not competitive without mechanization, at least for harvesting operation. Few projects have been tried to adjust low scale mechanization system for small producers without success.

The timing for plowing in the Brazilian savanna area (*cerrados)* is short for the conventional system. In order to plant in this large area within the right schedule, the conventional system does not apply efficiently, leading to losses in quality and soil management. This difficulty related to a lack of horsepower resulted in the preferential use of no-tillage technology by the farmers during the short rain period. In the last three years, more than 3 million ha of lands were added to this no-tillage crop production system.

A proper infrastructure construction is needed in order to use the existing agricultural potential in the *cerrados* and attend production demand. The increase in cotton production at Mato Grosso State (located within the limits of Longitude 50-58° W and Latitude 15.5 – 16° S) with the development of a resistant variety to insect infestation is an example. In this region, several projects have been worked introducing new technological alternatives to the farmers for a good qualitative and quantitative agricultural production response. It is also observed that some farmers struggle to reduce the grain production management and processing costs, for competing in the global market.

The country's dimension demands a criteriously technological evaluation for each country region as well as the distinct agricultural production systems adopting for a proper mechanization system, in order to attend the soils and cultural needs in an economic way.

The Brazilian agricultural systems have a great application potential in precision farming technologies, mainly in the center-west region, where most of the 50 combines with yield monitor are currently at work. An improvement has been observed in the last 10 years on agricultural project applications involving the use of machinery equipped with sensors, remote sensing, image processing (surface, aircraft and satellite). More recently, the precision farming technology is allowing the organization and maintenance of spatial and temporary crop production systems databases, which is important for the development of techniques seeking the rational use of natural resources and agricultural inputs, with consequent reduction of agricultural production systems costs and environmental impacts, assuring a sustainable exploration. This new technology is

Table 1. Evolution of Land with Agricultural Potential in Use

Year	1970	1980	1990	1995
Land witmtial (%)	197.84	220.95	240.80	245.20

Adapted from FAO, 1995.

Table 2. Farm Mechanization Level in Brazil, 1960-1998

Year	Cultivated area (1000 ha)	Wheel tractors (units)	Mechanization level ha/wheel tractors
1960	25,671.7	62,684	410
1970	34,811.1	97,160	359
1980	47,640.6	480,340	99
1990	47,666.4	515,815	92
1998	53,500.0	542,143	116

Adapted from Manitova et al., 2000.

being used as a tool to minimize losses and to reduce the production systems vulnerability. The traditional systems management with inefficient treatment of variability factors that affect crop production (fertility, soil moisture, plant disease control, etc.) uses the average concept for extensive areas.

Precision farming can be an economical strategy and ecologically more efficient, as it treats specific sites, and Brazilian agriculture can benefit from precision farming to produce more food for the internal market and to export with competitive prices compared to developed countries. The agricultural technological modification happening in the world each time more competitive, especially in food production, demands an adoption of these new technologies.

In spite of the precision farming being a new theme in Brazil, progresses have been obtained mainly in the machines and implements development that allow specific site management. The most advanced resources of the electronics and information technology, as GPS and GIS, remote sensing, control and data acquisition systems, sensors, among others, are being introduced in the field. Thus, it will be possible for the optimization of agricultural inputs, based in precision farming, for an economical return and environmental benefits. The variability quantification allows identifying the productive potential areas, which can be worth larger investment in inputs for maximizing production. Regarding the areas with low production potential, productivity improvement can or cannot be considered, depending on economical feasibility. The data analysis allows natural resources and agricultural inputs optimization and variable rate inputs maps generation that takes into account spatial and temporal field variability.

The Brazilian agriculture actual scenery can lead to a decreasing productivity, since technicians works with base in field considerations that can differ with the physical, chemistry and biological reality of different soils. For instance, the application of fertilizer levels based on the whole areas uniformity in farming fields that presents a great spatial variability (average treatment), can lead to unbalance those plots that are already fertile and not to benefit others presenting nutrient lacking. This kind of decision can compromise possible strategies of soil management addressed to the high productivity indexes. A methodological approach capable to work these differences in an automated way to allow adjustment in the fertilizer levels recommendations still needs to be investigated. In addition, the characterization and modeling of the crop production systems spatial variability and the evaluation of the technical feasibility of the agricultural inputs located application concepts can promote the associated use of more advanced technologies. The acquiring, organizing and use of database for management support decisions will allow for global diagnoses, involving all the decisive factors in the productive chain.

Trends in Irrigated Agriculture

Irrigated agriculture in Brazil is an important aspect, being responsible for 1.4 and 2.8 million direct and indirect jobs, respectively. The potential for irrigated agriculture is estimated in 49 million ha, of which 33 million ha are low flat lands (flood irrigation schemes) and 16 million ha are upper lands (Christofidis, 1999). According to the National Plan for Irrigation and Drainage, by the end of 2000, an expansion of about 500,000 ha is expected. In the last 50 years (1950 to 2000) the irrigated area has expanded from 60,000 ha to 2.87 million ha, of which about 0.96 million ha (33 %) are the low flat lands in the South, mostly used for flood irrigation. Presently, the total irrigated area represents about 6 % of the total national area planted, most of it is private, with only 4.2 % of public irrigation districts, comprising about 120,000 ha. Santos (1998) points out that the irrigated area in Brazil is contributes to 16 % of the total agricultural production and for 35 % of this production value, representing one of the most cost-effective ways to generate employment.

Brazil has a great potential to yield irrigated grain crops, such as soybean, corn and bean, in terms of quantity and quality. The country's Northeast region has developed tropical fruits crops, since the dry and hot climate is favorable, mainly in areas where irrigation is available. Fruits such as melon, grape, pineapple and cashew are economically important in this region. Also, irrigated corn and soybean has been grown with success.

Mechanization of different irrigation schemes occurred in Brazil mainly due to increase of farm labor costs, together with the shortage of labor for different farm practices and operations. This labor scarcity on irrigated farms has accelerated the trend toward mechanized irrigation systems, such as traveling gun sprinklers, side-roll sprinklers, center-pivot sprinklers, and some of the localized schemes (trickle or drip and micro-sprinkler systems). The surface irrigation scheme is the most used in Brazil, with about 1.7 million ha (59 %) which is concentrated at the North and South regions. On the other hand, in other regions the sprinkler scheme predominates in approximately 1,005 million ha (35 %). The lowest area is used with the localized irrigation schemes with about 176,000 ha (6 %), which is expanding, mainly at the Northeast and Southeast regions (Christofidis, op.cit.).

Conclusions

The level of research and technology development for different regions in order to reach the national demand for a convenient degree of mechanize agriculture was met through in the late years. There is an installed chain of trained professionals able to respond to an emerging demand for agricultural products in both research and educational systems. Apparently, despite all these the problems and limitations Brazil has developed an infrastructure capable of supporting the agricultural expansion to supply the internal and export market demand.

The trends lead to the development of the new agricultural frontier; in the Cerrados area, in terms of expansion of land with agricultural potential, and the use of precision farming in large cultivated land in order to reduce production costs.

Brazilian agricultural expansion potential is large and mechanization plays an important role for supporting the production systems. There is a need to decrease the gap between private enterprise, which provides equipment and modern technology for farmers, and the agronomic sectors which generate proper technology for extension.

Precision farming can be an efficient tool for Brazilian agriculture and can help farmers manage spatial variability, as well as to support food production for the internal market and to export with competitive prices compared to developed countries.

Brazilian irrigated agriculture has great potential in terms of food production and employment generation. Most mechanization of different irrigation schemes occurred due to increase of farm labor costs, together with the shortage of labor for different farm practices and operations.

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Farm Mechanization in LalgudiTaluk of Southern India

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Abstract

A study was conducted in Lalgudi Taluk of southern India in order to assess the level of farm mechanization. Interviewed were 540 farmers using a structured questionnaire. The energy usage in various agricultural operations in the region was studied. The level of mechanization in the Lalgudi region is higher than the national average. Among the major crops grown, paddy cultivation is highly mechanized compared to sugarcane and cotton. Lack of suitable machinery and training of farm machinery operators are the major problems towards complete mechanization in this region.

Introduction

In the past three decades, agricultural output in India increased rapidly mainly through the introduction of high yielding crop varieties, increase in irrigated areas and increased use of fertilizers and pesticides. Along with the increase in food production, the use of machinery in agriculture also increased. The wheat crop cultivation in the Punjab, Western Uttar Pradesh, and Haryana is almost completely mechanized. Mechanization of agriculture in this region has resulted in increased productivity and food production. The demand for labour in agriculture also increased due to mechanization (Pingali 1998). Many researchers have discussed the benefits of mechanization of agriculture in this region. A similar increase in the level of mechanization of the cultivation of paddy and other crops did not occur in the rest of India. Moreover, any reliable estimate of the mechanization itself is difficult to make in most parts of India because the basic data on the use of agricultural machinery for various crops is generally not available. Therefore a study was conducted in selected villages of Lalgudi Taluk of southern India to make an assessment of the level of mechanization currently practised by the farmers and to determine the scope for further mechanization in the region.

The area selected for this study lies in the Cauvery river side with assured water supply. The results obtained in this study pertain to Lalgudi Taluk only and can be extended safely to other similar agro-climatic regions of Tamilnadu with few assumptions.

Objectives

The specific objectives of this study in Lalgudi Taluk were:

1. To collect information on the present level of farm mechanization;
2. To determine the scope for further mechanization of agriculture; and
3. To identify the problems of agricultural mechanization.

Methodology

The Lalgudi Taluk lies in the Cauveri river basin. The farmlands in this region are mostly wet lands with assured irrigation either through canals or deep wells. The major crops grown in this region are paddy, sugarcane, and cotton. For this study 20 sample villages were selected randomly from the 117 villages in Lalgudi Taluk. These villages are located in 5 developmental blocks, namely; Anbil, Lalgudi, Peruvalappur, Pullambadi, and Valadi. At least 25 farmers were randomly chosen as sample farmers in each village under study. In total, 540 sample farmers were interviewed using a structured questionnaire to record information on agricultural mechanization practised by them. The specific information asked in the questionnaires were farm size, cultivation practices, use of tractors and implements, labour utilization and requirements, timeliness of agricultural operations, availability of repair facilities, availability of credit facilities, possibility of cooperative farming, and farmers' social conditions such as education, knowledge of farm machines, etc.

The assessment of mechanization

was done on energy basis. Suitable energy equivalents for human, animal and tractor power were used to convert the man-hr, animal-hr, and tractor-hr into MJ of energy (Ojha and Michael 1998). For the important crops grown in Lalgudi Taluk, the energy utilized in the various operations, namely; land preparation, sowing and planting, irrigation, crop protection, weeding, harvesting, and threshing were analyzed from the gathered information.

Results and Discussion

Present Scenario

In Lalgudi Taluk, most of the farms are small and fragmented. There are no big commercial farms. The farm size distribution is given in **Table 1**. Of the farmers interviewed, 67% own their land, 11% were tenants and 22% were mixed operators who tilled their own land and land on lease. The major crops grown in the area are paddy, sugarcane, and cotton. Vegetables, banana, pulses, sorghum, cumbu, gingelly, tapioca, and groundnut are also cultivated to a limited extent (**Fig. 1**). The crop rotation adopted in the blocks under study is given in **Table 2**.

Table 1. Distribution of Land Holdings in Lalgudi Taluk

No.	Farm size, ha	Farmers, %
1	Marginal (< 1)	28
2	Small (1-2)	34
3	Medium (2-5)	23
4	Large (>5)	15

The energy utilization pattern for all the major crops in this region is given in **Fig. 2** that closely reflects the actual energy utilization in small, medium and large farms. The conditions pertaining to marginal farms may deviate from the ordinary conditions presented here because small farm size and subsistence level of farming do not favour the use of large farm machineries.

The total energy requirement per hectare for paddy ranges from 12449 MJ in Valadi to 17129 MJ in Anbil. That for sugarcane ranges from 3566 MJ in Anbil to 3977 MJ in Lalgudi. The total energy requirement for growing paddy is approximately 4 times greater than that for sugarcane. The energy used for land preparation in paddy cultivation is 51% in Anbil and Pullambadi blocks and 70% in Lalgudi and Valadi blocks. Next to land preparation, threshing requires the most energy for paddy. About 32% of the total energy is used for threshing in Anbil and Pullambadi blocks and 10% of the total energy is used for threshing in Lalgudi and Valadi blocks. Irrigation is the second most energy intensive operation (31.7%) for sugarcane next to land preparation (38%). More than 95% of the total energy is drawn from mechanical sources for paddy cultivation whereas it is 55% for sugarcane cultivation. The energy requirement for cotton is 2339.01 MJ/ha, for chilli is 1820.98 MJ/ha, and for groundnut is 586.2 MJ/ha. While land preparation requires the most energy for the above three crops (58.6%, 46.0%, and 66.6%, respectively), irrigation is the second most energy intensive operation (21%) for cotton. Harvesting is the second most energy intensive operation for chilli (20.8%) and groundnut(29.3%).

For paddy, machine power is not employed for operations such as sowing, transplanting, and weeding. In sugarcane cultivation, machine power is not employed for operations such as sowing, planting, weeding, and harvesting. For cotton machine is not used for sowing, planting, weeding, harvesting, and threshing. In groundnut cultivation, machine power is used only for land preparation. All other operations are carried out manually. For the major crops, namely; paddy, sugarcane and cotton, the energy supplied by machines constitute 92, 60, and 76% indicating that mechanization has already taken place to a considerable extent in Lalgudi region. For crops such as chilli and groundnut the level of mechanization adopted is low.

Table 2. Crop rotation followed in Lalgudi Taluk

Block	Number of villages	Crop rotations
Anbil	5	1. paddy-paddy-gingelly 2. paddy-paddy-black gram 3. sugarcane-gingelly
Lalgudi	4	1. paddy-paddy-gingelly 2. sugarcane- -black gram 3. banana-black gram
Peruvalapur	4	1. paddy-cotton-sugarcane 2. paddy-chili-blackgram 3. groundnut-sorghum
Pullambadi	4	1. paddy-paddy-black gram 2. paddy-paddy-gingelly 3. paddy-groundnut
Valadi	4	1. paddy-paddy-gingelly 2. banana-black gram 3. sugarcane-black gram

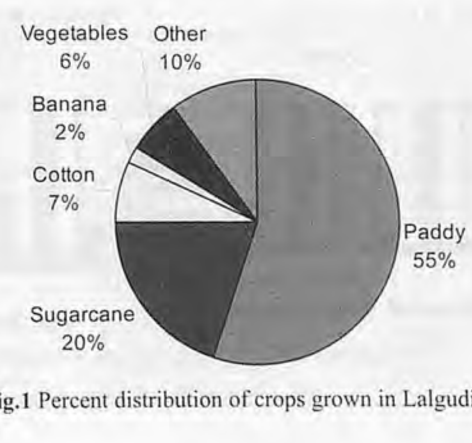


Fig.1 Percent distribution of crops grown in Lalgudi region.

Scope for Mechanization

Mechanization of agriculture is spreading fast in the Lalgudi region. Paddy is the economically important crop of this region. Mechanization of paddy cultivation has taken place to a greater extent compared to sugarcane, cotton, and other crops.

The power sources available for farming in the Lalgudi Taluk is shown in **Table 3**.

The bullock power available per hectare of land sown is 0.13 kW and the mechanical power availability is 4 kW/ha. The mechanical power available is considerably higher than the national average of 0.74 kW/ha (Singh, G. 1996). Growing labour scarcity and increasing wages of agricultural workers are the major causes for the rapid progress of mechanization in Lalgudi. Pingali (1998) concluded that rural urban migration, increases in labour productivity, and escalating wage rates in the non-farm sector put pressure on rural wage rates in Asian countries.

Although among the crops grown, paddy cultivation is highly mechanized, transplantation is yet to be done by machines. No transplanting machinery is available in the farms of Lalgudi due to non-availability of a machine of satisfactory performance. The successful prototypes of transplanters in Japan and South Korea were not entirely successful when tried in South Asia. This may be due to differences in climate and cultivation practices. A series of transplanters from China, South Korea, and locally developed prototypes were tested in Pakistan and none of them were accepted by the farmers due to operational problems, complexities, and initial high investment (Mufti and Khan 1995).

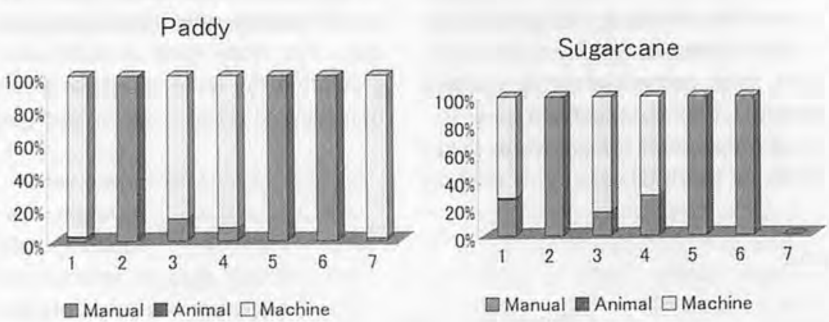
In sugarcane cultivation, planting, weeding, and harvesting need to be mechanized. No harvesting machinery for sugarcane is found in the farms of Lalgudi. Nearly 60% of the manpower used in sugarcane cultivation is for doing these operations. Similarly, the operations of planting, weeding and harvesting of cotton need mechanization.

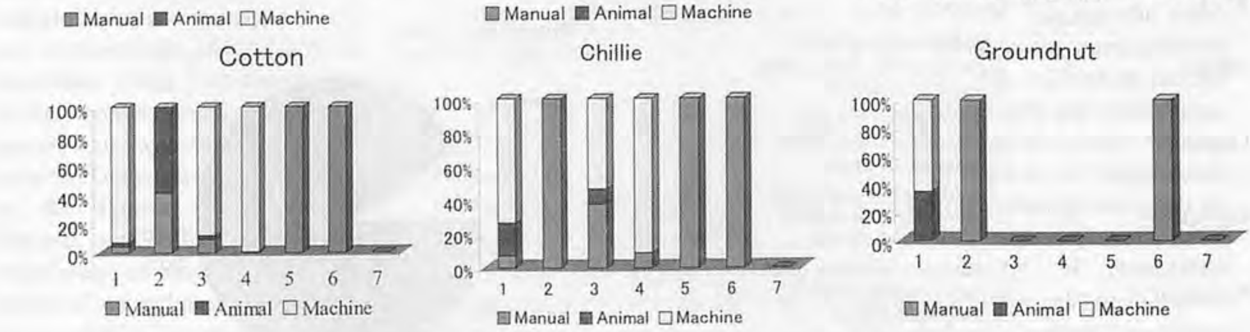
Problems of Mechanization in Lalgudi

Although the level of mechanization and the availability of power/ha are higher in Lalgudi compared to the national average, complete mechanization of agricultural operations has not been achieved. The bottlenecks for near complete mechanization are:

Farm size — Nearly 28% of the farmers interviewed possessed land holdings less than 1 ha. These farmers carry out farming mainly by manual and animal labour. Most of the small farmers holding 1-2 ha prefer hiring of machines from the neighbouring medium- and large-sized farmers. Although only 26% of the farmers own tractors (medium- and large-sized farmers together constitute 38% of the total number of farmers), 82% of the farmers used tractors for at least land preparation. This indicates that the awareness level of the farmers to using machines is high and the general trend is toward higher mechanization.

Farm machineries — Land preparation is done by machines for all the major crops by most farmers (82%). Diesel engine or motor-driven pumps are used for irrigation by most of the farmers interviewed. Besides land preparation and irrigation, the remaining agricultural operations for all the crops cultivated are done mostly manually. In paddy cultivation, threshers are used by 42% of the farmers. A suitable





1. Land preparation 2. Sowing/Planting 3. Irrigation 4. Protection 5. Weeding 6. Harvesting 7. Threshing

Fig. 2 Sourcewise energy utilization in major crops of the Lalgudi region.

number of threshers are not available at the peak season of harvesting to enable all the potential users to go for hiring the threshers. Harvesters and combines are not seen in the farms of Lalgudi Taluk. Non availability of harvesters and combines is the major reason for the farmers not to mechanize the harvesting of paddy. Successful introduction of rice combines in the adjoining Perambalur district shows that poor supply of labour and increased efficiency of machines over manual operation are the factors responsible for Perambalur farmers to adopt combine harvesters (Anonymous 2000a). Similarly, machines for transplanting paddy and planting sugarcane are not available. The farmers cultivating sugarcane in this taluk are in need of harvesting machinery. Farm implement dealers of the state have organized field demonstrations of imported machinery for harvesting sugarcane in this region. However, they received poor response from the farmers because clogging of the conveying mechanism due to twines in the field was a major constraint in using the harvesters. No machinery is available for cotton cultivation with the exception of land preparation. About 29% of the farmers complained about the non-availability of tractors in time for land preparation.

Farmers' literacy — Nearly 81% of the farmers had forward schooling up to at least the elementary level. However, only 8% of the farmers finished higher secondary school. Most of the farmers (88%) were unable to answer the questions related to the farm machineries. Training programs like the "TRYSEM" (Training Programme for Rural Youths for Self-Employment) organized by the state government to train the illiterate rural youths in using and repairing farm machinery are valuable. Similar training programs in Taiwan in the early years of mechanization were reported to be very successful in disseminating farm mechanization technology to farmers and extension workers (Tien 1978).

Inadequate service centers — The workshop facilities available in the Lalgudi region are given in **Table 4**.

Authorized drivers and workshops are located in Trichy City 30 km away from the region under study. The workshop facilities available at present are not adequate for complete mechanization. However, almost all farmers complained about the lack of good workshops and qualified technicians to undertake repairs and servicing of farm machineries. About 27% of the farmers complained about the lack of spare parts for farm machines and tools. The quality of services provided to the farmers is expected to improve in the near future because more tractor and farm machinery companies are trying to start their sales and servicing operations in Trichy district to exploit the opportunities offered by the economic liberalization policy of the government (Anonymous 2000b).

Purchasing power — The purchasing power of all the farmers in Lalgudi are not high enough to own tractors and other implements. For example, only 26% of the farmers own tractors and 9% own threshers. However, financial supports in the form of loans are forwarded to the eligible farmers by various financial institutions located in the area (**Table 5**). There are various finance schemes devised and operated by these institutions which help the farmers to buy agricultural machinery and implements. Short term and long term loans are also made available to the farmers to buy other inputs for crop cultivation.

Conclusions

The following conclusions can be drawn from this study:

1. The farmers of Lalgudi Taluk adopt a high level of mechanization. The use of mechanical power is highest for paddy and lowest for cotton among the crops grown.

(Continued on page 71)

Table 3. Sources of Farm power in Lalgudi Region

Item	Anbil	Lalgudi	Peruval-lapur	Pullam-badi	Valadi
Villages	4	4	4	4	4
Area sown (ha)	199.4	92.4	108.04	97	94.4
Bullock pairs	12	7	18	21	9
Tractors	37	18	12	23	7
Pumpsets	102	97	82	131	58

Table 4. Workshop Facilities

Place of workshop	Services available
Anbil	Tyre works, simple fabrications repair of implements, and motor winding.
Pullambadi	Tyre works, simple fabrications repair of implements, motor winding.
Lalgudi	Tractor servicing, and repair supply of spare parts, tyre works, fabrication works, motor winding.
Valadi	No workshop facility
Peruvalappur	No workshop facility

Table 5. Sources of Finance for Farmers in Lalgudi

Block	Source	Usage of loan
Anbil	Co-operative society, Primary co-operative bank	Fertilizer, Paddy, Sugarcane, Tractor
Lalgudi	State bank of India, Agricultural co-operative bank, Co-operative society	Tractor, Seeds, Fertilizer, Sprayer
Peruvalappur	Co-operative society, Indian overseas bank, State bank of India, Agricultural co-operative bank	Cotton seed, Fertilizer
Pullampadi	Agricultural co-operative bank, State bank of India	Tractor, Fertilizer, Sprayer
Valadi	Co-operative society, Money lenders	Paddy

A Review of Aerators and Aeration Practices in Thai Aquaculture

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Abstract

This review describes aerators commonly used in aquaculture ponds in Thailand and presents their technical data. Aeration practices in Thai aquaculture are discussed with respect to two important functions of aerators, namely transfer of oxygen into water and to disperse sediment mounds at pond bottom. In Thailand, most imported aerators are modified from their original design and used in many different patterns by farmers. To increase aeration efficiency, performance of locally manufactured aerators needs to be improved and standard oxygen-transfer tests be made available to local manufacturers and farmers. Finally, the conceptual design of an aerator suitable for Thai aquaculture is discussed.

Introduction

About a century ago, Thai farmers realized that marine shrimp could be grown naturally in confined bodies of water (Saisithi, 1989). Twenty years later commercial extensive culture of shrimps started in some suitable areas located along the coast of inner gulf of Thailand (Department of Fisheries, 1991). A typical culture pond has a surface area of about 0.5-1.0 ha and a depth of 1.5 m. The Thai Department of Fisheries (1999) has reported that an area of approximately 73,120 ha was used for shrimp culture in 1997. This area was made up of about 22,264 ha under extensive culture, 6,440 ha under semi-intensive culture, and the rest 44,416 ha under intensive culture. Export of sea prawn and other coastal aquatic products has generated significant income for the country, including US$ 1,250 million per year from shrimp exports alone (DOF, 1999). Government policies have encouraged expansion of area under semi-intensive and intensive culture, resulting in continuous increase in shrimp production since 1987.

The interrelationship between water quality and feeding in intensive aquaculture is complex. Water temperature, movement and dissolved oxygen (DO) level influence feeding activities and shrimp growth. Thailand, located at the range of 5°N to 20°N latitude and 97°E to 105°E longitude, has temperature in the range 25-35°C in most parts of the country throughout the year. This temperature is suitable for shrimp farming because the optimum temperature range for giant tiger shrimp is 28°-33°C and for giant freshwater prawn 25-30°C (Elliot, 1981). DO is probably the single most important environmental factor in shrimp ponds (Boyd, 1989). Respiratory and blood circulatory systems of shrimp are adapted to function over a range of DO concentrations. In intensive culture, a fundamental aspect of good husbandry is the maintenance of optimal or near optimal DO levels. Emergency aeration is usually activated when DO concentration falls below 2-3 mg/L (Boyd and Tucker, 1979; Boyd *et al.*, 1979). Low DO levels are a common cause of mortality and reduced growth in intensive shrimp ponds. DO tolerance values for shrimp range from 1.2-2.2 mg/L (Primavera, 1993), while DO values below 0.9 mg/L are lethal for most shrimp species. The critical DO level for growth of tiger prawn is estimated to be 2.2 mg/L (Tsai, 1989). The oxygen in water is limited by its solubility, which decreases as temperature increases, decreases exponentially with the increase in salt content, and decreases with atmospheric pressure. The optimum concentration of DO for shrimp is above 5 mg/L. Besides

DO demands in ponds, water circulation is also an important factor. Boyd (1997) reported that water circulation prevents stratification of the water, providing a uniform water quality throughout a pond.

Commonly Used Aerators in Thailand

Aeration has become an integral part of commercial aquaculture operations in Thailand. Aerators are mechanical devices, performing two basic functions: oxygenate water and induce water circulation. Both functions are important in pond aquaculture. Aeration is sometimes applied to prevent thermal and oxygen stratification in ponds in an effort to reduce the risk of oxygen depletion. Naturally, the shrimp habitat is near the pond bottom, which unfortunately has the least DO and the highest oxygen consumption. In Thailand, there are four types of soil: sandy loam, silt loam, clay and lateritic soil. If the soil is firm such as clay or laterite, the sediment mounds will be low. Sediment mounds are composed of 98% clay and the rest is organic matter. Aquaculture aerators in Thailand are used for oxygenating culture water and moving sediment mounds to the center of a pond. This practice makes sludge and mud accumulate at the bottom center of the pond. The bottom area through which the water passes provides a clean environment for shrimp, but the area where the sludge accumulates has toxic gases and also the least DO. Four most common types of aerators used in Thai aquaculture include paddle wheel aerator, propeller-aspirator-pump aerator, diffused-air aerator and water circulator.

Paddle Wheel Aerators

Paddle wheel aerators, imported from Taiwan or based on Taiwan design, are being used in Thailand on approximately 80% of 23,723 shrimp farms (Boyd, 1997). Paddle wheel aerators transfer about 1.1 kg O2 per kWh under standard test conditions. However, actual oxygen transfer rates are only 25% to 50% of the oxygen-transfer rates obtained in standard aerator tests. Paddle wheel aerators rely on slow speed paddles to splash large volumes of water into the air for aeration. They are generally more efficient than other types of splash aerators used in Thailand. Commercial paddle wheel aerators sold to farmers are indigenously manufactured with some imported parts. They oxygenate at the water surface level but provide less water movement near the pond bottom. A paddle wheel aerator consists of two or more wheels with a diameter of 70 cm and 6 paddles along its circumference. Each paddle is approximately 120 mm wide and 180 mm long with 12-16 holes inside (**Fig. 1**). The paddle wheel and paddle material may be special nylon or stainless steel. The power source is usually an electric motor. The electric motor size depends on the number of paddles, for example, 0.75 kW electric motor is used for 2 paddles and 1.5 kW electric motor is used for 4 paddles. The electric motor is installed on a support or pontoon and mounted together with a zinc-galvanized steel structure. The pontoon is made of high density plastic and contains plastic foam inside. The motor speed is reduced by a gear set connected directly with the motor shaft. The type of reduction gear is worm gear set made of high carbon steel. The most common aerator size in use at present is 0.75 kW aerator. Generally, a 0.75 kW paddle wheel aerator is suitable for a 0.16 ha pond area (**Table 1**). The paddle wheel aerator with two wheels has been found to be slightly more efficient than the one with four paddle wheels (Ruttanagosrigit et al., 1991). The reason for this difference is not known for certain, but it is suspected that the unit with two paddle wheels simply splashed more water into the air. Electric paddle wheel aerators are increasing in popularity in small ponds because they are quite easy to operate. Currently, shrimp farmers are using electric paddle wheel aerators for emergency aeration. However, several studies conducted in experimental ponds have shown that night-time aeration with electric aerators improves water quality and increases feed conversion efficiency and shrimp yield above levels achieved with emergency aeration (Plemmons, 1980; Hollerman and Boyd, 1980; Cole and Boyd, 1986).

Fig. 1 A four-row paddle wheels aerator with 1.5 kW electric motor.

Paddle wheel aerator requirements in intensive shrimp ponds vary depending upon biomass, feeding rates, and water quality. For small ponds, Fujimura (1989) reported that supplemental aeration is required only when the shrimp biomass exceeds 0.2 kg/m^2 and recommended 4.5 kW aerator

Table 1. Comparison of Two Different Sizes of Conventional Paddle Wheel Aerators

Power consumption (kW)	Number of rows of paddles	Overall dimensions* (W×L×D) mm.	Price (US$)
0.75	2	1770×1850×860	430
1.50	4	1770×2220×860	582

* The sizes vary slightly depending on the manufacturer.

Fig. 2 Engine driven paddle wheel aerators with a long drive shaft.

Fig. 3 Diagonal line pattern.

Fig. 4 Parallel line pattern.

Fig. 5 Cross line pattern.

capacity for one ha pond area assuming 12 hours aeration per night. Most investigators suggest biomass loading as the predictor of size/capacity of paddle wheel aerators by using the relationship between the capacity of aerators and the total respiratory rates of the biomass. Some atmospheric oxygen gets transferred from air into the water naturally. The amount of DO is greater if the water has a large surface area and moves actively, and the transfer of oxygen is slow if the water at the pond bottom is still.

In Thailand, for pond sizes 0.5 ha or more with a water depth of 1.4 m, the farmers sometimes install several paddle wheels on long shafts connected with a diesel engine or an electric motor in order to move water around the pond (**Fig. 2**). Typical patterns of paddle wheel aerator installation are parallel straight-line, cross-line, diagonal line and mixed patterns. These patterns usually depend on the shape of ponds. For a square area, the dike at the pond corner is formed as a circular curve and the diagonal line pattern is implemented (**Fig. 3**). For rectangular area, parallel straight-line or cross-line pattern is common (**Fig. 4** and **5**). For large rectangular area, a mixture of cross-line pattern and diagonal line pattern is implemented (**Fig. 6**). A 5-hp electric motor can operate 4 long shafts with 16 paddle wheels fixed on each shaft. An 11-hp diesel engine can operate 8 long shafts. Two 5-hp electric motor aerator sets are enough to aerate and circulate pond water in a 0.5 ha pond and they can compensate for one 11-hp diesel engine aerator set. Sixteen paddle wheels on one shaft are arranged at varying distance. Since the water near the dike moves more distance, paddles are closely spaced at the outer end of the shaft (**Fig. 7**). This practice produces sludge and mud accumulation at the bottom center of the pond. The bottom area through which the moving water passes provides a clean environment for shrimp, but the area where sludge accumulates has an abundance of toxic gases and also the least DO. Eventually, the effective feeding area becomes smaller than the expected feeding area of a pond (**Fig. 8**).

Fig. 6 Mixed pattern between cross line pattern and diagonal line pattern.

Fig. 7 Paddle wheels arrangement on a long drive shaft.

Fig. 8 The muddy area at the center of pond gives a clean environment area around it.

Many investigators have studied the effect of various parameters on performance of paddle wheel aerators. Ahmad and Boyd (1988) found that shaft power input and standard oxygen transfer rate (SOTR) increased linearly with increasing paddle depth, rotational speed, and number of rows of paddles. Standard aeration efficiency (SAE) decreased slightly with increasing paddle depth and was essentially constant with increased number of rows of paddles. However, there was no marked influence of speed on SAE. Efficiency of paddle wheel aerators is apparently related to rotational speed. Ruttanagosrigit, *et al.* (1991) found that paddle wheel aerators had higher SAE values than the propeller-aspirator-pump aerators.

Propeller-Aspirator-Pump Aerators

Propeller-aspirator-pump aerators rely on a high-speed propeller to propel water rapidly away from the end of a diffuser mounted on the end of a housing that is open to the atmosphere. The Venturi principle causes air to be drawn into inside the hollow shaft and then passed through the diffuser. A strong turbulence at high water velocities causes an intensive mixing of the entrained air with the water, which leads to dispersion of fine bubbles (**Fig. 9**).

Fig. 9 A locally manufactured propeller-aspirator-pump aerator.

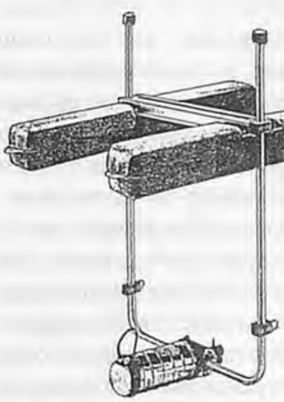

Fig. 10 Typical form of the commonly used Air-O_2.

Propeller-aspirator-pump aerators are commonly used in intensive aquaculture ponds in Thailand. These aerators produce strong horizontal mixing and they can be highly efficient. The most frequently used power source is an electric motor connected by a stainless steel shaft to rotate a plastic propeller. The propeller drive shaft is placed inside a hollow plastic housing. A 3000-rpm speed of the propeller is adequate for operation. Technical data on commercial air jets is given in terms of the ratio of dissolved oxygen per unit power input as shown in **Table 2**.

Table 2. Technical Data on Commercial Air Jets

Dissolved oxygen (kgO_2/hr)	Power input (kW)	Price (US$)
3	1.5	314
15	7.5	1,700

Propeller-aspirator-pump aerator, locally called Air-O_2, is also used in some cases (**Fig. 10**). It is composed of a high-speed submersible electric motor with a small propeller installed underwater in a horizontal position. Air is sucked in through small holes in the tubular frame based on Venturi principle. A mixture of air and water is discharged into water at high velocity. The dissolution of oxygen occurs as the air passes through the water. This process moves only a small volume of water in horizontal direction because the thrust force generated by the rotating propeller is small. This type of aeration is commonly used in ponds with water depth of 1.5 m or more with firm pond bottom. Propeller-aspirator-pump aerators are usually installed near the pond corners in order to move sediment mounds to the central area of pond. Air-O_2 does not produce strong current of water, so it is suitable only for oxygenating water.

Diffused-Air Aerators

Diffused-air aerators release air at the bottom of ponds. As air bubbles rise, oxygen diffuses from bubbles into the water. The efficiency of oxygen transfer is related to bubble size as small bubbles offer a greater air-water interface than large bubbles. Furthermore, a greater concentration gradient between oxygen in the bubble and oxygen in the water may be achieved by using pure oxygen or compressed air. Diffused-air aerators employ an air blower and tubing to deliver air to diffusers placed at the pond bottom. Small air bubbles released by the diffuser rise through the water, and oxygen in the air within the bubbles diffuses into the water. Diffused-air aerators must have diffusers at many places in the pond to provide uniform aeration and mixing. They are limited by water depth unless air is released very slowly from diffusers. The terminal velocity of rising bubbles is 0.32 m/s for a diameter of 1.2 mm and 0.24 m/s for a diameter of 6 mm (Ippen, Campbell and Carver, 1952). The short exposure time between gas and liquid phases lowers the efficiency of diffusion.

Bubble size is the major factor determining the surface-to-volume ratio of the gas phase and the flow pattern around the air bubbles in a gas-liquid mixture. It consequently affects mass transfer rate in several processes often encountered in aquacultural applications (Hackney and Colt, 1982; Watten and Beck, 1985; Reinemann and Timmons, 1989; Mohapatra *et al.*, 1989; Watten and Boyd, 1990), including degasification (Miller and Libey, 1983; Colt and Bouck, 1984) and foam fractionation (Chen, 1991). Factors affecting bubble sizes have been extensively studied (Kumar and Kuloor, 1970). In a typical diffusive bubble generation system, bubble size is mainly affected by airflow rate, orifice diameter, and surface tension of liquid (Bowonder and Kumar, 1970; Kumar and Kuloor, 1970; Azbel, 1981; Popel 1979). The effects of different factors on bubble size result from their impact on the process of bubble formation. At low air flow rates, the bubble size is independent of the air rate, and the frequency of bubble release is proportional to the airflow rate. At high air flow rates, the bubble diameter increases as a function of flow rate and the frequency of release remains constant. The mean bubble diameter is an exponential function of the airflow rate (Popel 1979).

There are many ways available to determine bubble size (Semiat and Dukler, 1981); Viswanathan and Rao, 1984; Bieso *et al.*, 1985; Meernik and Yuen, 1988). The most common approach to measure size involves photography (Shah *et al.*, 1982; Dobby, 1984; Cheremisinoff, 1986). Besides photography and light scattering, another optical approach, which has received considerable attention in the past twenty years, is laser-doppler anemometry

(LDA) extended to two-phase flow. This technique is most readily applied to bubble or particle sizes up to a few hundred microns (Ungut *et al.*, 1978; Yule *et al.*, 1977; Lee and Srinivasan, 1978).

Because ponds for shrimp farming are shallow, diffused air aerators, which release bubbles at the bottom, are inefficient. The vertical distance through which bubbles rise is not large enough to allow time for efficient transfer of oxygen from bubbles to water. Other problems are diffuser clogging problem and the time required for maintenance. Diffused-air aeration is not widely used in shrimp farming except on some farms in southern part of Thailand.

Water Circulators

Induced circulation of pond water increases water flow and delivery of DO to the surface of the sediment, lowering the possibility of anaerobic conditions at the sediment-water interface. Because aerators induce water circulation and cause greater velocity of water across pond bottoms, they may resuspend sediment. Solids suspended by aerator-induced currents can increase the turbidity of pond water. Also, solids can settle in areas of ponds where water currents are low to create sediment mounds. These sediment mounds consist primarily of mineral soil particles, and some organic solids suspended by aeration. The sediment mounds in ponds have a high oxygen demand. In intensive shrimp farming, the superficial layer of sediment mounds may become anaerobic even though aeration maintains sufficient concentrations of DO in pond water.

Bottom sediments are the major consumers of oxygen in shrimp ponds. Fast *et al.* (1988) found that respiration rates in 1-m deep, 0.1 ha shrimp ponds were about 0.43, 0.12 and 0.02 kg O_2 per hour for sediment, plankton, and shrimp, respectively. Sediment respiration rates are further increased by uneaten feed. Organic matter from uneaten feed, feces, and dead plankton settles to the pond bottom and decomposes, leading to anaerobic conditions in the superficial layers of bottom sediment and release of toxic microbial metabolites into the overlying pond water. Bottom waters are typically depleted of oxygen due to respiration and are isolated from replenishment via photosynthetic activity and surface diffusion. Aeration alone is not always able to correct this imbalance since the oxygenation effects of aeration are felt mostly near the surface. Aerators vary in their ability to generate horizontal water movement. Water circulators or mixers are more appropriate for this purpose. There has been considerable interest recently in water circulator equipment that directs most of its energy to circulating pond water instead of aerating it. The low-energy water circulation devices could be used to circulate pond water during the daytime when DO concentrations are high. This would blend oxygen-supersaturated surface waters with deep layers of low DO concentrations. Ideally, a water circulator can produce uniform gentle water currents over pond bottom only to suspend fresh organic particles without suspending mineral soil. Suspending organic particles in the water would enhance the availability of DO for their decomposition. Preventing the deposition of mixtures of organic and mineral particles at the pond bottom would reduce the likelihood of areas with anaerobic conditions at the soil-water interface. Rogers and Fast (1988) described 2,000 gallons per minute axial flow circulator with a 600 mm propeller driven at 60 rpm using only a 0.25 hp engine. Using this device for controlled mixing, they increased production in prawn ponds by as much as 11% over that in ponds with no provision for circulation. Fast *et al.* (1988) found that growth of tiger shrimp in ponds with circulation increased, and that deeper ponds benefited from the use of water circulators. Successful deployment of water circulators depends on proper sizing and selection of flow velocity. Rogers (1990) noted that a minimum velocity of 50 mm per second is necessary to prevent stratification in most ponds, whereas 150 mm per second is required to maintain sediment in suspension. He suggested that an intermediate flow velocity of 76 mm per second would provide sufficient flow for destratification and waste removal without disturbing the pond bottom. Excessive velocity is economically wasteful, and the resulting scouring effect may erode the pond bottom and increase turbidity.

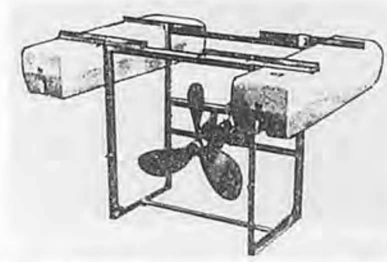

Fig. 11 General view of a locally manufactured water circulator.

In Thailand, most water circulators utilize large diameter propellers turning at slow speeds and are quite energy efficient (**Fig. 11**). A submersible gear motor is connected to an aluminum axial propeller positioned underwater and supported by zinc-galvanized steel frame. Two polyethylene pontoons support all components. Rotary speed of the blades is 120 rpm. The size of the electric motor required depends on the depth of submergence of the propeller as shown in **Table 3**. Typically, Thai farmers install locally manufactured propellers on a long shaft driven by an electric motor or a diesel engine in order to circulate pond water (**Fig. 12**).

Discussion

Aerator selection for a particular system depends on system characteristics, economics, aerator avail-

Table 3. Technical Data for Comparison of Water Circulators

Power input (kW)	Rotor revolution (rpm)	Rotor diameter (mm)	Adjustable depth (mm)	Water depth (m)	Generated water velocity (m/s)	Price (US$)
0.75	120	600	630-1120	1.2	0.6	1,000
1.50	120	600	630-1120	1.4	0.6	1,225
2.20	120	600	630-1120	1.6	0.6	1,650

Fig. 12 Many propellers installed on a long drive shaft for circulating pond water.

ability and other factors. Most aerators used in Thai aquaculture are based on modifications of wastewater aerator designs. Aerators for wastewater treatment are designed for maximum oxygen transfer efficiency with little consideration to its influence on soil. Design modifications imposed to make aerators less expensive for aquaculture often result in lower oxygen-transfer efficiency. Oxygen-transfer tests are not widely practiced in commercial aquaculture in Thailand. Standard test rig and other apparatus are not easily available. However, some Thai researchers have studied the aerator performance in standard test conditions, for example, Ruttanagosrigit *et al.* (1991) studied the effect of salinity on oxygen transfer by propeller-aspirator-pump and paddle wheel aerators used in shrimp farming. The oxygen-transfer tests were conducted in a circular, concrete tank with a water depth of 0.65 m and a volume of 49 m^3 at Aquaculture Department of Kasetsart University, Bangkok. They found that oxygen transfer efficiency for the propeller-aspirator-pump aerator manufactured in USA (1.20 kg O_2/kWh) was roughly 1.5 times greater than that of the Taiwan-style paddle wheel aerators.

Statistical information on the number of each aerator type used in shrimp farming in Thailand is not available. The annual report of DOF has never reported aerator types, number of aerators used and power demand for aerators used in farming. Thai farmers also do not pay enough attention to variable costs.

Aerator testing is expensive, but it can provide very useful information. It is clear that aerator testing can provide data for comparing the efficiencies of different aerators. It also may be used to determine how changes in aerator design influence efficiency. Aquaculture aerators manufactured in or out of the country should be tested and evaluated. The manufacturers should receive certificates of standard quality from an authorized government agency. The technical standardization criteria for the investigation of aquaculture aerators are yet to be established.

Summary

Aerators in Thai aquaculture are used for oxygenating the culture water and moving sediment mounds to the center of pond. Thai farmers use a variety of aerators in their ponds. Each aerator type has certain advantages and disadvantages.

Paddle wheel aerators force water away from them and do not create small zones of influence. They can oxygenate water at the surface level, but induce less water movement at deeper level. Moreover, they cannot blend oxygen-saturated surface waters with deep layers of low DO concentrations.

Diffused-air aerators inject air into water in the form of bubbles, and oxygen is transferred from the bubbles to the water by diffusion across the liquid film. The vertical distance through which bubbles travel should be large enough to allow adequate time for efficient transfer of oxygen from bubbles to water, which is seldom the case in aquaculture ponds. Therefore, these aerators are quite inefficient. Other problems with this type of aerator are clogging of diffuser holes and frequent maintenance.

Propeller-aspirator-pump aerators rely on a high-speed propeller. Venturi principle causes air to be drawn and passed through the diffuser to enter as fine bubbles into highly turbulent water in front of the propeller. They are particularly efficient in mixing pond water because the aeration shaft may be positioned at an inclined angle with the horizontal to direct water forward and also downward. This provides better water flow across the pond bottom and tends to cause more vertical mixing between surface and bottom layers than is achieved with aerators that produce mainly horizontal water movement. However, because of inclined angle operation, the force generated by moving water may suspend mineral soil to increase turbidity in the pond. Moreover, because of high speed blade revolution, the propeller blade can be easily damaged by cavitation. For Air-O_2 aerator, since there is little or no difference in the velocities of water and air bubbles, the renewal of the interfacial surface is low and so is oxygen-transfer efficiency.

An ideal aerator should perform following functions:

1. Destratification of temperature and dissolved oxygen,
2. Reduction of toxicity at the soil-water interface,

3. Maintenance of small particles in suspension, which facilitates the decomposition of organic matter and reduces the incidence of localized anaerobic micro-environments in the pond, and
4. Improvement of habitat utilization and distribution of the shrimp over the feeding area.

Based on this review of various aerators used in Thai aquaculture, authors suggest that design changes are needed so that an aerator can effectively perform both aeration and water circulation in ponds. This will help in improving water quality in ponds. For circulation, the unit should have large diameter propeller rotating at low speed in order to move a large volume of water. The rotational speed should be low enough to produce a gentle water movement not to disturb or erode the bottom soil and also to prevent cavitation. To achieve this, the configuration of propeller shape should be further improved. For oxygenation benefits of aeration, propeller-aspirator-pump aerator, having higher efficiency than most other aerator types, is suggested. It uses venturi principle for aeration. However, the renewal of the interfacial surface is low in the venturi process. To overcome this problem, the renewal surface can be created by the operation of propeller. The renewal surface is produced by continuously passing a portion of two-phase flow from a venturi nozzle and moving the water over the pond. Oxygenating efficiency of various ratios of airflow rate to water flow rate in venturi operation should be tested according to standard test conditions. Such aerator should be designed for maximum SOTR with minimum SAE.

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(Continued from page 63)

Farm Mechanization in LalgudiTaluk of Southern India

2. Planting and harvesting operations of all the major crops, namely; paddy, sugarcane, and cotton need to be mechanised.
3. Non-availability of suitable machinery for planting and harvesting is the major bottleneck in the progress of farm mechanization. As the educational level of farmers is low, training programmes to improve farmer's technical skills are necessary for successful farm mechanization. Government needs to play a major role in this issue.

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ABSTRACTS

The ABSTRACT 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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A Study of the Photo-electrometric Technology Controlling Precise Planter. He Pei-xiang, Director, Agricultural Engineering College, Southwest Agricultural University, Chongqing, 400716, CHINA. Wu da-ke, Graduate student of the same university. Chen Zhong-hui, Associate Professor of the same college.

The paper introduces the structure controlling principle and the related software diagram of a precise planter, which adapts to plant the plastic seedling plate during the industrial growing seedling and is controlled by a single chip microcomputer with the photo-electrometric technology. After the initial test, it is shown that there is 98% one seed in every hole of the plate, 2% two seeds and 0% three seeds or over three. The hole-rate is zero.

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Effect of Level of Energy Inputs on Yield and Energy Requirements in Agriculture. S. K. Dash, Associate Professor, Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar, Orissa, INDIA. D. K. Das, Professor and Head of the same.

The experiment was conducted for paddy groundnut crop rotation with 12 hp power tiller as the power source except diesel pumpset and electric motor being used for specific operations. The experiment was layed with three level of depths, 8 cm, 11 cm and 14 cm and four level of tillings, 1,2,3 and 4 passes of the rotary tiller. The energy input was increased by increasing the depth of tillage and number of tillings. The design of experiment was split plot design. The depth of tillage had significant effect on yield, human energy, indirect energy and total energy for paddy and for groundnut crop the interaction had significant effect on yield, indirect energy and total energy. The highest yield was obtained with 11 cm depth of tillage and four tillings for both paddy and groundnut crops.

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Production Technologies and Agricultural Mechanization in San Luis Potosi, Mexico. Héctor Martín Durán García, Professor, Facultad de Ingeniería, Av. Dr. Manuel Nava 8, Zona Universitaria, Universidad Autónoma de San Luis Potosí, San Luis Potosí, C.P. 78290, MEXICO. César Posadas Leal, Professor of the same. E-mail: cposadas@deimos.tc.uaslp.mx.

One of the most important economic factors in agriculture is the soil and its efficient preparation, using the appropriate production means, completing in time and with standard of acceptable quality. However, when it is not worked in an appropriate way, serious problems are presented due to alteration of the natural cycles of reinstatement of nutrients and to the affectation of the relationship of dynamic balance between soil, flora and fauna. The soil physical, chemical and biological deterioration is manifested by decreasing fertility, erosion and contamination that it is reverted towards man. With the vision to create a strategy of mechanization and agricultural development, this work approached the situation that agricultural mechanization be kept in San Luis Potosi, Mexico. To achieve that, huge amount of information was obtained in libraries and field visits. It is concluded that there is a close relationship between the self-consumption, the agricultural instruments and animal traction, as well as commercial crops and agricultural machinery. However, in the latter are present some practices that can only be performed with agricultural instruments. The use of machinery requires a total change on technology. This explains the existence of both means of production in commercial agriculture in San Luis Potosi, the crops and traditional practices change which implies that animals tend to be displaced.

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Comparative Tractor Use in Borno State of Nigeria between 1984 and 1998. M. A. Haque, Reader, Department of Agricultural Engineering, Faculty of Engineering, University of Maiduguri, Maiduguri, NIGERIA. E-mail: haque@unimaid.edu.ng. Bobboi Umar, Senior Lecturer of the same. E-mail: bobboi@unimaid.edu.ng. A. Y. Arku, Lecturer of the same. E-mail: arku@unimaid.edu.ngcollege.

The paper compares the levels of tractor use in Borno State, Nigeria, in 1984 and 1998. The major operations performed by tractors in 1984, namely; disc harrowing and disc ploughing were still the important operations carried out in 1998. The available tractor makes and models rose from 12 and 31 in 1984 to 16 and 61, respectively, in 1998. Despite this increase, however, the specific tractor population density (STPD) decreased from 0.28 in 1984 to 0.22 in 1998. Also, there was a decrease in the specific tractor wattage from 14 W/ha in 1984 to 12 W/ha in 1998. This means that farm mechanization suffered a setback during the 15-year period, with fewer functional tractors and less power available per 1000 ha of cultivated land. The major problems of tractor use in the State were high overhead cost, lack of spare parts of some makes and poor operational skills. Despite these odds, there was an appreciable improvement in tractor maintenance culture by both private and public sectors in the State during the 15-year period. The STPD needs to increase considerably and tractor use needs to be diversified so as to uplift farm mechanization in Borno State in the new millennium. ■■

2nd WASAE International Conference on Agricultural Engineering Kumasi, Ghana.

20-24 September, 2004, Ghana.

Organized by the West Africa Society of Agricultural Ingineering (WASAE) and the GHANA Society of Agricultural Engineering (GSAE), under the Auspices of the Ghana Institution of Enginners (GhIE).

Background:

The West Africa Society for Agricultural Engineering (WASAE), a regional grouping of agricultural engineers and allied professionals in West Africa, was conceived in Kumasi Ghana during the second GSAE international conference held in Kumasi in 2000. The first WASAE international conference was held in Abuja, Nigeria in 2002. Ghana the birth place of WASAE is hosting the 2nd International conference under the theme:Hunger without frontiers.

WASAE has taken up the challenge and is pushing to serve as the technical advisory committee to ECOWAS in the solution of food insecurity and poverty reduction problems in the sub-region.

The agricultural industry is currently faced with the need to diversify production, improve product quality, safeguard the health of workers and consumers and protect the environment. WASAE is therefore poised in taking a leading role in achieving this in West Africa.

In support of the above, an international conference is being organized to create a forum for experts to deliberate on the issues and provide recommendations for research, development and policy directions.

Topics:

The conference will focus on engineering in Agriculture. Several state-of-the-art papers are expected to be presented to gain a broad up-to-date understanding of the field. Invited papers are expected in the following areas:

-Food Security, Hunger and Malnutrition in West Africa.
-HIV/AIDS and its impact on Agricultural Production
-Power and Machinery Engineering
-Soil and Water Engineering
-Post-harvest Engineering and Biotechnology
-Conservation Agriculture interventions
-Agro-energy Sources and Management
-Rural transport and IMTs
-Environmental Conservation
-Gender, Policy, Training, Extension etc.

Conference Venue:

The venue of the conference will be the Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. Kumasi, located in the forest zone, is the Garden city and the cultural capital of Ghana.

For further information, please contact:

Emmanuel Y.H.Bobobee
Conference Secretary
Agricultural Engineering Department
KNUST
Kumasi-Ghana
Tel: +233 51 60242
Fax: +233 51 60137
E-mail:ebobobee@yahoo.com; yebobobee@yahoo.co.uk
Or wasae2004@yahoo.co.uk

Registration:

The registration fee for the conference will include the cost of proceedings, refreshments, lunch, banquets and a technical and cultural tours.

Registration on site is also possible but payments in advance are preferable. The cost of registration is US$200. Registered members of GSAE and local participants will pay a discounted rate of 250,000 cedis. Payment by foreign participants should be in international money order and should be made in the name of "Ghana Society of Agricultural Engineering. (GSAE)"

UNACOMA Agricultural Machinery Production, 2002

Italy

Agricultural machines went well in 2002 and show growth prospects in 2003 and 2004; earth-moving machines down. Guglielmo Gandino elected as new president. Outgoing President Aproniano Tassinari calls for an "ethical vision of the economy"

Italian manufacturers of machines for farming, park maintenance and earth-moving closed 2002 with total turnover of 9.293 billion euros, and production that weighed in at 1,447,000 tons.

The figures, which were presented by Aproniano Tassinari, the outgoing president of UNACOMA, the Unione Nazionale Costruttori Macchine Agricole, a Confindustria memger, confirm that the sector is at about the same level as last year in terms of value, even if weight is down by 1.45% on 2001.

The figures, which Tassinari illustrated at UNACOMA's annual assembly at San Lazzaro di Savena near Bologna on June 24, show significant gains for agricultural machines, but a fall for earth-moving machines. This confirms the forecasts of the UNACOMA-Prometeia Observatory for the sector in November.

Agricultural machinery rose by

NEWS

1.38% in weight to 911,665 tons and 2.64% in value to 6.505 billion euros.

15th International Conference of the International Society for Terrain-Vehicle Systems Integration of Technologies 25-29 September 2005

Shonan Village Center in Hayama, JAPAN

The results from the two sectors are in lline with international trends which show a resumption of agricultural machine sales, in Europe above all.

Export figures painted much the same picture. Agricultural machines rose by 3.09% in weight and 3.91% in value.

The sector's trade balance compared to 2001 showed a 5.69% fall in weight and one of 5.54% in value. But there was still a good surplus of exports over imports at 3.146 billion euros.

Comforting figures from Istat for the first quarter of 2003 showed that, compared to the same period of 2002, tractor exports held their own, other types of agricultural machine gained 10% and earth-moving machines rose by 13%. Forecasts for 2003 and 2004 show further growth, above all for agricultural machines. In particular, Italian tractor production, which fell from 84,458 in 2001 to 84,234 in 2002, should rise to 84,856 in 2003 and 87,220 in 2004. Domestic sales should rise from 33,081 in 2002 to 33,809 in 2003 and 33,927 in 2004.

Invitation to the 15th international conference

The ISTVS has been working to advance knowledge, innovations and improvements in terrain-vehicle systems in engineering practice for over forty years. We focus on topics that govern and impact the safe, efficient, economical, productive and environmentally responsible operation of vehicles and machinery, principally on off-road terrain and accumulated research outcomes. We also promote the transfer of advanced knowledge to industry at large in environmental protection, energy conservation and sustainable development.

Having entered the new century, the pace of advancement of new Information Technologies is faster than ever before. The conference organizing committee selected "Integration of Technologies" as the main theme of the 15th international conference. It is time to integrate our historical assets as well as new technologies into terrain-vehicle systems and to create new currents.

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Crop Management and Postharvest Handling of Horticultural Products Volume 2 -Fruits and Vegetables

(USA)

by Ramdane Dris, Raina Niskanen, Shri Mohan Jain

The aim of this volume is to provide the scientific community with an accurate and up-to-date information in the field of postharvest handling and technology. The book highlights the achievements in minimizing the postharvest loss, and provides information on postharvest technology, physiological changes, storage problems and processing aspects.

The book will stimulate researchers and students alike with information to identify and solve problems related to postharvest quality and familiarize themselves with techniques used before, during and after the storage of a wide range of commodities grown under different environmental conditions.

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