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AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.49, No.3, SUMMER 2018

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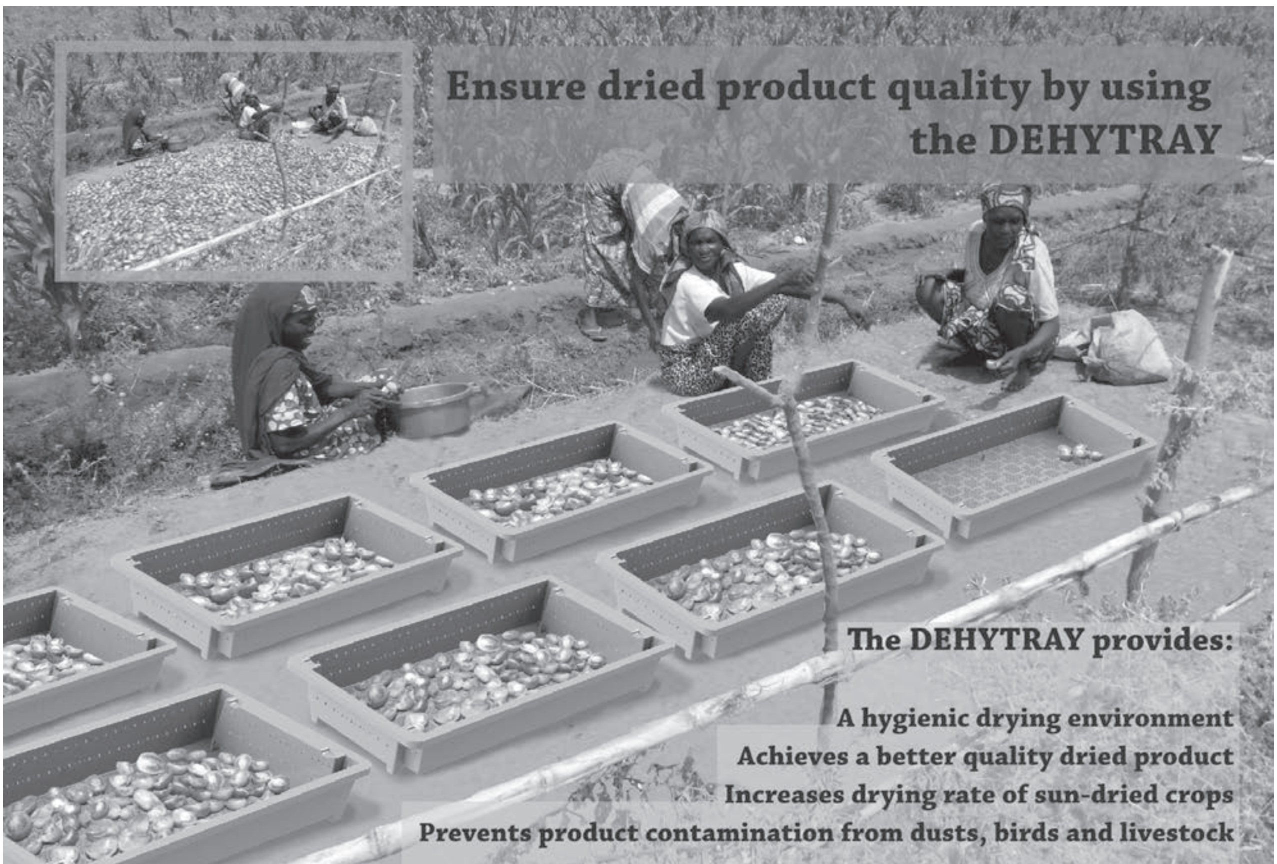
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This is the 176th issue since its maiden issue in the Spring of 1971

EDITORIAL

We strongly featured the agricultural mechanization in Africa in the spring issue this year. Africa encompasses more than 50 countries and there are huge differences in the level of agricultural mechanization among them. Given the rapid increase in population in Africa, its sustainable agricultural development is necessary for food security in the world. To achieve this, mechanization will play a significant role. This was the reason we focused on Africa. However, as you know, there are lot of countries in Africa and reporting on all of them in one go was beyond our capacity. So we plan to feature Africa from time to time. Actually, we are going to do so in the coming autumn issue.

I recently attended a lecture on the current situation of agriculture and its mechanization in Russia. Perestroika destroyed Russia's systems including the agricultural mechanization system. The dysfunction left a half of its farmland unattended. It amounts about one hundred million hectares. This is a precious resource not only for Russia, but also for the world to feed its ever-increasing population. Each country has different challenges in the field of agriculture and its mechanization and we need to tackle them hand in hand as the world citizen. To do so, strengthening international communication among people in this field is essential. It is very important that Prof. Umezuruike L. Opara, our cooperating editor in South Africa and the incoming President of CIGR, took the initiative and organized a new regional society of agricultural engineering in Africa, AfroAgEng-the Pan African Society for Agricultural Engineering. It needs to get attendance and cooperation not only from African countries but also from other regions in the world to achieve great success.

As I have insisted again and again, there are limits to available resources for food production although the population increase seems limitless. Especially, we cannot hope for expansion of the farmland. Therefore, improvement in land productivity is absolutely imperative. To achieve this, timely and precise work is required and the role of agricultural machinery is more and more significant. With development of AI, agricultural mechanization is entering a new era. Like the spread of smartphones throughout the world, various forms of agricultural robot will also contribute to agricultural mechanization in the world.

Yoshisuke Kishida
Chief Editor
July, 2018

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Standadising the Farm Machinery Research Prototypes for Commercialization—Case Study

by
V. M. Duraisamy
Professor (Farm Power & Machinery)
Dept. of Farm Machinery
Agril. Engr. College & Research Institute
TNAU, Coimbatore
INDIA
vm_durai@yahoo.com

Abstract

Rural artisans and small scale manufactures are the major producers of the farm implements in Indian agriculture. They lack in manufacturing technologies and still continue to fabricate and produce either the traditional implements and machinery or nonstandard farm machines. Also, the artisans and most of the small scale manufacturers do not understand the manufacturing drawings developed by the researchers and they fabricate the prototypes by copying the sample piece. Hence quality and standard machines are not available to the farmers and these equipment fail in the field. Hence a better linkage is needed to be created between the research institutes, manufacturers and farmers to promote farm mechanization. The research and development efforts are left with a functional prototype. In many cases, the quality and performance of the commercial farm machines copied from the research prototype do not meet the real function and they fail in the field. Based on these issues, a research was focused on the development of production designs/technologies for mass manufacturing. In as many as 10 research prototypes suitable for rice, groundnut and horticulture crops were taken; they were manufactured in large quantity and introduced to the farmers. The production design concepts, production processes, production drawings, specialized manufacturing tooling and technologies were developed for the selected research prototypes. These techniques and properly developed human resource management led to commercialization and popularization with considerable cost saving. The standardized production and manufacturing technologies resulted in 28-35% saving in production cost on mass manufacturing technology.

Keywords: Agricultural machinery, prototype, manufacture, designs, tools, commercialization

Introduction

In agriculture, farm equipment is highly important for maximizing the efficiency of inputs like seeds, fertilizers, pesticides and irrigation water. The improved, efficient and reliable farm equipments are required in adequate number which can be achieved by commercializing the potential research prototypes developed by various organizations. Over hundred numbers of research prototypes were developed at Tamil Nadu Agricultural University, Coimbatore, India but only a very few have reached the commercial stage. In the present scenario the artisans and small scale manufactures, who are major producers of the farm implements, still continue to fabricate/produce the traditional implements/machinery and the users have no alternative except to use these for various agricultural operations. The research and development organizations have poor infrastructure, therefore, most of research efforts are left at the stage of producing a functional prototype. On the other hand the artisans in the rural areas and most of the small scale manufacturers do not understand the manufacturing drawings prepared by the research organizations. They can fabricate the prototypes only by copying the sample piece. In many cases where the manufacturers have taken some research prototypes for commercialization, the quality of manufacture and performance has not been up to the mark as the copying is done from the functional design in absence of engineering production design and production technology. The other important reason for production of non quality implements has been non development of production process/technology for manufacturing and mainly the hammer and chisel techniques are followed in most of the cases. Therefore, the problem remains and the farmers/users do not get the adequate/desired benefit of the efforts of research organizations. The small scale manufacturers, manpower employed by them and the artisans could not upgrade their skills in manufacturing technology up to the mark due to weak linkages between the agencies and them. With this aim a study was undertaken for the development of production designs of selected research prototypes, develop production process for their multiplication and produce them in sufficient numbers for pilot introduction and popularization.

Review of Literature

Development and commercialization of new technologies has inherent uncertainties and associated risks. In a competitive world of scarce resources, new technologies fight for survival against developed technologies that promise immediate returns with comparatively little risk. Technology is a key resource of profound importance for the well being of a national economy as well as international competitiveness (Kumar and Jain 2002) in addition to the vitality for corporate profitability and growth. Technologists and policy makers need to provide wider perspectives that encourage an entrepreneurial spirit that nurtures new technologies in an enabling environment through appropriate policy initiatives. In addition to teaching and research, universities are increasingly expected to take on technology transfer and commercialization as a part of their mission (Einar Rasmussen *et al.*, 2004). This development gives new challenges to the institutions in making initiatives to promote commercialization of university knowledge. Attempts have to be made to look at the issue of commercialization of university technology from the viewpoint of the institutions themselves (Jillian MacBryde, 1997). Constructive model has to be provided with the aim of providing universities and researchers with a tool to aid decision making as to which ‘technologies’ to commercialize and which route to commercialization would be most suitable in each case. In the light of evidence put forward by applying the framework, alternative routes to commercialization are to be discussed along with possible outcomes. Christoph Grimpe (2004) said that the fruits from research and development activities (R&D) do not always necessarily follow a company's technology strategy. The article reports from an internal Corporate Venture Capital (CVC) unit at a large German industrial conglomerate that is dedicated to promoting innovative shelf warmer technologies. It is shown that successful innovations ‘off the beaten track’ require more than simple start-up financing but a solid organizational commitment to such ‘irregular’ projects. Scott Shane (2002) discusses four dimensions of university-entrepreneurial firm collaboration—(1) industry-sponsored contract research, (2) consulting, (3) technology licensing and (4) technology development and commercialization—of which practitioners involved in university-private sector technology interaction need to be aware. The article identifies specific findings in each of the four areas and suggests important avenues for future work.

Methods and Materials

The improved agricultural machinery is to be made available to the farmers off the shelf. The research efforts put in by the various organizations will bear the fruits only if these reach the intended users. The rational approach will be the commercialization of these research prototypes and making them available to the users/farmers. The use of these improved and better machines will contribute towards increasing production and productivity. For commercialization it is important to create their need among the users which can be done by making these prototypes available in sufficient numbers for pilot introduction, demonstration, and popularization. The small scale manufactures will only take up the product if there is a demand for these implements and machinery. Therefore, the batch type productions facility at the research center and desired to convert the functional prototypes into commercial propositions were taken up.

The activities viz., strengthening of the capabilities of the centre in the mass production of research prototypes, development of production design and toolings for the ten selected ten agricultural implements and machines designed and developed by TNAU, batch production of the prototypes in large quantities, human resource development to train the rural artisans and agricultural machinery manufacturers and development of linkages with the manufacturers, extension departments and social service and non governmental organizations by conducting field days and exhibitions, personal contacts and industrial visits were undertaken.

Results and Discussions

Renovating the Facilities of Research Centre

The modern equipment, for example, metal inert gas welding machine, under crank shearing machine, universal shearing and punching machine, high capacity press brake, lathe, diesel generator set with automatic main failure control, universal tool and cutter grinder, portable electrical and hand tools and assembly tools, quality control inspection and measuring instruments, loader, power press, air compressor, manual sheet metal machines, measuring instruments and hand tools and computer with design software were procured and installed for ensuring enhanced workshop facilities for mass production of prototypes with sufficient work and office spaces. Sufficient quantity of raw materials like steel rods, flats, angles, special sections, mild steel sheets, galvanized iron sheets, standard components, bolt and nuts, etc were procured for the production of prototypes.

Development of Manufacturing Design and Mass Production Technology

The characterization, selection of materials and material specifications, selection of standard parts, selection of production process and selection and development of tooling for the prototypes (the sample details are furnished in **Fig. 1**) listed in **Table 1** were made.

The large scale production of prototypes, manufacturing tools developed and the saving production cost for the prototypes are furnished in **Figs. 2** and **3**.

Commercialization Influenced by Industrial Linkage

A series of trainings were organized in parallel for both the rural artisans and the small scale manufacturers selected from the project operating area. A set of 130 rural artisans were trained on "Manufacturing and fabrication techniques of agricultural implements", while another set of 130 numbers of were trained small scale manufacturers were trained on "Advances in manufacturing technology of agricultural implements and machinery". Trainings were offered for 20 and 2 days respectively for the rural artisans

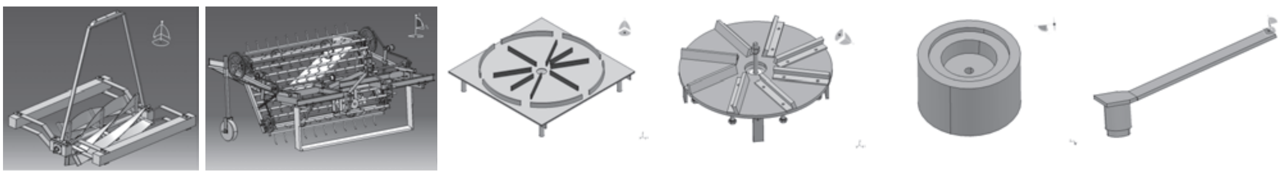


Fig. 1 Manufacturing design and development of toolings

Table 1 Operation-wise research prototypes and developed manufactuing tools

Operation	Name of the research prototype	Name of the tool/manufacturing aid
Filed/Seedbed preparation	Helical blade puddler	Fixture for welding the helical blade
	Post hole digger	Auger flight template
		Fixture for fabricating the auger flights
Sowing/Transplanting	Tractor cultivator mounted seed planter	Template for seed box
		Templates for seed funnel & shutter slots
		Template for seed box partition
		Templates for seed funnel sheets
		Welding fixture for ground wheel
		Drill jig for seed cup
		Fixture for welding seed cup with disc
	Manual Paddy drum seeder	Sketch out pattern of seed hopper
		Die for bending the frame body & lever
		Fixture for welding the frame
		Die for bending the ground wheel
		Dies for forming the end cup
	Manual Rice transplanter	Welding fixture for assembling the rice transplanter
Intercultivation	Cono weeder	Wooden die for cone shape,
		Die for forming the big end cap,
		Die for forming the end cap (top and bottom)
		Welding fixture for handle
	Rotary power weeder	Template for fixing the tynes in the rotary disc
Harvesting	Groundnut harvester	Fixture for welding the pegs in picker conveyor
		Die for bending the picker pegs
	Self propelled paddy reaper harvester	Fixture for welding the cage wheel spokes
Post-harvest operation	Groundnut thresher	Template for threshing cylinder
	Vegetable seed extractor	Welding fixture for welding the spokes
		Conveyor flight template

and the small scale manufacturers.

One hundred and forty nine field demonstrations and trials were conducted benefiting about 120,000 farmers, extension officials and scientists. Twelve field days/exhibitions were organized benefiting 16,000 farmers, extension officials and scientists. The linkages were developed with the manufacturers and the details are furnished in **Table 2**.

With the conduct of large scale demonstrations and field trials, the centre gets lot of enquiry and there is gain a momentum in the sale

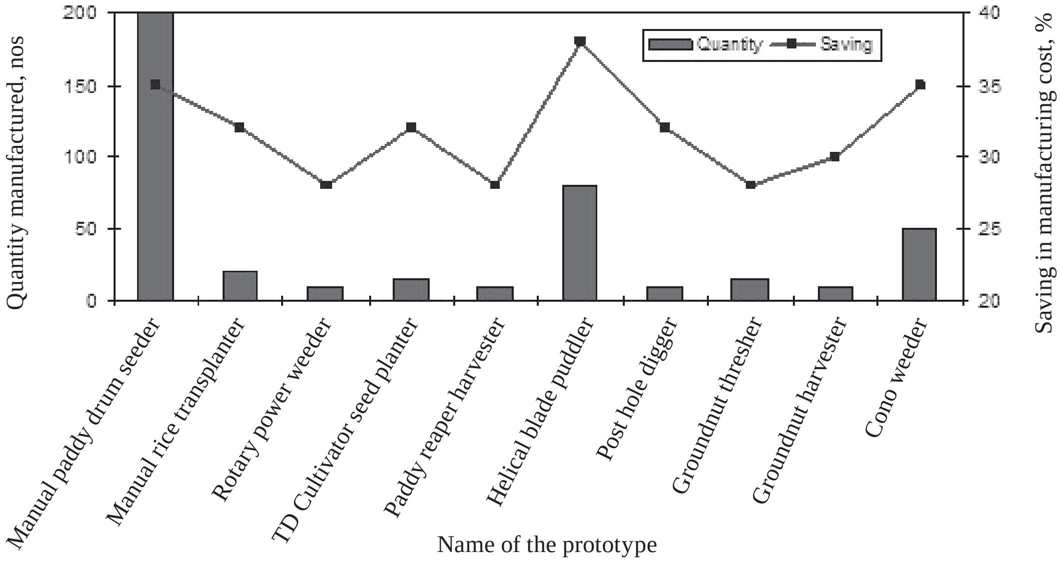


Fig. 2 Mass manufacture of prototypes

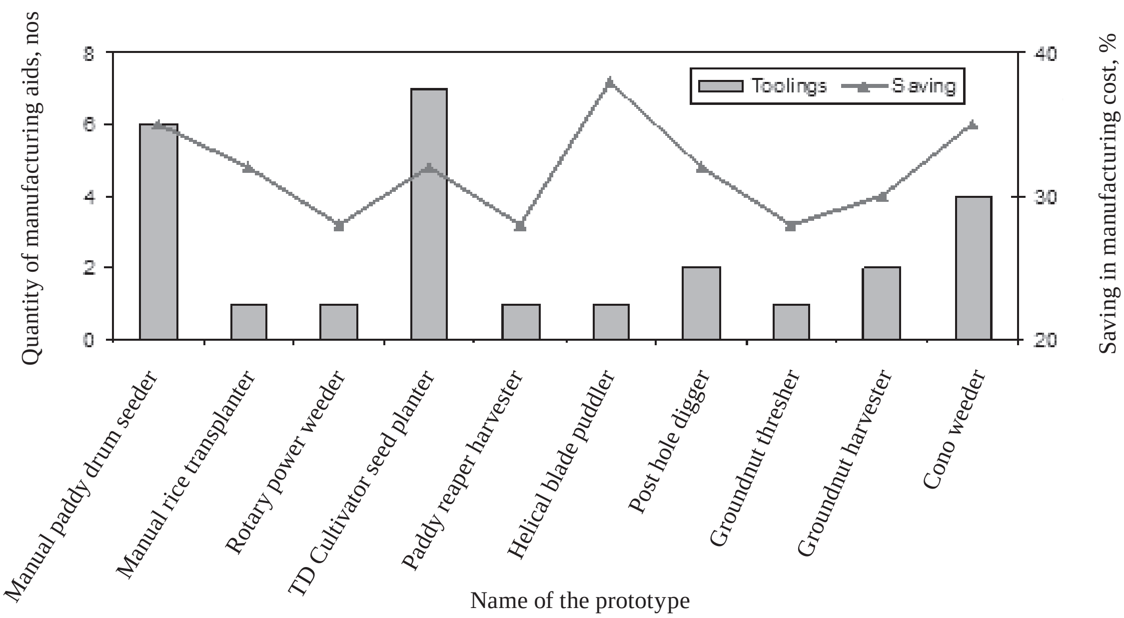


Fig. 3 Tools for mass manufacture of prototypes

of prototypes to the farmers and institutions. Many agricultural machinery manufacturers are coming forward to manufacture the equipments. All the 420 prototypes fabricated under the project were either sold out or taken on loan for use at the farmers' fields and in research farms. Eight research prototypes viz., Post hole digger, Tractor drawn cultivator seed planter, Manual paddy drum seeder, Cono weeder, Rotary power weeder, Self propelled paddy reaper harvester, Groundnut harvester and Groundnut thresher were successfully commercialized through the manufacturers.

Conclusion

- Production technologies and manufacturing tools for mass manufacture of ten research prototypes were prepared.
- Large scale manufacture of the ten research prototypes was undertaken at the research centre was undertaken.
- There is 28-35% saving in production cost with the use of manufacturing and production technologies
- The machines produced in large scale were sold out to farmers/institutions/organizations in different parts of Tamil Nadu and India.
- Eight prototypes were successfully commercialized by virtue of the development of linkages, demonstrations and trainings.

Acknowlegdements

The funding and technical guidance provided by the National Agricultural Technology Project, ICAR, and Tamil Nadu Agricultural University, India in carrying out the project is duly acknowledged.

REFERENCES

Anon. 1987. Small Manufacturing Enterprises, A World Bank Reserve Publications, Oxford University Press.

Grimpe, C. 2004. Making use of the unused: shelf warmer technologies in research and development Technovation, In Press, Corrected Proof, Available online 10 November 2004.

Rasmussen, E., Ø. Moen and M. Gulbrandsen. 2004. Initiatives to promote commercialization of university knowledge Technovation, In Press, Corrected Proof, Available online 23 December 2004.

Goetsch, D. L. 1990. "Advanced Manufacturing Technology", Delmar Pub Inc.

(Continued on page 15)

Table 2 Linkages developed for commercialization and popularisation

Linkages developed with (Name of organization)	Purpose for which linkages developed	Outcome
Department of Agriculture, Agricultural Engineering, Horticulture, Farm Science Centres and Non-Government Organisations	Demonstration and trials with the prototypes at farmers fields	The government has identified to supply the following prototypes to the farmers 12 nos of groundnut harvester 10 nos of groundnut digger 182 nos of long handled weeder
Trident Dynamics Ltd (AGRO), Coimbatore	Technical guidance in the manufacture of Rotary power weeder and self propelled paddy haevester (0.75m).	Successfully came out with commercial version of Rotary power weeder with different attachments
Valampuri Industries, Coimbatore	Technical guidance in the manufacture of groundnut harvester and power weeder	Started producing groundnut harvester
Ramkumar Industries, Coimbatore	Technical guidance in the manufacture of groundnut thresher	Started producing groundnut thresher
Sree Annapoorna Farm Equipments, Coimbatore	Technical guidance in the manufacture of Multi purpose thresher, Maize shellers & Groundnut machines	Working out modalities and arranging funds for large scale production of power threshers
Sree Bhuvaneshwari Industries, Coimbatore	Technical guidance in the manufacture of Groundnut thresher, T.D.Seed planter & Crop thresher	Commercially manufacturing the multicrop thresher. Procured the manufacturing drawings of the groundnut thresher
Vigneshawara Textile Engineers, Coimbatore	Technical guidance in the manufacture of Groundnut thresher, Power weeder & Power tiller implements	Started producing the equipments for the power tillers
TUCAS Ltd., Coimbatore	Technical guidance in the manufacture of all implements	The hand tools and bullock drawn equipments are being manufactured
Kovai Engineering, Coimbatore	Technical guidance in the manufacture of Groundnut Thresher & Crop threshers	The power threshers are being manufactured in large quantity
KSNM Marketing, Coimbatore	Technical guidance in the manufacture of paddy drum seeders and cono weeders	With tie-up the paddy drum seeders and cono weeders are manufactured in large quantity duely substituting the plastic material

Development of a Tractor Operated Mat Type Paddy Nursery Sowing Seeder

by
J. S. Mahal G. S. Manes Anoop Dixit

Aseem Verma Arshdeep Singh

Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana-141004
INDIA

Abstract

Paddy occupied 2.84 million hectares in Punjab state during 2012-13 with total production of 11.37 million tons. Paddy transplanting is still done manually in the state which is highly laborious requiring 180-250 man-h/ha. Farmers are facing difficulty in timely transplanting of paddy due to dearth of labour. For mechanical transplantation of paddy large numbers of plastic trays are required for raising of mat type nursery, which increases the cost of mechanical transplanting. Further, manual method of raising mat type nursery requires a number of operations. To accomplish all these operations in one go and to reduce the labour requirement, a tractor operated mat type paddy nursery sowing seeder has been developed. It consisted of 100 cm wide blade, two mould boards at both sides of blade and two counter rotating conveyors. In first prototype, choking of belt conveyor was observed due to accumulation of soil in pulleys and conveyor. Thereafter, soil collection unit was replaced by a positive drive chain conveyor. Performance of the conveyor unit for soil collection was found to be satisfactory, however, even depth of soil mat could not be maintained. The machine is having capacity of sowing nursery in 0.88 ha/day which is sufficient for transplanting paddy nursery in an area of about 160 hectare. There is saving of labour up to 85-90% and saving of 80-85% in cost of sowing mat type nursery as compared to traditional method of sowing mat type nursery on polythene sheet.

Key words: Mat type nursery, mechanical paddy transplanter

Introduction

Paddy occupied 2.84 million hectares in Punjab state during 2012-13 with total production of 11.37 million tons (Anon., 2014). Paddy transplanting is still done manually in the state which is highly laborious requiring 180-250 man-h/ha (Dixit *et al*., 2007). Farmers have to depend on migratory labour from other states for this job resulting in escalation of transplanting cost by two times in the past three years. Due to severe water crisis in the state, window period for paddy transplanting has been reduced by 10-15 days by the state government, as transplanting after June 10 leads to water saving. So, farmers are facing difficulty in timely paddy transplanting due to dearth of labour and high rates being demanded for transplanting operation. State government introduced paddy transplanters in Punjab state in 2009 and thereafter year by year adoption of paddy transplanters is in upward trend. These paddy transplanters use mat type nursery for transplanting paddy seedlings which is raised in plastic trays conferring the type of paddy transplanter. For transplanting one acre of paddy nursery, single wheel riding type paddy transplanter requires 140-150 mats and walk behind or four wheel drive transplanter needs 90-100 mats. Thus a large number of plastic trays are required which increases the cost of mechanical transplanting. Punjab Agricultural University, Ludhiana developed mat type nursery raising technique in which frames made of rectangular hollow steel pipes having 2 cm height are used along with 50-60 gauge thick plastic sheet (Mahal *et al*., 2010). For transplanting nursery for one hectare about 50 m^2 nursery area is required and two persons are required to sow mat type nursery for 2-3 hectare area in one day. Manual method of raising mat type nursery requires a number of operations. A well-prepared seedbed is used for sowing mat type nursery. One meter wide plastic sheet having thickness of 50-60 gauge is spread on the well prepared field and steel frames are placed on plastic sheet in line. Soil from the sides of frames is filled in the compartments of frames. Pre-germinated paddy seeds are evenly spread in each compartment to achieve a uniform density of 2-3 seedlings/cm^2. The seeds are covered by a thin layer of soil and water is sprinkled by hand sprayer for proper setting of soil and thereafter steel frames are removed. To accomplish all these operations in one go and to reduce the labour requirement, a tractor operated mat type paddy nursery sowing seeder was developed. The machine will help in timely sowing of mat type paddy nursery thereby will help in adoption of mechanical transplantation of paddy on a large scale.

Material and Methods

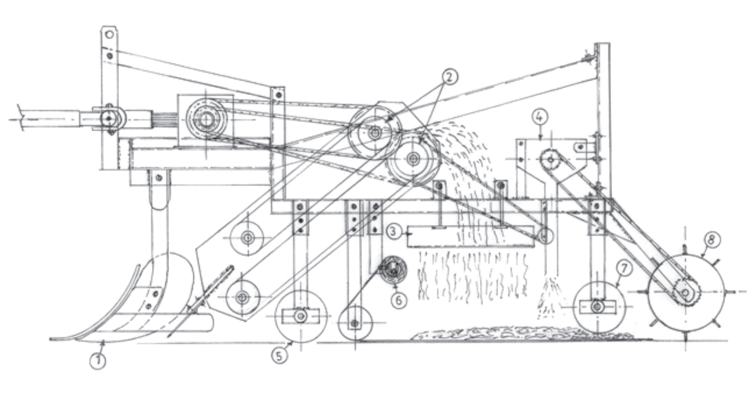
Development of Tractor Operated Mat Type Nursery Sowing Seeder (Table 1)

The conceptual design of the machine was developed. The machine consisted of 100 cm wide blade and two mould boards at both sides of blade to collect the soil from side of the blade and guide the soil on to the blade. These mould boards at the same time create trenches which act as irrigation channel for irrigating mat type nursery. The cut mass of soil is then guided into two counter rotating conveyors rotating at different speeds to crush the soil lumps/clods. The power to these conveyors is provided by belt and pulleys through tractor PTO. At the rear end of these conveyors an oscillating sieve was provided in which the soil coming in a layer from conveyors falls to remove all the unwanted material from the soil.

Below the counter rotating conveyors, two rollers were provided, one for pressing the soil and on another roller one meter wide plastic sheet was wrapped. With the movement of the machine, the roller would lay the plastic sheet on the ground. The soil coming from sieve would fall on the plastic sheet and makes one meter wide strip. A seed box having a fluted roller along its entire length drops the metered quantity of seed over the soil. The spring loaded roller at the end slightly presses the strip of soil and the seed. The strip is irrigated by guiding the water through the trench made by MB plough and then on the sown strip. The line diagram of conceptual machine is shown in **Fig. 1**.

Table 1 Brief specifications of tractor operated mat type nursery sowing seeder

Particular	Specification
Type of machine	Tractor PTO driven, mounted type (45 hp or above tractor)
Machine dimension (L × B × H), cm	240 × 215 × 168
Width of soil cutting blade, cm	100
No. of mould boards attached	2
Soil pressing roller	
Width of roller, cm	100
Diameter of roller, cm	16.5
Chain conveyor	
Length of chain conveyor, cm	390
Width of chain conveyor, cm	30
Chain pitch, cm	4
Soil conveyor auger	
Length of auger, cm	100
Diameter of auger, cm	19
Sieve unit	
Sieve dimension (LxB), cm	107 × 59
Oval sieve size, cm	5 × 2.5
Seed metering mechanism	
Type	Fluted roller type
Width of seed box, cm	100
Diameter of fluted roller, cm	5
No. of grooves	14



1. Ridge Former 2. Soil Conveyer 3. Sieving System 4. Seeding Machine 5. Gauge Roller 6. Sheet Wrapping Roller 7. Soil Smoother 8. Ground Wheel

Fig. 1 Line diagram of conceptual tractor operated mat type nursery sowing seeder

Fig. 2 A field view of first prototype of tractor operated mat type nursery sowing seeder

The first prototype of the machine was fabricated in Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana. It consisted of 100 cm wide blade and two mould boards at both sides of the blade to collect the soil from side of the blade and guide the soil on to the blade. Two counter rotating conveyors rotating at different speeds were also fabricated and fitted behind the blade. The power to these conveyors was provided by belt and pulleys through tractor PTO. Below the counter rotating conveyors, a MS roller of diameter 16.5 cm and width 100 cm was provided for pressing the soil. A view of the first fabricated prototype is shown in **Fig. 2**.

Field trials were conducted to access the depth of operation and uniformity of spread of soil from counter rotating conveyors. Choking of belt conveyor was observed due to accumulation of soil in pulleys and conveyor. To overcome this problem, a positive drive chain conveyor having 390 cm length and 30 cm width was fitted on one side to pick up the soil from rear of the tractor tyre (**Fig. 3 a**). Chain conveyor unit was supported by wooden frame and L-shape iron bars were fixed on chain conveyor to carry the soil. Chain of pitch 4 cm was used. Further the soil was carried away by a soil conveyor auger (**Fig. 3 b**) having length of 100 cm and diameter of 19 cm. The carried soil was then delivered to sieving unit having size of 107 × 59 cm. The oval shaped sieve hole was of size 5 × 2.5 cm. Seed box of width 1.0 m with fluted roller seed metering unit covering entire span of seed box and soil sieving unit was fabricated (**Fig. 3 d**). Diameter of fluted roller was 5 cm and had 14 grooves. The side view of the mat type nursery sowing seeder is shown in **Fig. 4**. The stationary and field view of the machine is shown in **Fig. 5**.

Results and Discussion

Prototype of tractor operated mat type paddy nursery sowing seeder was developed. Chain conveyor unit was fabricated and evaluated in the field to assess the soil mass collected per unit distance covered. For a run of 114 cm, soil measuring 0.0163 m^3 equivalent of filling 8 mats of nursery was picked and conveyed. The performance of the conveyor unit for soil collection was found to be satisfactory however even depth of soil mat could not be maintained. Mat type nursery sowing seeder have capacity of sowing nursery having mat area of 0.88 ha/day which is sufficient for transplanting paddy nursery in an area of about 160 hectare. The machine uniformly spreads paddy seed at the rate 0.6-0.7 kg/m^2. In some cases problem of tearing off of the polythene sheet was observed. The fuel consumption of tractor was observed to be 4.5 to 5.0 l/h while operating machine at forward speed of 1.5-2.0 km/h. There is saving of labour up to 85-90% and saving of 80-85% in cost of sowing mat type nursery as compared to traditional method of sowing mat type nursery on polythene sheet.

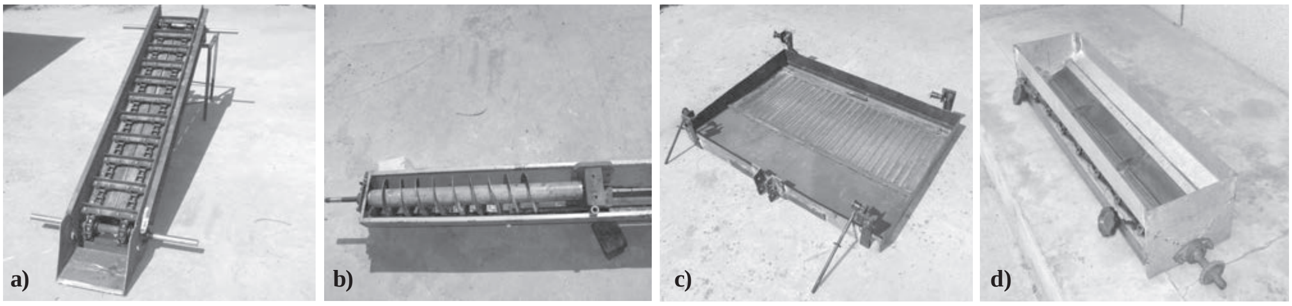


Fig. 3 A view of the different assemblies developed for mat type nursery sowing seeder
a) Conveyor unit; **b**) Soil auger; **c**) Sieving unit; **d**) Seed metering unit

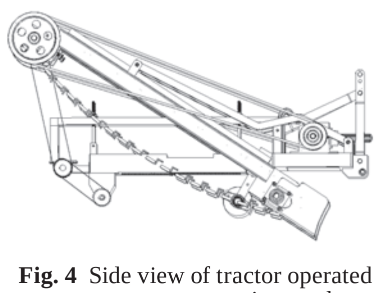


Fig. 4 Side view of tractor operated mat type nursery sowing seeder

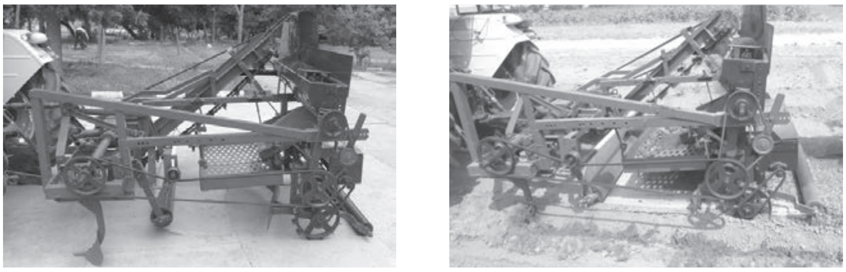


Fig. 5 A stationary and field view of the tractor operated mat type nursery sowing seeder

Conclusions

- A prototype of tractor operated mat type paddy nursery sowing seeder was fabricated which consisted of 1 m wide blade, two mould boards at both sides of blade to collect the soil from side of the blade and guide the soil on to the blade and two counter rotating conveyors. In the first prototype, choking of belt conveyor was observed due to accumulation of soil in pulleys and conveyor. Thereafter, soil collection unit was replaced by a positive drive chain conveyor having 30 cm width and 4 cm pitch. During field evaluation, the machine picked the desired amount of soil for bed formation however even depth of soil mat could not be maintained.
- Soil auger unit, sieving unit and seed metering units were also designed and fabricated.
- The machine is having capacity of sowing mat type nursery in 0.88 ha/day which is sufficient for transplanting paddy nursery in an area of about 160 hectare.
- In some cases problem of tearing off of the polythene sheet was observed.
- There is saving of labour up to 85-90% and saving of 80-85% in cost of sowing mat type nursery as compared to traditional method of sowing mat type nursery on polythene sheet.

REFERENCES

Anonymous. 2014. Package of practices for crops of Punjab - kharif 2014. Punjab Agricultural University, Ludhiana.

Dixit, A., R. Khurana, J. Singh, and G. Singh. 2007. Comparative performance of different paddy transplanters developed in India - A Review. Agric. Rev. 28(4): 262-269.

Mahal, J. S., G. S. Manes, A. Dixit, B. Dogra, and A. Singh. 2010. Mat type nursery and use of mechanical paddy transplanters. Extension Bulletin. Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana.

Manes, G. S., A. Dixit, A. Singh, J. S. Mahal, and G. Mahajan. 2013. Feasibility of mechanical transplanter for paddy transplanting in Punjab. Agricultural mechanization in Asia, Africa and Latin America 44(3):14-17.

■■

(Continued from page 11)

MacBryde, J. 1997. Commercialisation of university technology: A case in robotics Technovation, 17 (1), January 1997, P 39-46

Kumar, V. and P. K. Jain Commercializing new technologies in India: a perspective on policy initiatives Technology in Society, 24 (3) August 2002, P 285-298

Saranavel, P. 2000. Entrepreneurship Development Principles, Policies and Programmes, Ess PeeKay Pub House

Shane, S. 2002. Executive Forum: University technology transfer to entrepreneurial companies Journal of Business Venturing, 17 (6) 1 October 2002, P537-552

Suri, K. B. 1988. Small Scale Entrepreneurs on Industrial Development: The Indian Experience, Sage Publications, New Delhi.

Tijunelis, D. and E. Mckee Keith. 1987. "Manufacturing High Technology Handbook : Marcel Dekker, Inc NY.

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Status of Resin Tapping and Scope of Improvement: A Review

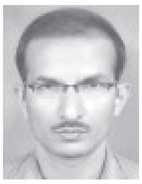
by

S. C. Sharma
Scientist

N. Prasad
Principal Scientist

S. K. Pandey
Scientist (SS)

ICAR - Indian Institute of Natural Resins & Gums, Ranchi (Jharkhand)
INDIA



S. K. Giri
Principal Scientist
ICAR - Central Institute of
Agricultural Engineering,
Bhopal (Madhya Pradesh)
INDIA

Abstract

Resin tapping is done by exposing the resin ducts by making suitable incision on the stem of trees. Most of the natural resins are collected in small quantities by forest dwellers by adopting traditional tapping methods. Present tapping practices from selected trees are traditional and location specific. Resin tapping is a tedious job and needs attention while working with available devices and techniques. The available devices for tapping resins are less efficient, add more injury to the trees and drudgery to the tappers/collectors and require more time and labours. Reduction in drudgery of resin tappers/collectors and increase in efficiency of tapping techniques and devices with increase in yield could be materialized with little improvement in the existing techniques and devices. Similarly, improved tapping techniques and devices will minimize injury to the trees and help in sustainable production of resins.

Key Words: Resin, Tapping, Technique, devices, Tools

Introduction

In India, natural resins are derived from the selected tree species. Resin sector is one of the most important sources of livelihood support of more than 50 million population inhabiting forest and sub forest area, besides, being a major source of employment. India is rich centre of plant bio-diversity having more than 45,000 plant species including about 120 gum and resin yielding plants (Gupta, 1994). Average annual export of gum, resin and gum-resin during 2010-2011 was 368,804.00, 7,025.77 and 1,481.87 tons of USD. 5,336.83, 430.09 and 5,815.94 respectively (Pal *et al*., 2012).

In India, Non-Timber Forest Products (NTFPs) provide 50% of total forest revenues, 55% of forest based employment and 70% of forest based export earning (Tiwari and Campbell, 1995). National average value of NTFPs is Rs. 1,671.54 per ha and the gross value of NTFPs harvested in India as Rs. 41.89 billions. Similarly, NTFPs based industries provide 1.6 million man days of employment per year in India (Behera, 2009). The gross value of goods and services provided by the forestry sector is estimated as an average of Rs. 26,330 crores i.e. about 2.37% of GDP. It is admitted fact that neither the forest nor the tribals and poor inhibiting in the area should be removed for environmental protection (Giri *et al*., 2008).

Resins occupy a prime place among NWFP and are known to mankind since time immemorial. These are perhaps the most widely used and traded NWFPs other than items consumed directly as food, fodder and medicine. Use of resins for domestic consumption and sale, to earn some cash is very common among the forest dwelling communities, particularly tribals in India. Thousand of forest dwellers particularly in the central and western Indian states depend on resins as a viable source of income. Resin secretion occurs in special cavities or passage in many plant species. They are formed in the specialized structures called ducts. Resins exude or ooze out from the bark of the trees and tend to harden on exposure to air (Giri *et al*., 2008). Resins, commonly used in every day life, are having ample importance as non-timber forest produce. Apart from use in torches, embalming chemicals, waterproofing and caulking ships, incense, paints and medicines, a major portion of the resins are also used as food additives, paint, lacquer, paper, cosmetics, food, pharmaceutical and chemical industries. Now-a-day's, food industries, worldwide, are emerging as potential users of resins.

The resins are produced by plants in the form of nodules spontaneously or by making incisions in the bark of the tree trunk. The natural resins are non-toxic, biodegradable and eco-friendly in nature for use in various industries. Resin tapping involves exposing the resin ducts by making suitable incision on the stem of trees. The resin is exuded from the resin canals where incision is made. The size, frequency of occurrence and pattern of distribution of resin canals depends upon age of the trees, its heredity characters and environmental conditions (Negi, 1992). Most of the natural resins are collected in small quantities by forest dwellers by adopting traditional tapping methods. Resin tapping/collection is labour intensive operation and mostly rural and tribal people are engaged. Benefit mainly depends on the quality of the produce. The existing techniques and devices of resin and gum tapping is traditional and location specific except bore hole technique for pine resin. The techniques and devices which are in vogue are less efficient and time consuming and having problem in handling and its operation. Therefore, there is tremendous potential to develop the sector further. The paper discusses different methods of resin tapping, national and international scenario, factors affecting yield of resin, variation in yield of resin, economics of resin tapping, effect of freshening on resin yield and scope of improvement in it.

Lac Production from Kerria Lacca

Lac is hardened resin secreted by tiny lac insect which thrives on the cell sap of certain host plants. Lac production involves pruning, inoculation, *phunki* removal and harvesting. Farmers perform these operations manually using traditional equipments. The lac insects thrive best on tender shoots rather than old and woody once. In order to provide a suitable ground for the insect to feed well and thrive upon, the host-plant must be receptive and sustainable. For young plants no pruning is required to receive their first infection since there is abundance of tender shoots. For older plants, however, a process of pruning is to be observed prior to infection in order to stimulate the production of fresh and succulent branches, ordinarily branches less than an inch in diameter should only be pruned. After pruning inoculation is performed by cutting lac bearing twigs from infected trees a few days before emergence of larvae. Bundle of such twigs known as broodlac is tied to an uninfected tree on which tender new shoots are available. The broodlac produces larvae which settle down on succulent branches of the tree. After settlement of broodlac on the branches of lac host plant, broodlac sticks (*phunki*) is removed. When settled lac mature on the branches (**Fig. 1**) of tree, the branches along with lac incrustations is cut for harvesting lac crop using pruning knife/secateurs/tree pruner. The lac encrustation bearing branches thus obtained is further worked upon to remove leaves and portion of branches without encrustation using secateur. The lac encrustation bearing branched thus obtained having live encrustation is used as broodlac and branches having dead encrustation are scraped to obtained sticklac (**Fig. 2**).

Fig. 1 Lac settlement on mature branches

Fig. 2 Harvested Sticklac

Resin Tapping

The first systematic study on improvement of resin tapping was done during World War II because of the urgent need of oleoresin. Chemical stimulation experiments on resin flow by application of sulphuric acid, hydrochloric acid and sodium hydroxide were carried out. The prolongation of oleoresin flow by acid stimulation resulted in 50 to 100% higher production (Snow, 1949). The oleoresin flow is also prolonged by inoculating wounds on pine trees with the suspensions of pitch canker fungus, *Fusarium lateritium* and *F. pini* (Hepting, 1947; 1954; Clapper, 1954). Ethephon (2 Chloroethylphosphonic acid) and paraquat (1,1 dimythyle 4,4'-bipyridium chloride) or other herbicides when administered alone or in combination into the stem, induces extensive oleoresin soaking within the stem of pines (Roberts, 1973; Roberts *et al*., 1973; Cooper, 1976; Nix, 1976; Peters *et al*., 1978; Schnell and Toennisson, 1978; Kossuth *et al*., 1984).

For commercial purpose, resin from pine trees is obtained by tapping standing trees i.e. by making a cut which exposes the surface of the wood. The resin in the longitudinal ducts tends to reach the surface through the transverse ones in the rays. Consequently, for tapping the trees, only a shallow incision is necessary as the flow of resin from the transverse ducts stimulates secretion of resin in large ones. The maximum flow of resin is from the top of the incision, where both the horizontal and vertical ducts are cut (Negi, 1992). Sharma, 2002 conducted study on efficient resin tapping and its processing in Himachal Pradesh. Based upon resin tapping techniques developed and past experience, different methods of resin tapping had been in practice in Himachal Pradesh.

Methods of Resins Tapping

In India for pine resin production, two kinds of tapping are in vogue such as light continuous tapping and heavy tapping. Light continuous tapping is done in girth of trees above 0.9 m from the ground level. Trees between 0.9 and 1.8 m in girth are tapped in one channel while above 1.8 m in girth in two channels each at a time. The first set of two channels each is tapped for five years. At the end of five years, a new channel or a new set of channels, as the case may be, is started leaving an inter space of 10 cm between the old and new channels. At the end of second five year period, another channel or set of two channels is again made leaving another inter-space and so on till tapping progress round the tree. This is the method of tapping practiced in India and the trees are regularly tapped throughout the life without any rest (Negi, 1992 and Tiwari, 1994). In heavy tapping/ tapping to death, maximum possible out turn of the resin is derived before the trees are due for felling and it is achieved by cutting on the tree as many channels as it can bear, with a minimum inter space of 10 cm between the successive channels. It is generally started five years in advance of main felling in prospective regeneration areas and two years in advance of thinning in areas marked for thinning. The lowest girth prescribed for heavy tapping is 60 cm. There are four methods of tapping resin in India from pine trees like, box method, cup and lip method, rill method and bore hole method and are discussed in detail below.

Fig. 3 Box method of rosin tapping

Box Method

This is the oldest method of resin tapping. In this method, a cavity or box of 10 cm × 10 cm size and up to 12 cm deep is chopped at the base of the trees (**Fig. 3**). It is meant to collect the resin as it exudes from the blaze or incision that is made just above the box by chipping the bark and outer layer of the sapwood. The resin oozes out of the blaze and is collected in the box.

Box method of tapping is one of the oldest technique and is having the problem of maximum injury to the trees and tends the tree to die within few years after resin tapping is started (Negi, 1992).

In India, Styrax and Benzoin tapping involves removing 3-5 narrow strips of tree bark, 90-120 cm from ground level. Within 12 days of tapping, the grooves become filled with the resin, which oozes out a whitish liquid that becomes brown soon on drying. The exudation in the cavities continues and the resin is collected (Appanah and Turnbull, 1998).

***Resin tapping from* Aquilaria spp.**

The collection of gharu (*Aquilaria spp.*) in most parts of Southeast Asia is accomplished by felling the tree. As there are no external signs to indicate whether a tree contains this valuable resin, collectors frequently fell every *Aquilaria* tree they find. Once a tree containing gharu has been felled, collectors use axes and knives to hack out the blackened heartwood. The uncontrolled exploitation of this exudate, together with the wasteful trial and error method of searching for it, has virtually eliminated *Aquilaria* trees from all but the most remote and inaccessible forest areas (Peters, 1994).

Resin tapping in Nepal

Resin is obtained by tapping the tree in Nepal by making a cut, which expose the surface of the wood. The resin contained in resin canals which are either large longitudinal ducts in wood and or small ducts in the ray at right angles to the larger ducts. The maximum flow of resin is from the top of the incision, where both the horizontal and vertical ducts are cuts (Meheta, 1981). Tapping involves making physical injury to the cambium layer and sapwood of the tree by making a blaze with an adze and collection of exuded resin in a metal or plastic pot (Chaudhari, 1995).

Resin tapping from dipterocarp species

In Philipines, tapping resin from dipterocarp species, incisions in the trunks of trees should not exceed in width one-fifth the circumference of the tree, nor more than one-fifth of the diameter. Incisions should be made at least 50 cm above the ground and not past the first branch. Tapping is authorized only in trees at least 40 cm in diameter. With Benguet pine, tapping of oleoresin is allowed only on trees that will be cut within five years and on trees at least 30 cm in diameter. For trees 40 cm and over in diameter at breast height, chipping may be done on two faces, but only one at a time, with a space of about 10 cm to be left between the faces. The width of each face should not exceed the diameter of the tree and the depth of the cut should not exceed 1.5 cm.

Styrax benzoin *and* S. paralleloneurum *tapping*

The Indonesian method of tapping *Styrax benzoin* and *S. paralleloneurum* uses three tools (**Fig. 4**). A hoop-shaped knife is used to rub and clean off the bark; a wedge to insert between the bark and wood to make the tapped area into a semi-parabola for collecting the resin (**Fig. 5**). After that, the bark around the tapped area is beaten. Resin is collected for about 3-4 months after tapping. A semi-parabola knife is used to cut along the tapped area to open the bark before collecting the resin (Kashio and Johnson, 2001).

The traditional method of obtaining Asian styrax in Indonesia is to remove pieces of bark and boil them in water. The crude, softened balsam separates out and settles to the bottom of the vessel, from which the water is subsequently decanted. Further quantities of balsam are obtained by pressing the "extracted" bark to remove any residual material. Some styrax is also obtained by making incisions into the exposed stemwood and either collecting the exudate in small cans fixed to the tree or scraping it off directly (Coppen, 1995). At that time, the bark is easy to cut. About 1-3 weeks after tapping, the styrax tree closes the tapping cuts with benzoin, but sap and resin continue to secret. During the cooler, dryer winter season, the resin will dry and become hard and fragile.

In Lao, tapper makes a notch having 8-10 cm wide and 5-6 cm long into the cambium of the trunk with a knife for removing the bark. The knife is then twisted to open the bark before allowing it to close (**Fig. 6**). A number of incisions are made, staggered at intervals of 20-30 cm along the trunk. The lower incisions are made about 30 cm from the ground; the higher ones at the level of the first branches. Sometimes the incisions are made up to a height of 2 m only; a new 2 m section is then tapped the following year. Village benzoin tappers also climb on the trees using a fixed bamboo pole with a rope to serve as a ladder. In this manner, tapping can be done up to a height of 10 m. The exuded oleoresin is left on the tree to harden, and it may be as long as 4-5 months after tapping (during the first cold days of winter) that the tears of benzoin are picked from the tree. In some locations, the bark surrounding the tapped area is beaten to stimulate resin flow. Tapping continues for up to 6-8 years; it may be less if bark removal is excessive and permanent damage is done to the tree (Pinyopusarerk, 1994).

Oleo-resin is collected from Dipterocarpus trees by chopping large holes into the trunk and then lighting a fire inside to maintain the flow of resin. This sequence of "boxing and firing" is usually repeated several times and a large tree may be "boxed" at two or three places along the trunk. This process severely weakens the vigor of the tree. The oleoresin is also collected by making a circular incision on the main stem in North Carolina, no thicker than the bark (Sabinsa Corp., 2000).

Dammar tapping

Dammar is a trade name of the resins obtained from the family Dipterocarpaceae. *Canarium strictum* found in the South and West India yields Black dammar, which is mainly used for the manufacture of varnish, bottling wax and for medical plasters. The resin obtained from *Vateria indica* when soft is known as piney varnish, but when hard is called White Dammar. Rock dammar, obtained from *Hopea odorata*, is used for the manufacture of varnish, as a medicine for wounds and sores.

***White dammar tapping from* Vateria indica**

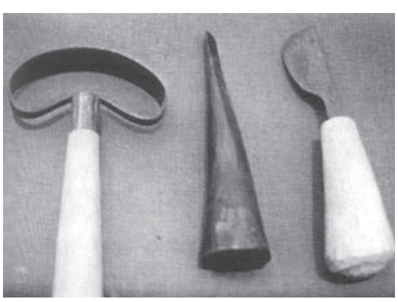


Fig. 4 Indonesian tools used in benzoin tapping

Fig. 5 Indonesian Method of resin harvesting

Fig. 6 Harvesting of benzoin from a notch under the Standardized Traditional Method

Fig. 7 Collection of dammar resin flowing from *Shorea javanica* tree

Fig. 8 Incision after lighting fire around the tree of *Canarium strictum*

Fig. 9 Resin flow from *Canarium strictum*

White dammar tapping is done by making semi-circular incisions on the stem of the tree (*Vateria indica*) up to the surface of the sapwood. Blazes or cuts are so spaced as to cause least damage to the tree. The resin starts oozing from the incisions in 3-4 days and continues for 60-90 days. The resin is also exuded when the bark is scorched by lighting fires around the base of the tree. This method gives a high yield of resin but damages the timber and may even kill the tree (Giri *et al*., 2008).

***Sal dammar tapping from* Shorea robusta**

In India, tapping sal dammar involves removing 3-5 narrow strips of bark of tree (*Shorea robusta* and other species) 90-120 cm above the ground. In about 12 days, the grooves become filled with the resin, which oozes out a whitish liquid that becomes brown soon on drying (**Fig. 7**). The exudation in the cavities continues and the resin is collected. The process is repeated several times in a year (Tiwari, 1994).

***Black dammar tapping from* Canarium strictum**

Black dammar tapping is done by making vertical incisions on the bark (**Fig. 8**) in a belt about 1.8 m from the bottom and then lighting a fire around the base of the *Canarium strictum* tree. The resin flows out after two years and continues for about 10 years. The flow lasts for about six months every year from November to April. The viscous resin that oozes out hardens into a somewhat translucent mass (**Fig. 9**) of a bright shining colour, which is collected manually (Tiwari, 1994).

Yang oil tapping from* Dipterocarp *spp

Mostly resin (Yang oil) tapping is done by cutting into the trunk of the tree in Thailand. To tap yang oil, a hole about 30 cm × 30 cm × 20 cm deep is made in the trunk of the tree. The tapper collects the oil every 10 to 15 days. At each collection, a fresh fire is lit for 2 minutes to melt the hard resin and stimulate flow. Only trees with a minimum girth of 200 cm are allowed to be tapped. The first cut is usually 15 cm long, 10 cm wide and 3 cm deep. The resin is collected every 7th day and enlargement of wound is done by freshening. After 1 year, the wound should not be longer than 30 cm. The width and the depth should not be more than the first cutting.

***Oleo-resin tapping from* D. kerrii**

The method of tapping oleo-resin from *D. kerrii* by the Orang Asli at Tasek Bera and Buloh Nipis in Pahang showed heavy damage on the trees. An axe called 'beliong' was used to cut a rectangular shaped hole into the tree trunk. The hole was about 24 × 7 × 18 cm in size and had a floor that sloped downward away from the mouth, thereby forming a deep container that could collect the oleo-resin exuded from the walls of the hole. The injury stimulated a slow flow of oleo-resin. A fire was set in the hole and it spread through the hole as the already accumulated oleo-resin began to burn. The firing which took about 5 min stimulated more oleo-resin flow. The hole was left for about a week, a span of time believed to allow for the maximum amount of oleo-resin to collect in the hole. The oleo-resin was collected by ladling it into a metallic container. The hole was burnt again to supply another week's collection of oleoresin. The firing was repeated until the hole could not yield anymore oleoresin. Then a new hole would be made on another part of the tree trunk (Jantan *et al*., 1991).

Cup and Lip Method

In this method, the outer bark of the tree is scraped off with the help of adze to a reasonably smooth surface, 60 cm long and 15 cm wide and 25 cm above the point where the lip is fixed. In light tapping channels are initially located on south or south-west face of the tree as better yields are obtained from the warmer side. Subsequent channels are made in an anti-clockwise direction. A cut of about 15 cm broad and slightly slanting outwards is made with a curved chisel and mallet at a height of 16.5 cm above the ground. The lip, a rectangular piece of galvanized iron (15 cm × 5 cm) is driven into the cut to collect resin into a pot

Fig. 10 Cup and lip method

kept below (**Fig. 10**). Pot is partially covered to prevent falling of pieces of bark, dirt etc. into the oleoresin, and also to minimize the evaporation of the resin (Negi, 1992).

In order to open up the clogged resin ducts and aid in the smooth and continuous flow of resin, the channels are freshened at definite intervals. Freshening consists in removing a thin shaving of wood (2.5 cm) from the channel with the help of an adze. During freshening, it is ensured that the strip of bark and wood removed at the top of the blaze does not exceed about 1.0 cm in length and the channel is not deeper than 1.25 to 2.5 cm in light tapping and 3.1 cm in heavy tapping. Freshening, ordinarily starts by early March and continues up to early November.

The cup and lip method of tapping has a number of disadvantages. Even though a channel depth of 2.5 cm has been prescribed for the blazes, very often the depth exceeds the prescribed limit. The inherent hacking action is involved in the case of adze, makes it very difficult to control the depth of the blazes. Also the tapper makes much deeper blazes in the hope of getting more resin. Deep cuts around the hole result in loss of timber and make the trees less resistant to the wind storms. Moreover, after covering the circumference of the tree, a second cycle of tapping is not possible because of the slow healing of deeper blazes. This generally results in abrupt fall in resin production (Tiwari, 1994).

In Himachal Pradesh till 1984, resin tapping was being done under "French Cup and Lip" method. In this method, serious loss of timber was observed partly due to inherent hacking action involved in the use of freshening tools i.e. adze, which makes it difficult to control the depth of the blazes and partly due to carelessness on the part of tappers in the use of such tools. Strong winds and forest fires caused serious loss/damage to the trees tapped by this method. The butt end log of 200 mm length of the tree used to yield almost no timber (Sharma, 2002).

Resins are obtained from mature *chir* pine (*Pinus roxburghii*) greater than 40 cm in diameter, using the "French cup and lip" method. Trees above 70 cm in diameter are given two blazes per year.

The French method of resin tapping, introduced in 1888, is still in use in Pakistan. Trees between 30-57 cm girth are given 1 blaze and those above 57 cm are given 2 blazes. When a tree is tapped for the first time, a 20-cm broad cut is made about 15 cm above ground level. A thin sheet of iron, 15 cm long and 5 cm wide is hammered into this cut to form a lip. Above the lip 15 × 12 cm cut is made in the wood. This is called a "channel" or "blaze". An earthen pot is hung below the lip to collect the resin and blaze is freshened every week. At each freshening, the length of blaze is increased by about 0.8 cm. The process continues for about 5 years after which a new blaze is started about 15 cm to the left of the old one. At each freshening of the blaze, the resin from the clay pot goes into empty tin. This method yields 1.5 to 2 kilograms of resin per tree each season (Sheikh and Hafeez, 1977). The operation of resin tapping is carried out manually with small hand tools. It is seasonal and lasts for 7 to 8 months from March/April to October/November (Khattak and Amjad, 1981). Some times tapper makes larger and deeper channel or blaze in hope of getting more yield. Such action damages resin yielding trees. The situation is exacerbated when the resin blazes catch fire and valuable butt logs are scarred and damaged (Iqbal, 1980).

In Honduras, it is more usual to collect the styrax by tapping only, without treatment of the separated bark. A small gutter and cup are fixed to the tree and a cut is made in the stem where the pockets of balsam are located. Systems of tapping developed in the United

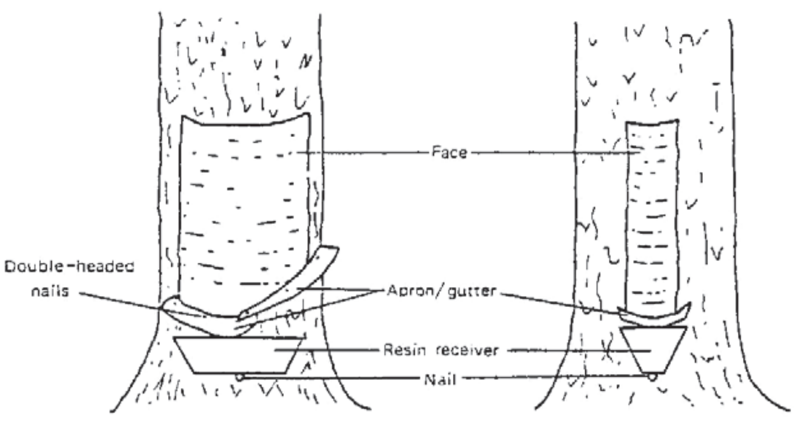


Fig. 11 Systems of resin tapping using a wide and narrow face

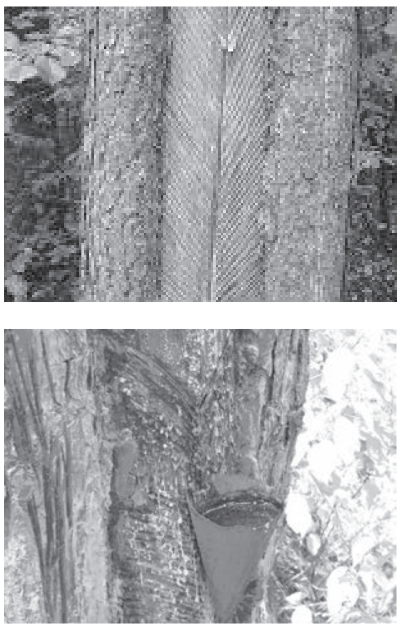


Fig. 12 Rill method of resin tapping

States and Portugal, both entail the removal of bark and the application of sulphuric acid as a stimulant, but whereas the former uses a wide face for intensive tapping, the latter uses a narrow face with a simpler system of guttering (FAO, 1992; De Beer, 1993). The systems of resin tapping from styrax using wide and narrow face are illustrated in **Fig. 11**.

Rill Method

This is an improved method (**Fig. 12**), standardized at Forest Research Institute, Dehradun to overcome the disadvantages of the cup and lip method (Verma, 1983). In rill method, the bark of the tree over a surface area of about 45 cm × 30 cm and about 15 cm above the ground level is removed with the help of a bark shaver. The thickness of the bark left should not be more than 2 mm with smooth surface to facilitate freshening of the blaze. The blaze frame is kept on the stem in the vertical position, 15 cm above the ground level and the position of the blaze is marked with a marking gauge. The control groove is cut with a groove cutter by drawing it from top to bottom. The lip is then fixed in the tree with nails (Tiwari, 1994).

For freshening of the blaze, the tapper stands near the tree on one side of the blaze and holds the freshening knife at the lowest point of the control groove. The knife is then pulled up by the tapper along with blaze line marked on the tree. The depth of the rill is about 2 mm into the wood. After making a freshening on both arms of the blaze a 1:1 mixture of dilute sulphuric acid (20%) and dilute nitric acid (20%) is sprayed on the freshly cut rill with help of spray bottle. Exudation of oleoresin starts soon after the rills are made. The control groove is also increased to avoid accumulation of resin in it (Tiwari, 1994). Chaudhary *et al.*, 1991 have found that the application of 20% mixture of nitric acid and sulphuric acid in equal proportion (20% each) by volume gives better yield than when these dilute acids are applied in equal quantities by weight.

In Nepal, rill method (**Fig. 13**) of tapping was considered more economical than other method due to fact that there is minimum cutting depth which save heart wood from the damage and does not reduce the economic value of the wood (Chaudhary, 1995). The technique provides fast healing of blaze which reduces the tapping cycle and increase tapping life of tree and forest. The technique saves trees from the fire and wind comparatively. Stimulant used make prolonged flow thus increases resin production. The technique yields about 50% more resin per tree per season and generates more employment due to 8 months tapping and transportation.

There are two methods of Styrax and Benzoin tapping followed in Malaysia. The first consists of tapping the trunk about 40 cm above the ground. A triangular cut of 15-20 cm long is made using a sharp knife with the triangle pointing downwards (**Fig. 14**). Three such triangles are cut into the tree bark at the same level, to a depth of about 2 mm. The bark and wood are removed from each cut and the resin begins to secrete (Kashio and Johnson, 2001). In the second method, tapping is done using a V-shaped cut, each side of the V measuring 7.5 cm in length and 2.5 cm in width. After making the cut, a 5 sq cm piece of zinc sheet is attached and bent into a V-shape to direct the flow of benzoin into a tin positioned at the bottom of the V and nailed to the trunk.

The second Malaysian tapping method also employs triangular-shaped cuts pointing downwards, but is somewhat different from the first (**Fig. 15**). In this method, three lines having three cuts each are made, one above the other. The first line is 40 cm from the ground; the second is at 80 cm, and the third at 120 cm (Kashio and Johnson, 2001).

Forest Research Institute, Dehradun developed a method of resin tapping called “Rill Method” was introduced in Himachal Pradesh in 1984 when 21,000 blazes were tapped with this method. Tapping by rill method is about 16 years old in Himachal Pradesh. With the result and advantages of this method over French “Cup and Lip” method, more and more blazes were brought under this method. It was in the year 1991 when the Himachal Pradesh Forest Department/Himachal Pradesh State Forest Corporation completely switched to this new method of resin tapping (Sharma, 2002).

In Himachal Pradesh, an experiment on resin tapping from lower diameter classes of *chir* pine using rill method with group of different blazes width was carried out by Brahmi, *et al.*, 2000. The outcome of the experiment revealed that resin yield increased with the increase in diameter class 20-22.5 cm to 27.5-30.0 cm and the group of blaze width from 8, 10, 12 and 14 cm to 14, 16, 18 and 20 cm. The resin yield also increase as blaze width

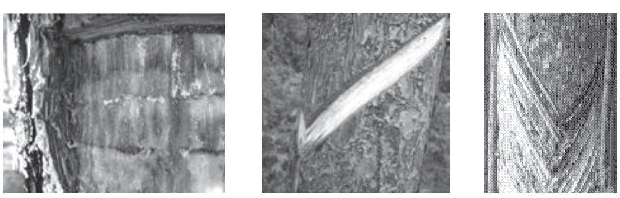


Fig. 13 Resin Tapping by Rill Method

Fig. 14 Malaysian method of benzoin tapping

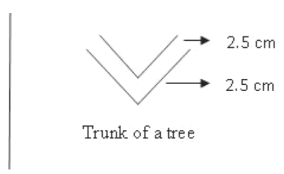


Fig. 15 V-shaped Method and resin flow

increased within blaze group itself. The tree in diameter class 20-22.5 cm yielded resin less than 2.0 kg per season, thus it is not feasible to commercially tap the trees of such diameter class. The trees of other diameter classes are feasible for commercial resin tapping because they yielded more than 2.0 kg of resin per season. The maximum resin yield was obtained in the month of May (hottest) and the lowest in the month of October (coldest). The eight month tapping period showed the average resin yield of 2.30 kg per tree per season.

Bore Hole Method

Forest Research Institute, Dehradun has developed a new tapping technique known as bore hole technique (**Fig. 16**) of resin extraction from *Pinus roxburghii* (Rawat, 2001). In this method, holes are made near the ground level with the help of a machine into tree's sapwood to open the resin ducts and exudating resin is collected in closed container. The hole in each tree is done approximately 1m above the ground. The holes are drilled straight into the tree stem with a slight slope towards the opening so that resin drains freely.

Immediately after making the hole, the stimulants/chemicals (mixture of sulphuric acid and ethephon i.e. 2-chloro-ethyl phosphonic acid) are sprayed inside each freshly made hole by squeezing the plastic bottle/spray bottle. Spray volume of 1 to 2 ml are applied to each hole. Chemical treatment is done once only, immediately after boring holes. After treatment a spout is installed inside the hole by gently hammering with a small mallet or pushing with palm to achieve compression fitting in the hole. The spout is meant for joining the collection container (polybag made up of high density poly ethylene, HDPE, 35.3 × 12 cm) tightened to each spout. Once the polybag is filled with resin, it is removed from the tree and poured into collection can and immediately new poly bag is tied for future collection of resin. It has been found from the studies that hole of 15 cm depth and 2.5 cm diameter is found to be suitable for obtaining maximum resin yield (Rawat, 2001).

Investigation on borehole resin tapping in *chir* pine (Pinus roxburghii) was carried out by Rawat, G. S., 2000 in Dehradun, Uttarakhand. During the investigation holes were drilled approximately 101 mm (4 inch) above the ground. Holes of 101 mm (4 inch), 152.4 mm (6 inch), and 190.5 mm (7.5 inch) depth and 25.4 mm (1.0 inch) diameter were drilled to study the effect of depth of hole on resin yield. The holes were drilled straight in to the tree stem with a slight slope towards the opening so that resin drains freely. The study revealed that the maximum yield of resin from *chir* pine with minimum damage to the tree was obtained from the bore holes of 152.4 mm (6 inch) depth and 25.4 mm (1 inch) diameter.

Effect of Stimulant on Resin Yield

It has been found that the treatment of blazes with acids and other stimulants increases the yield of oleoresin (Rajkhowa and Khan, 1962, Verma *et al.*, 1976, Sheikh, 1978, Qureshi *et al.*, 1983, Deshmukh and Dutt, 1983). Research carried out at the Forest Research Institute, Dehradun has revealed that spraying the blazes with hydrochloric acid increases the resin yield by 18% while washing the blazes with turpentine and alcohol increases the yield by 25-30% and 7-11% respectively. Application of 20% solution of sulphuric acid and nitric acid in equal quantities in water in the form of a spray increases the yield of resin by around 50%.

Effect of Season/Month on Resin Yield

The yield of resin varies with the season or month of collection (**Table 1**). This has been brought out in the data of monthly yields of 100 channels in West Almora forest division of Uttarakhand (Negi, 1992). Experiments conducted on trees growing at the Forest Research Institute, Dehra dun, have shown that a maximum yield of 5.13 kg/blaze/year of resin can be obtained by rill method, while the corresponding yields by the other two traditional methods viz., Silva Hill Basula & Bark chipped method are 1.5 kg/blaze and 3.1 kg/blaze per year, respectively (Chaudhari *et al.*, 1990). The rate of healing of blaze made by rill method ranges from 19.2 to 512.3 cm^2/year, where as in case of blazes made in lip method it is only 4.8 to 12.2 cm^2/year (Chaudhari *et al.*, 1988).

Effect of Freshening on Resin Yield

Study on effect of freshening period and acid treatment on oleo-

Fig. 16 Bore hole method

Table 1 Variation in resin yield during the year

Month of collection	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Yield per 100 channels, kg	No collection	No collection	3.7	14.9	33.6	49.7	29.8	24.9	10.7	11.5	5.0	0.7

resin yield from blue pine (A.B. Jackson) was carried out by Sharma and Kausal, 1986. The freshening periods of 3 and 4 days were found to be statistically at par, thus 4 days freshening period can be adopted. Acid mixture of 20% sulphuric acid and nitric acid (1:1) has yielded highest amount of resin during the period. The resin yields were maximum and minimum during the hottest and coldest months, respectively.

With the increase in frequency of freshening the increase in resin yield in one day cycle may be as high as 2.5-3.0 times to the yield obtained from 7 days cycle (Lohani, 1984). Even the periodicity of freshening with the same depth and rise of the channel per season exercises maximum influence on the oleo-resin yield. The increase in the number of equispaced freshenings per year increased resin yield up to 250% of that obtained under the standard 6 days cycle in French Cup and Lip method (Rajkhowa and Seth, 1964). The depth of channel has not been found to affect the resin yield in case of 2-6 days freshening cycles, however, it has shown significant effect in one day cycle (Lohani, 1984). The depth of blaze has been found to weaken the main stem of the tree, which ultimately falls due to the strong wind. In rill method of tapping, 4 days freshening interval has been reported to yields higher resin (Kaushal *et al.*, 1987). The freshening period of 3 and 4 days registered statistically similar resin yields, which were significantly higher to 5 and 6 days fresheinig intervals (Sharma and Kaushal, 1991).

Economics of Resin Tapping

A study on economics of resin tapping from *Pinus Kesiya* in Orissa, India was carried out by Swain and Patnaik, 1998. They reported that proper period of resin collection from *Pinus Kesiya* is from February to October and cost of resin collection comes to Rs. 900/- per quintal whereas the sale price of one quintal of resin would be Rs. 2,100/-.

Scope of Improvement in Resin Tapping

Resin tapping is done by exposing the resin ducts by making suitable incisions on the stem of trees which is a tedious job and needs attention while working with available devices and techniques. Most of the natural resins are collected in small quantities by forest dwellers by adopting traditional tapping tools/methods. Present tapping practices from selected trees are traditional and location specific. The available devices for tapping resins are less efficient, add more injury to the trees and drudgery to the tappers/collectors, time consuming and require more labourers. Reduction in drudgery of resin tappers/collectors and increase in efficiency of tapping techniques and devices with increase in yield could be materialized with suitable improvement in the existing techniques and devices. Similarly, improved tapping techniques and devices will minimize injury to the trees and help in sustainable production of resins. Concerted efforts are urgently needed to improve method of tapping and collection for sustainable production of resins and livelihood of rural and tribal people. The plant physiological aspects need to be considered while designing new method of resin tapping and tool used in different tapping methods.

Conclusions

- The natural resins and oleoresins have tremendous potential for use in paint, varnishes, paper, food, textile, pharmaceutical, cosmetic & chemical industries. Hence, there is an urgent need to follow scientific methods of tapping and collection of the natural resins in order to get remunerative prices of the products.
- Resin tapping is a tedious job and needs attention while working with available devices and techniques. The available devices for tapping resins are less efficient and time consuming and having problems in handling and its operation.
- Workers involved in tapping resin are facing problem of drudgery with available techniques and devices. Present techniques and devices of tapping resins require more time and labour and bring into existence more injury to the trees with low yield.
- Reduction in drudgery of resin tappers/collectors and increase in efficiency of tapping techniques and devices with increase in yield could be materialized with little improvement in the existing techniques and devices. There is need to popularize bore hole technique/method of rosin tapping.
- Improved tapping techniques and devices will minimize injury to the trees and help in sustainable production of resins. Sustainable resin production will provide alternative option of livelihood in areas having migration problem for search of work in urban areas.

REFERENCES

Anonymous. 2009. Directorate General of Commercial Intelligence and Statistics, Kolkata.

Appanah, S. and J. M. Turnbull. 1998. A Review of Taxonomy, ecology and silviculture. Forest Research Institute, Malaysia Pp. 220.

Behera, M. 2009. Non-Timber Forest Products and Tribal Livelihood-A study from Kandhamal District of Orissa. Indian Forester. August, Pp. 1127-1134.

Chaudhari, D. C. 1995. Manual of Rill Method of Resin Tapping From Pines, Forest Research Institute, Dehradun, India.

Choudhari, D. G., C. L. Goel and

D. N. Uniyal. 1990. Rill method of resin tapping vis-a-vis traditional methods, J. Econ. Bol. Phytochemistry, 1 (I): 47-50.

Choudhari, D. G., C. L. Goel, A. K. Chaubey and D. N. Uniyal. 1991. Prosting review production with 20% (volumatric) acid mixture stimulant from *chir* pine (*Pinus roxburghii* Sargart). Indian For. 117(1):37-43.

Choudhari, D. G., D. N. Uniyal and M. P. Shiva 1988. Comparative studies on the healing rate of blazes tapped by cup and lip method (Channels) and method (Rill) in vinus roxburghii. Indian For., 14(8):446-452.

Clapper, R. B. 1954. Stimulation of pine oleoresin flow by fungus inoculation. Economic Botany 8: 269-284

Cooper, R. W. 1976. Lightwood inducement. Its status today. Proceedings of the Lightwood Coordination Council Annual Meeting, Jacksonville, Florida. Pp : 3-5.

Coppen, J. J. W. 1995. Non-wood forest products 6: gums, resins and latexes of plant origin. Food and Agriculture Organization of the United Nations, Rome.

De Beer, J. H. 1993. Benzoin, Styrax tonkinensis. In Non-Wood Forest Products in Indochina. Focus: Viet Nam. FAO Working Paper FO:Misc/93/5. Rome: FAO pp: 17.

Desmhmukh, D. K. and U. Dutt. 1983. Some aspects of resin tapping in *chir* pine. Proceeding of the Eleventh Silvicultural Conference, May 15-25, 1967. Forest Research Institute and College, Dehradun, India: 340-345.

FAO. 1992. Benzoin gum [published in FAO Nutrition Meeting Report Series 57, 1977]. pp 187-188. In Compendium of Food Additive Specifications. FAO Food and Nutrition Paper 52 (Joint FAO/WHO Expert Committee on Food Additives. Combined Specifications from 1st through the 37th Meetings, 1956-1990). Rome: Food and Agriculture Organization.

Giri, S. K., N. Prasad, S. K. Pandey, M. Prasad and B. Baboo. 2008. Natural Resins and Gums of Commercial Importance—At a Glance. Technical Bulletin, Indian Institute of Natural Resins & Gums, Ranchi. Pp 38.

Gupta, B. N. 1994. India, Non Wood Forest Products in Asia, Rome, Food & Agricultural Organization of the United Nation.

Hepting, G. H. 1947. Stimulation of oleoresin flow in pines by fungus. Science, 105: 209.

Hepting, G. H. 1954. Gum flow and pitch-soak in Virginia pine following Fusarium inoculation. USDA Forest Service. Southeast Forest Experiment Station. Paper No.49.

Iqbal, M. 1980. Revised working plan of the Siran Guzara Forests (1980-81 to 1989-90). Government of NWFP, Forest Department. Peshawar.

Jantan, I., A. S. Ahmad and A. R. Ahmad. 1991. Tapping of oleoresin from Dipterocarpus kerrii. Journal of Tropical Forest Science 3(4): 348-355.

Kashio, M. and D. V. Johnson. 2001. Monograph on benzoin (Balsamic resin from Styrax species). Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific Bangkok, Thailand. Pp. 210.

Kaushal, A. N., D. P. Sharma, V. Persad and K. R. Sharma. 1987. Standardization of tapping technique for *Pinus roxburghii* sergent. J. Tree. Sci. 6 (1): 25-29.

Khattak, G. M. and M. Amjad. 1981. A survey of socio and economic conditions of manpower engaged in forests and wood-based industry in Pakistan. Pakistan Forest Institute. Peshawar.

Kossuth, S. V., D. R. Roberts, J. B. Huffman and S. Wang. 1984. Energy value of parquets treated and resinsoaked loblolly pine. Wood and Fibre Science, 16: 398-402.

Lohani, D. N. 1984. Resin tapping research—a review of past work and the current approach. Proc. 1st For. Conf. Dehradun: Pp. 649-656.

Negi, S. S. 1992. Minor forest products of India. Periodical Experts Book Agency, Delhi, pp-146-168.

Nix, L. E. 1976. Paraquat induction of resin soaking in pines in South Carolina Piedmont. Proceedings of the Lightwood Research coordination Council Annual meeting, Jacksonville, Florida. Pp :102-108.

Pal, G., A. K. Jaiswal and A. Bhattacharya. 2012. Lac Statistics at a Glance. IINRG, Ranchi.

Peters, C. M. 1994. Sustainable Harvest of Non-timber Plant Resources in Tropical Moist Forest: An Ecological Primer. A user's guide to the manual. http://www.worldwildlife.org/bsp/bcn/learning/primer/impacts.htm#plant

Peters, W. J., D. R. Roberts and J. W. Munson. 1978. Ethrel, diquat, paraquat interaction in lightwood formation. Proceedings of the Lightwood Research Coordination Council Annual Meeting, Atlanta, Georgia. Pp. 31-39.

Pinyopusarerk. 1994. Styrax Tonkinensis: Taxonomy, Ecology, Silviculture and Uses. ACIAR Technical Report 31. 14pp. Canberra: Australian Centre for International Agricultural Research.

Qureshi, I. M., D. K. Desmhmukh and U. Dutt. 1983. Acid stimulants in resin tapping in *chir* pine (*Pinus roxburghii*). Proceeding of the Eleventh Silvicultural Conference, May 15-25, 1967. Forest Research Institute and College, Dehradun, India: 337-340.

Rajkhoma, S. and M. A. Waheed Khan. 1962. Use of chemical stimulants in tapping resin from Pinus roxburghii. Indian Forester, 88(3): 188-201.

Rajkhowa, S. and S. K. Seth. 1964. The effect of periodicity and length and depth of freshening on the yield of resin from *Pinus roxburghii*. Ind. For. 90 (12) : 724-734.

Rawat, G. S. 2000. Borehole resin tapping in *chir* pine (*Pinus roxburghii*). Indian Forester, June, Pp. 595-602.

Rawat, G. S. 2001. A manual of borehole resin tapping technique in *chir* pine (*Pinus roxburghii*), Forest Research Institute, Dehradun, India.

Roberts, D. R. 1973. Inducing lightwood in pine trees by paraquat treatment. USDA Forest Research Notes SE-191.

Roberts, D. R., N. M. Joyejr, A. T. Proveaux, W. J. Peters and R. V. Lawrence. 1973. A new and more efficient method of naval stores production. Naval store Review 73: 4-5.

Sabinsa Corp. 2000. Commiphora mukul: The plant source of Gugulipid®. Internet address: http://www.gugulipid.com/commip.htm. Last accessed on July 8, 2002.

Schnell, R. L. and R. L. Toennisson. 1978. Paraquat and pine trees in east Tennessee. Proceedings of the Lightwood Coordination Council Annual Meeting, Atlantic Beach, Georgia. Pp. 4-6.

Sharma, K. K. and R. Ramani. 2011. Recent Advances in Lac Culture. IINRG, Ranchi. Second edition, Pp. 1-319.

Sharma, K. R. and A. N. Kausal. 1986. Effect of freshening period and acid treatment on oleoresin yield from blue pine (Pinus Wallichiana A.B. Jackson). Indian Journal of Forestry, Vol. 14 (1): 8-15.

Sharma, K. R. and A. N. Kaushal. 1991. Effect of freshening period and acid treatment on oleoresin yield from blue pine (Pinus wallichiana A. B. Jackson). Ind. J. For. 14 (1):8-15.

Sharma, O. P. 2002. Efficient resin tapping and its processing in Himachal Pradesh: an overview. Indian Forester, 128 (4): 371-378.

Sheikh, M. I. and M. Hafeez. 1977. Forests and forestry in Pakistan. Pakistan Forest Institute. Peshawar.

Shiekh, M. I. 1978. More efficient resin production for Pinus roxburghii (*Chir* pine). Pakistan J. Forestry, 28(1): 43-60.

Snow, A. G. 1949. Research on improvement of turpentine practices. Economic Botany 3: 375-394.

Swain, D. and T. Patnaik. 1998. Economy of resin tapping from *Pinus Kesiya* in Orissa, India, Indian Forester, July, Pp. 511-515.

Tiwari, D. D. and J. Y. Campbell. 1995. Developing and sustaining non-timber forest products: some policy issues and concerns with special reference to India. J. Sustainable Forestry, 31 (1): 53-77.

Tiwari, D. N. 1994. Resins and Oleo-Resins. Tropical Forest Produce, International Book Distribution, Dehradun.

Verma, V. P. S. 1983. Field guide to modern methods of resin tapping. Revised by Gulati, N. K. Publicity and Liaison Branch, Forest Research Institute and College, Dehradun, India.

Verma, V. P. S., P. S. Payal and S. P. Pant. 1976. Search for non corrosive chemicals for increasing resin yield from *chir* pine (Pinus roxburghii Sargent). Indian Forester, 102(6): 408-413.

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New Co-operating Editor

Minzan Li

Date of Birth: January 2nd, 1963

Nationality: China

Present Position: Professor, College of Information and Electrical Engineering, China Agricultural University. Beijing, China

Education Background:

2000: PhD, Tokyo University of Agriculture and Technology. Tokyo, Japan

1991: M.S., Beijing Agricultural Engineering University. Beijing, China

1982: B.S., Beijing Institute of Agricultural Mechanization. Beijing, China

Professional Experience:

2002.11–present: Professor, College of Information and Electrical Engineering, China Agricultural University. Beijing, China.

2001.4–2002.11: Associate Professor, College of Information and Electric Engineering, China Agricultural University. Beijing, China.

2000.4–2001.3: Researcher, National Institute of Sericultural and Entomological Science, Tsukuba, Japan.

1992.7–1996.3: Associate Professor, Department of Agricultural Engineering, Beijing Agricultural Engineering University. Beijing, China.

1982.3–1992.6: Assistant Professor, Department of Agricultural Engineering, Beijing Agricultural Engineering University. Beijing, China.

Email: limz@cau.edu.cn

Comparison Between Two Rice Cultivation Practices in Sierra Leone: Traditional and Alternative Methods

by

Daniela Lovarelli
Dept. of Agricultural and Environmental Sciences, Production, Landscape, Agroenergy
Università degli Studi di Milano, Via G. Celoria 2, 20133 Milan
ITALY

Jacopo Bacenetti
Dept. of Environmental and Policy Science
Università degli Studi di Milano
Via G. Celoria 2, 20133 Milan
ITALY

Joseph Bishan Tholley
Head of Department of Agriculture
University of Makeni
Azzolini Highway Makeni
SIERRA LEONE

Marco Fiala
Dept. of Agricultural and Environmental Sciences, Production, Landscape, Agroenergy
Università degli Studi di Milano, Via G. Celoria 2, 20133 Milan
ITALY
Dean of Faculty of Agriculture and Food Sciences
University of Makeni, Azzolini Highway Makeni
SIERRA LEONE

Abstract

In Bombali district, located in Sierra Leone, a comparison between the traditional cultivating method (manual) and an alternative method consisting of ploughing and harrowing was fulfilled in experimental tests to analyze the respective benefits. The alternative method resulted being feasible; thanks to reduced mechanization (tractor, plough and harrow) and modern agronomic practices locally introduced. The methods were applied to rice and intercrops cultivation and resulted in yields (+6.4%) and farmers workload (-6.0%) improvements in the alternative method. However, the traditional one still reaches higher economic profits (+96.5%) due the lower costs, in particular of the broadcasting sowing solution.

Introduction

Food production in Sub-Saharan Africa, of which Sierra Leone is an integral part, is characterized by small-scale farms with limited resources access and lack of adequate modern technical knowledge to maximize production and products transformation (Costa *et al*., 2013; Alieu, 2008; Defoer *et al*., 2002; Johnny *et al*., 1981).

Seventy-five percent of the total population (5,752,000 people) of Sierra Leone is employed in agriculture, which is considered the most appropriate activity of sustainably solving food issues, if properly practiced.

Sierra Leone (total surface 71,620 km^2) has an agricultural area equal to 39,300 km^2, of which 85% is dedicated to rice production (FAOSTAT, 2015). The average rice yield in the upland is 0.5-2.0 t/ha (FAOSTAT, 2015), almost similar to neighboring countries and significantly influenced by the tropical climate and the lack of adequate irrigation infrastructures. The mean annual rainfall is 2,500 mm (The World Bank Group, 2015) but its distribution is not uniform at all, resulting in large water surplus during the rainy season (May-October) and severe water deficit during the dry season (November-April).

Therefore, appropriate tillage practices are crucial to increase and guarantee crop yields and ecosystem stability (FAO, 1993), providing the best opportunity for halting degradation and for restoring and improving soil productivity (FAO, 1993; Costa *et al*., 2013).

To investigate some achievable improvements to produce rice-staple food and to try to increase the rice yield, a research was carried out in the North of the country; more precisely in Bombali district (8°52′48″N 12°03′00″W). Essential skills in mechanization to carry out tillage operations and modern agronomic methods have been introduced and taught to farmers, who directly took part in the research. Finally, the economic and social benefits were identified.

Materials and Methods

By focusing on agronomic, mechanical and economic strategies, the study aimed to investigate the improvement of: (i) yield (t/ha), (ii) acreage worked per farmer (ha/farmer), (iii) quality of work, and (iv) working time (h/ha), trying to reduce significantly the time dedicated to fieldwork (manpower).

To analyze this system, two cultivation practices for upland rice and intercrops cultivation have been compared. The comparison was made between:

(i) the "Traditional Method" (TM) consisting of the manual cultivation through hoe and cutlass (machete);

(ii) the "Alternative Method" (AM) made of basic mechanization, where only soil tillage—ploughing and harrowing—were mechanized.

The experimental field was made of a total surface of 2.0 ha that was equally divided in 4 plots of 0.5 ha each; each plot, which represents the average dimension of local fields, was attributed to one farmer (family) and further divided into two halves (0.25 ha each): one as TM and the second as AM.

Additionally, every plot was distinguished in different treatments:

(i) the Traditional Method was composed of one Traditional Treatment (TT), with a total surface of 0.25 ha;

(ii) the Alternative Method was composed of 5 Alternative Treatments (AT) each measuring 0.05 ha. These 5 consisted of:

a. pure rice only (*Oriza sativa*) - ATRR,

b. rice and pigeon peas (*Cajanus cajan*) - ATRP,

c. rice and beniseed (*Sesame indicus*) - ATRB,

d. rice and sorghum (*Sorghum bicolor*) - ATRS,

e. rice and all the 3 intercrops - ATTC.

This distinction was due to a compromise got with farmers, since tests could be fulfilled only after having guaranteed the presence of an adequate surface cultivated with their traditional production system, in order to assure food for survival issues. Other solutions would have been at the expenses of the study. **Fig. 1** shows plots division and treatments location within the plots.

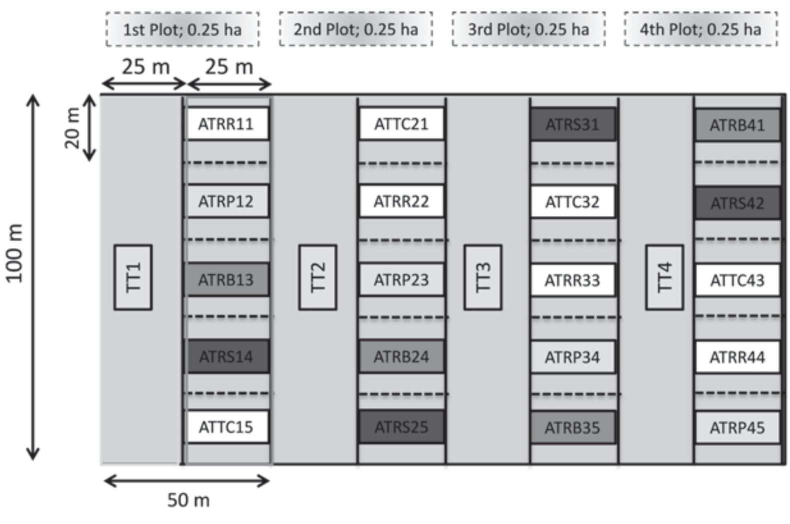

Fig. 1 Experimental land area
For each of the four plots, TT is the Traditional Treatment, AT is the Alternative Treatment. Other letters are meant for only rice (RR), rice and intercrops (pigeon peas RP, beniseed RB, sorghum RS, and all of them TC. The first figure stands for the number of the plot (1-4) and the second for the number of treatment per plot (1-5).

As regards to the mechanical operations, the 0.25 ha of AM were completely tilled by the same tractor (FIAT 780; 4WD; 58.5 kW), implements (disc plough and disc harrow) and operator in a sequential manner. On the other hand, farmers using traditional tools, such as machetes and hoes, cultivated the 0.25 ha of TM.

As concerns sowing, manual random broadcasting of rice and mixed crops was done in TM, while manual row sowing of rice and intercrops was carried out in AM. In both methods no seeder was used. However, a fixed row distance in sowing was defined by means of a furrow maker manually pulled. The furrow maker was made of three prongs and two external wheels with a circumference of 1 meter. The distance between each prong and wheel was equal to 0.25 m, which defined the distance between the rows. As regards to rice, it was sown on the impressed prongs lines with a seed distance on the rows equal to 0.025 m. On the other hand, intercrops were only sown on the soil impressed by the wheels, at a distance on the row equal to 1 m, defined by means of- a point made on each wheel.

Vegetative response was studied: every month, rice density was measured in 1 m^2 with five repetitions per treatment, while that of intercrops was calculated by manual head counting. Rice growth was monthly assessed both measuring plant height and counting tillers and intercrops growth measuring both plant height and canopy spread at an interval of 3 months after sowing.

Weeds presence in each treatment

was assessed by counting weed density per m^2; their presence was an high yield-conditioning problem (Ismalia *et al.*, 2013) and the control was made by manually removing weeds every two months.

Also the effects of insect pests were observed, while rodents and birds were controlled using fencing and bird scaring one month long after the panicle bearing.

Harvesting of rice and intercrops in both TM and AM was done manually, using local tools such as knives and winnowers. Rice yield was measured in 1 m^2: five samples per treatment were harvested, threshed, naturally dried to 14% moisture content and weighed. Intercrops yield was assessed by harvesting 20 stands per treatment, drying and weighing.

As concerns the production inputs, tractor and equipment (i.e., plough and harrow) were obtained from local contractors. Work depth and speed were measured in each treatment and averaged. Seeds and fuel were bought from a commodity. Seed quantities (kg) per treatment were weighed and tractor fuel consumption (L) was measured by quantifying the topping up at the end of each treatment.

For all production inputs, local prices were taken into account and for each working activity the number of workers involved and the amount of worked hours were recorded.

Finally, the economic balance of the two methods was assessed and compared.

Results and Discussion

The results of the comparison between TM and AM are reported in **Tables 1** and **2**.

In more details:

- the work time for land preparation (land clearing from weeds and soil tillage) is 12.4 h/ha in AM (ploughing and both 1st and 2nd harrowing). In this case one worker is considered. TM took 128.0 h/ha for land clearing and 168 h/ha for manual hoeing and sowing, totally involving 10 workers. A comparison is not completely affordable as TM includes sowing within hoeing, however through AM there was about 90% of time saved by considering the mechanical operations;
- during ploughing, the work time was 7.7 h/ha, one worker considered. Fuel consumption was 40.2 L/ha. Depth and width of plough were 0.31 and 1.10 m respectively, while the average speed was 2.4 km/h;
- during 1st harrowing, the work time was 2.7 h/ha, one worker considered. Fuel consumption was 12.0 L/ha. Depth and width of harrow were 0.18 and 2.30 m respectively, while the average speed was 5.1 km/h;
- during 2nd harrowing, the work time was 1.8 h/ha, one worker considered. Fuel consumption was 8.1 L/ha. Depth and width of harrow were 0.11 and 2.30 m, respectively with an average speed equal to 6.2 km/h;
- rice density was higher in AM, with 178 plants/m^2 (+18.6%) with 55 kg/ha of seed, while in TM it was 150 plants/m^2, moreover with 60 kg/ha of seed. This implies better seed germination in AM;
- the weed density was lower in AM with, on average, 51 weeds/m^2 while in TM it was 60 weeds/m^2 (+17.6%); in TM more resources (e.g., time and manpower) were needed to control weeds;
- rice growth was qualitatively better in AM rather than in TM in terms of both height and tillers. The average rice height (measured 4 months after sowing) was equal to 1.16 m and 1.08 m in AM and TM, respectively. Rice stands tillering and panicle bearing were also better in AM, with an average of 6 tillers per stand with 1 tiller without rice panicle, while in TM there was an average of 5 tillers per stand with 2 without rice panicles;

Tables 1 and **2** Comparison between Traditional Method and Alternative Method

Table 1

Production parameters	Unit of measure	TM	AM
Seed-bed preparation time	h/ha	296	12.4
Seed-bed preparation work capacity	ha/h	0.007	0.13 plough 0.47 harrow
Seed rate	kg/ha	60	55
Plant density	plants/m^2	150	178
Weed density	weeds/m^2	60	51
Average height	m	1.08	1.16
Tillering	n.	5	6
Panicle bearing	n.	4	5
Rice yield	t/ha	2.2	2.34
All intercrops yield	t/ha	0.08	0.42
Total yield (rice plus intercrops)	t/ha	2.28	2.76
Total worked time	h/ha	2,000	1,880

Table 2

Economic parameters	Unit of measure	TM	AM
Total cost of production*	$/ha	683	818
	$/t	299	296
Total income of production*	$/ha	839	898
Total profit of production*	$/ha	155	80

* Both rice and intercrops

Table 3 Total costs of ploughing distinguishing among labor, consumables and machinery

Alternative method			
OP_01:	Ploughing (mechanical operation)		
	Components	Unit	Plots Average
	Area	ha	0.25
Labor	Number of day	nr	0.00
	Employed (men/women)	nr	0.00
	Human total time	h	0.00
	(A) Labor cost	$	0.00
Consumables	Consumable_01	kg	0.00
		$/kg	0.00
	Consumable_02	kg	0.00
		$/kg	0.00
	Consumable_03	kg	0.00
		$/kg	0.00
	(B) Consumables costs	$	0.00
Machinery	Total fuel consumption	L	10.25
	Machines total time	min	115.50
	Operator total time	min	115.50
	(C) Machinery costs	$	21.35
Costs	Operation cost (A + B + C)	$	21.35
		$/ha	85.39

- rice yield was 2.34 t/ha (14% moisture content) in AM and 2.20 t/ha in TM, which implies a small yield increase (+6.4%). Intercrops yield was much higher in AM (+525%) than in TM (0.42 and 0.08 t/ha, respectively);
- the total cost of production (both for rice and three intercrops) in AM was higher (818 $/ha) when compared to TM (683 $/ha). As shown as an example in **Table 3**, total production costs were calculated by summing:
  1) labor cost (manpower),
  2) consumables cost (cost and quantity of inputs such as seeds),
  3) machinery cost (fuel for the machinery and labor for the worker).

This was made for all operations included in both TM and AM. Finally, the total profit was obtained.

- as concerns the whole production process, there was less time (-6.0%) spent in AM (1,880 h/ha) compared with TM (2,000 h/ha) (**Fig. 2**). Although time for post-sowing activities was predominant (1,676 and 1,704 h/ha for AM and TM, respectively), the time reduction in the mechanized section was evident;
- row sowing in AM was made in 192 h/ha, which significantly impacted on the total working time, if compared to TM, where seedbed preparation (hoeing) was carried out simultaneously with sowing (168 h/ha).

It can be observed from data that AM implies the best performances in terms of yield and agronomic features of the crops. In addition, a reduction of time associated to fieldwork is shown as well. However, the economic results are still more interesting in TM, since costs are lower.

The lower profit in AM is mainly a cause of the row sowing method carried out with no mechanical support that considerably influences production costs. On the opposite, the manual sowing carried out through random broadcasting in TM saves time and labor.

Hence, at the moment, time saved in AM is not convincing to reach a comparable economical threshold, but can be further improved by engaging additional activities such as mechanical sowing. Actually, the essential achievable improvement entails focusing on the manual alternative sowing method (192 h/ha): if this time was reduced to 3-4 h/ha by using an equipment coupled with the tractor already available, the time saved would significantly increase, since the whole production

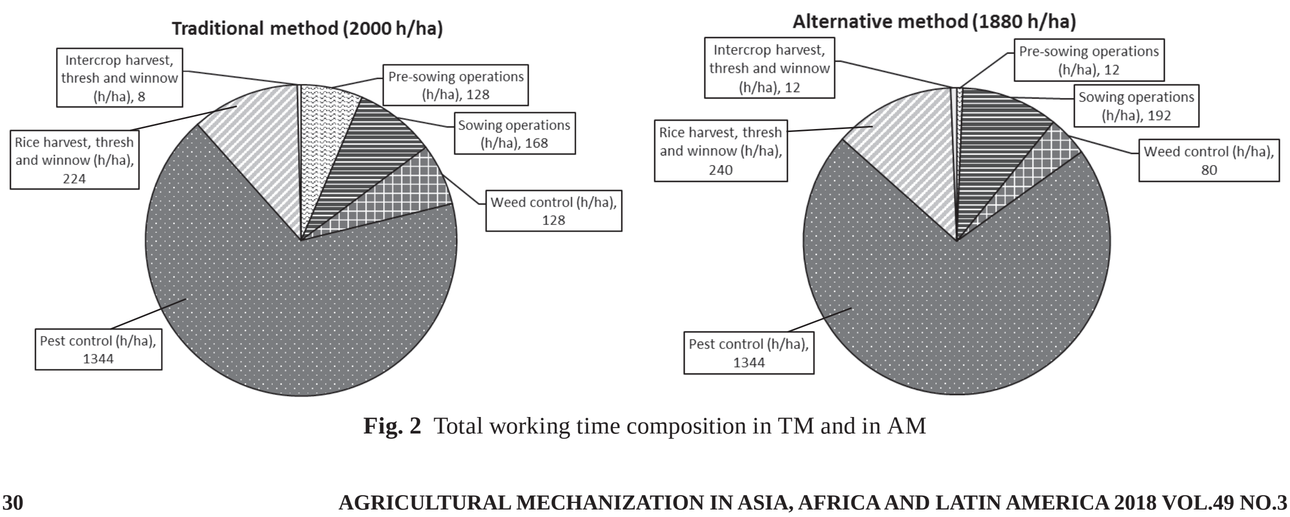

Fig. 2 Total working time composition in TM and in AM

would require 1,682 h/ha instead of 1,880 h/ha. In more details, the workload for all the mechanical operations would reduce from 204.4 h/ha (AM with manual sowing) to 16.4 h/ha (AM with mechanized sowing). As a consequence, the reduction of work time obtained when comparing land-preparation and sowing operations in TM (296 h/ha) with those in AM (16.4 h/ha) would be equal to 94.4%. In addition, the same sowing equipment could also be used for other crops, determining an increase in the economic value of both the machine and the equipment.

Conclusions

Mechanized operations represent an important tool to improve crops yields, as other possibilities commonly lack, such as chemical fertilizers, herbicides, insecticides or motorized farm equipment (Costa *et al*., 2013). In fact, in Sierra Leone, these input materials are available for a very small part of farmers (< 5%). In addition, widespread use of local unimproved varieties, coupled with unchanged cultural practices, adversely affects rice production (Abdelrasoul *et al*., 2013). Higher levels of agricultural technology are commonly not affordable, due the low economic returns from commodities.

The results of the research show that the introduction of essential mechanization and basic modern agronomic practices have relevant social impacts on the production process of rice and its allied intercrops, concerning mainly farmers lives, especially women', who represent the main source of manpower.

The essential mechanization practiced through ploughing and disc harrowing resulted in a total saving of 6% (120 h/ha) of farmers work time and in reducing 5.5% of farmers labor cost (lower manpower). This increase in time availability can lead to extremely positive contributions to the betterment of their lives, such as increasing their engagements in other economic activities, creating room for women and children in social welfare, enabling adequate time to rest and increasing the mechanical, agronomic and productive possibilities and capabilities.

The workload can be reduced even more by introducing a mechanized sowing, which entails lower time per hectare and therefore a total saving of approximately 280 h/ha. Total work time would reduce to 1,682 h/ha, which means -15.9% if compared with TM. The higher level of fieldwork capacity can also lead to better crops performance, since farmers can complete the sowing in good environmental conditions for crops growth. Another achievable solution can be the mechanized weeding, to reduce even more the work time.

Generally, although there is higher yield per hectare in AM, economically the results of this study show a higher income return per hectare with TM. This is due to the cost of manpower for row sowing, which also entails a strongly higher amount of worked hours when compared to the traditional broadcasting. As concerns the costs of the mechanical operations, the higher cost due to the machinery loan in AM is balanced by the higher manpower needed in TM. This means that these activities do not significantly influence the difference in profit of the two practices.

Anyhow, the economic benefit must be weighted, in order to compare its importance with the social and health benefits of farmers, of women in particular. By reducing the work time on fields, women can take part in other activities, taking care of their family and paying more attention to health issues and finally improving lives, which can mean a lot in such a poor country.

In conclusion, the introduction of AM approach does not only create social gains but also exposes farmers to new skills, knowledge and techniques that will enable them to improve their farming capabilities and assume lasting solutions to farming activities.

REFERENCES

Abdelrasoul, A., A. Childs, J. Clerisme, E. Dzakuma, B. Pittman and E. Sogut. 2013. Pioneering High-Yield Rice Production in Sierra Leone. Recommendations for an outgrower model. SIPA, School of international and public affairs.

Alieu, E. K. 2008. Policies and strategies for promoting food security in Sierra Leone with special reference to rice. Rice Research Station, Rokupr. Editor Kormawa P., Touré A. A. pp. 341-352.

Costa, S., G. M. Crovetto and S. Bocchi. 2013. Family Farming in Africa, an overview of good practices in Sub-Saharan Africa. Food We Want Campaign.

Defoer, T., M. C. S. Wopereis, M. P. Jones, F. Lancon and O. Erenstein. 2002. International Rice Commission. Sustainable rice production for food security. Part V. Regional strategies on rice production. FAO Corporate Document Repository.

FAO. 1993. Soil Tillage in Africa; Needs and Challenges. FAO Soils Bulletin 69.

Ismaila, U., A. C. Wada, E. Daniya and A. U. Gbanguba. 2013. Meeting the Local Rice Needs in Nigeria through Effective Weed Management Sustainable Agriculture Research. Sustainable Agriculture Research. Vol. 2, No. 2.

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Modern Farm Technologies for Enhancing Work Productivity with Reduced Drudgery of Rural Women in Hill Agriculture

by

D. K. Vatsa
Principal Scientist & Head
Dept. of Agricultural Engineering
CSKHPKV, Palampur - 176 062
INDIA

Neena Vyas
Senior Scientist
Dept. of Family Resource Mangt.
CSKHPKV, Palampur - 176 062
INDIA

Abstract

Over the years, there is a gradual realization of the key role of women in the field of agricultural development. Agriculture bears great significance in the hilly region of Himachal Pradesh, because more than 80 percent of the population living in rural areas depends directly or indirectly on it. Majority of the rural people are either cultivators or agricultural labourers. The food grain production in the state is stagnating at about 1,500-1,700 kg/ha for the past one decade in spite of providing modern inputs like seed, fertilizer etc. This is because of poor resource availability in different form. Presently, farm power available from different sources was 0.9 kW/ha which is quite low for timely operations in which the total contribution of animate power was maximum i.e. 60% in hill farming. In hill agriculture workers are extensively engaged in carrying out various field operations. Here productivity of workers is less, drudgery involved is very high and safety is concern. Hill agriculture mainly includes valley cultivation, terrace cultivation and growing crops and orchards on slopes. Carrying of inputs to fields and produce to roads involve severs drudgery. There is strong need for improvement in existing tools, development of new tools and study of working methods.

Farm women using traditional tools and implements had reported that these tools gave too much fatigue and were not easy to operate. Few tools and equipment developed to enhance working productivity, evaluated and recommended for hills in different operations are power tiller rotavator, seed drills, paddy seeder/transplanter, wheel hoe/cono weeder, serrated sickle, bush cutter, paddy thresher, tubular maize sheller, horizontal & vertical cob sheller for reduction of women drudgery. To sustain the hill farming, appropriate farm mechanization is the requirement and the farm women working most of the time in hill agriculture has to be given attention. The major priority should be small and marginal farmers for mechanizing the hill farm who dominate the peasantry. The paper is highlighting the present status, available modern technology and prospects of farm mechanization with respect to rural women in hill agriculture.

Introduction

In hills of Himachal Pradesh, rural population is about 90% and doing mainly farming to make their life better and comfortable (Anonymous 2015-16). This shows that farming has always been the main stay of the economy of the state. On the other hand, the rural youths are not interested to do the farming with present resources at their farms as it is time consuming, cumbersome and not up to the dignity after getting the proper education. Presently the literacy rate of the state is more than 85% (Anonymous 2015-16). In farming, the farmers are still using primitive conventional tools and equipment drawn by human and animal power which involve severe drudgery. The manual force is the major power for hill agriculture in which almost 60-80% of the power met out by the women folk (Singh and Vatsa 2015). By 2020, the ratio of agricultural workers to total workers will go down to 40% from 52% present, though the number of workers will remain same that is around 240 million, of these about 50% will be women worker (Gite, 2012). The use of animal power is limited to land preparation. Mechanization is a difficult task in hills because of unique topography and undulating terrain. The hill mechanization is possible only by using small power source and improved light-weight agricultural equipment.

To modernize the farm in our country, numbers of agricultural hand tools, implements and machineries have been developed but they have, by and large, helped men folk in carrying out various farm operations. Besides, the tools and equipment were also developed for women folk to make the operations easier specifically for plain regions (Singh *et al*., 2009). Rural women form the most important productive force in the economy of Himachal Pradesh. The women folk working most of the time in hill agriculture using primitive tools and implements. These tools and implements are not ergonomically designed as per their physique in various operations which resulted they have to work under the adverse conditions of drudgery. The plight of women can be well imagined by the fact that during the seedbed preparation (after harvesting paddy crop), when the men plough the fields with soil stirring plough, the women crush the clods with the help of wooden clod hammers. More than 80% area is rain fed where cultivation is not possible without appropriate moisture content in the field. This also forced the farmers to complete the various farm operations in shorter duration. Not only this, efficient use of inputs, precision and timeliness of farming could also not be achieved particularly in rain fed by using these tools and equipment. Due to this reason, productivity of hill agriculture is very low. However, with the introduction of mechanical power and improved farm tools, mechanization scenario of Indian agriculture in plain region has drastically and significantly changed in some states. Thus there is a need to introduce appropriate improved tools and equipment for hills so that the drudgery of hill farm women in various farm operations could be reduced and the productivity will be increased. There is also a great need for ergonomic analysis of various operations, to study the fatigue, posture, stress, musculoskeletal problems etc. Therefore, improved productivity and health are expected benefits out of drudgery reduction through technology interventions. This paper illustrates the importance and need of appropriate farm mechanization particularly for women and its relevance to the sustainable hill farming.

Scenario of Hill Agriculture

Himachal Pradesh is located on a sloping terrain of Himalayas, having snow clad mountains, rolling hills and valleys which permit the cultivation of a wide variety of crops and fruits. The elevation of the state widely ranges from 350 m to 6,975 m above mean sea level. On account of the wide variations in altitude and topography, the state has broadly been divided into four zones of sub-montane and low hills sub-tropical, mid hills sub humid, high hills temperate wet and high hills temperate dry.

Land Use Pattern and Production

The state has total geographical area of 5,567 thousand hectares out of which only 539 thousand hectares (about 10% of geographical area) is under cultivation. The overall view of land use pattern in Himachal Pradesh is shown in **Fig. 1**.

All the zones have good potential to grow various agricultural crops such as maize, paddy, wheat, barley, mustard, pulses and different vegetables; and horticultural crops such as apple, kinnow and citrus fruits, walnut and dry fruits, tea etc. However, agriculture in general is handicapped due to steep and hilly terrain, hazards of climate, uneconomic scattered holdings comprising of shallow and stony soils. Typical terrace farming with higher vertical interval is practiced (**Fig. 2**) in all the zones of Himachal Pradesh due to undulating topography.

The information regarding area, production and average yield on main agricultural and horticultural crops grown in the state is given in **Table 1**. The yield per unit area is quite low for most of the cereal crops.

Size of Land Holding

The average size of land holding with different categories of farmers is shown in **Fig. 3**. It is clear

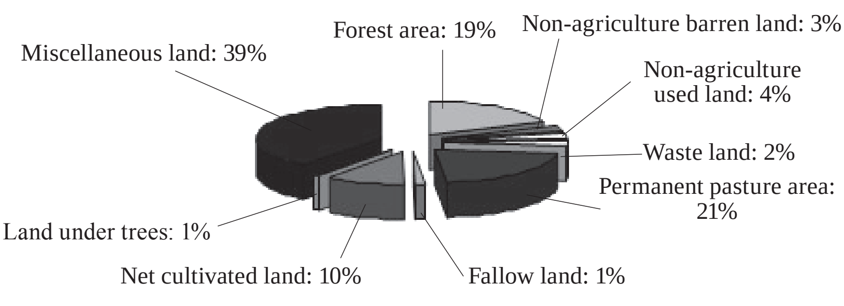


Fig. 1 Land use pattern of Himachal Pradesh

Fig. 2 A View of typical terrace farming

that the marginal and small farmers comprising 87% dominate the peasantry of the state having average size of land holding less than 1.0 ha whereas a very small number of farmers fall under medium and large category. The overall land holding of Himachal Pradesh is 1.04 hectare, which is lower to India's average holding size of 1.15 ha. It shows that small power sources and implements will play a major role in hill farming.

Status of Farm Power Sources and Implements

The power sources and the implements used for agriculture in Himachal Pradesh are shown in **Table 2**. The major power source for hill agriculture is bullock which is approximately 0.54 million for operating the plough. The most common implement is plough, which are more than 0.63 million and replacing the indigenous plough with passage of time. The other implements used by the hill farmers are electric pumps and threshers. It is evident that the hill farmers are not using seed drill for sowing, wheel hoe for interculture and reaper for harvesting. Mostly traditional tools are being used such as spade, plough, wooden hammer, breaking clods, hand hoe (Khuntee), kudali, rake, plain sickle etc. for land preparation, weeding, clearing and other farm operations. The breaking of the clods and paddy transplanting need higher women force (**Fig. 4**) and has to exert maximum force for good preparation of land and transplanting. Thresia (2004) also revealed that tedious manual activities such as transplanting, weeding, harvesting, transporting, threshing, drying were wholly done by women and on an average, they got three and half months of work in a year. Harvesting was completed with both traditional and serrated sickles. About 50% of respondents were aware of serrated sickles. Maximum number of respondents completed threshing

Table 1 Area and production of main crops in Himachal Pradesh

Crops	Area, 000 ha	Production, 000 MT	Av. Yield, kg/ha
Agricultural Crops			
Rice	72.5	125.3	1,728
Wheat	330.4	646.5	1,956
Maize	292.6	677.8	2,316
Barley	21.7	37.7	1,737
Potato	18.1	183.3	10,127
Other vegetables	75.2	1,608.5	21,389
Horticultural crops			
Apple	109.5	777.1	7,097
Citrus fruit	22.3	28.7	1,287
Walnut and dry fruit	11.1	3.6	316
Other fruits	76.4	103.4	1,353

Source: Statistical Abstract of Himachal Pradesh (2015-16)

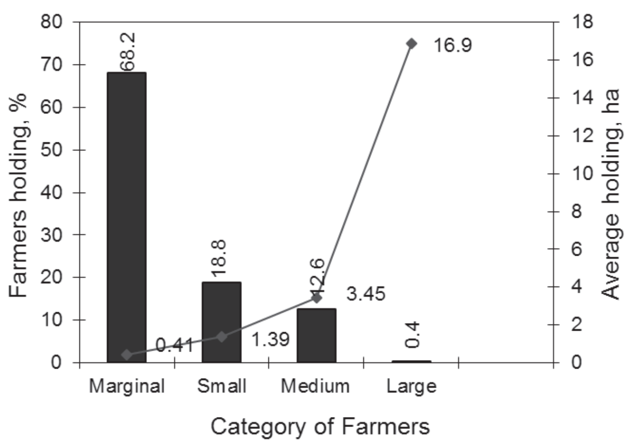


Fig. 3 Distribution of land holding

Table 2 Number of power source and implements in Himachal Pradesh.

Type of power source	Number	Type of implements	Number
Bullocks	543,767	Tractor	6,966
He-buffaloes	1,139	Diesel Engine	3,664
Mules	18,985	Electric pumps	7,325
Yak	1,705	Plough	631,470
Donkey	7,376	Thresher	19,458
Horses & ponies	13,155	Bullock Cart	2,404

Source: Statistical Abstract of Himachal Pradesh (2015-16)

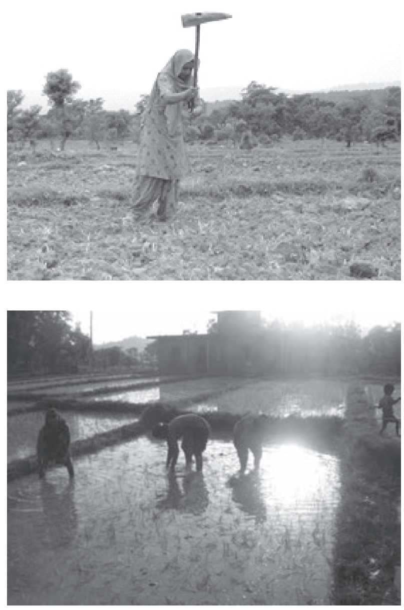


Fig. 4 Traditional field preparation and transplanting

with the help of oxen and storage was done in metallic bins.

The capacity of farm tools and implements used in the field is presented in **Table 3**. It is clear from table that the field capacity of soil stirring plough was 0.023 ha/h. Similarly, the field capacities were 0.009, 0.003, 0.008 ha/h for clod breaker, Khuntee and sickle respectively. Farm women using these tools and implements had reported that these tools are much heavier, gave too much fatigue and were not easy to operate (Vatsa and Singh, 1998). In addition, proper posture could also not be achieved while working with these tools.

Availability of Power From Various Sources

The farm power available from different sources was 0.91 kW/ha which is quite low for timely operations (**Table 4**). Studies show that the farm power requirement is 2 kW/ha for getting the better production (Srivastava, 1999). It is also clear from Table that the total contribution of animate power was maximum of 60% in hill farming. To meet the requirement of farm power, there is a need to supplement the appropriate mechanical power for timely and precision farming as well as reducing the women drudgery involved in various operations.

Farm Women Involvement

Human power involvement is one of the most important factors in various agricultural operations for determining the drudgery. **Fig. 5** shows the percentage gender participation in various agricultural operations.

It is evident from the **Fig. 5** that 60- 80% women were involved actively by contributing in clod breaking, sowing, manuring, transplanting, channel making, interculture, fertilizer application, harvesting, plucking, grading and transporting the fodder and produce of farm whereas 100% men were engaged in ploughing, puddling and planking etc.

Table 3 Capacity of hand tools and implements used in the field

Hand tools and implements	Source of Power	Field capacity, ha/h
Soil stirring plough	Bullocks	0.023
Planker	Bullocks	0.20
Wooden clod breaker	Manual	0.009
Khuntee	Manual	0.003
Sprayer	Manual	0.06
Sickle	Manual	0.008

Table 4 Availability of farm power from various sources in Himachal Pradesh

Power Source	Number Lakhs	Total power, Lakhs kW	Available power, kW/ha	Contribution of power, %
Human	20.50	1.53	0.28	31
Animals	5.44	1.42	0.26	29
Tractors	0.07	1.83	0.31	34
Diesel Engine	0.04	0.24	0.03	3
Electric Motors	0.07	0.26	0.03	3
Total		5.28	0.91	100

One Lakh =100,000

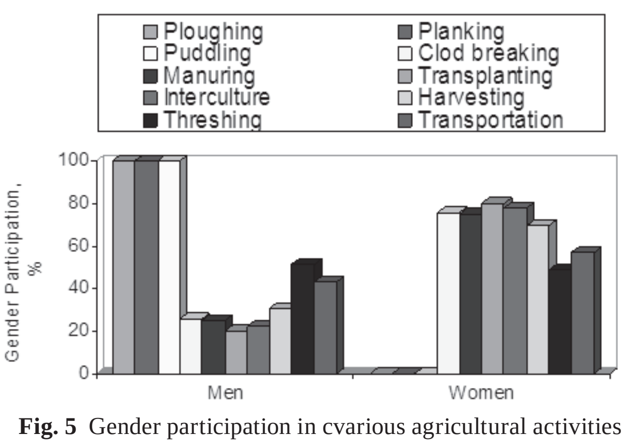


Fig. 5 Gender participation in cvarious agricultural activities

Modern and Suitable Farm Technologies for Hills

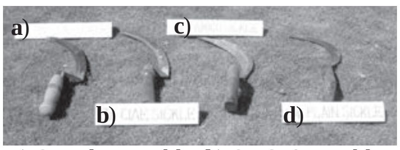
To mechanize the hill farming, the technology available is quite scanty as well as not matching to the women folk involved in the various operations. Few studies carried out in mechanizing the hill agriculture with the help of improved tools and equipment for reducing the drudgery of women are enumerated below:

Power Tiller Rotavator

The rotavator was found good for land preparation (**Fig. 6**) as well as very effective in puddling operation. By using rotavator, the 60% time and 80% labour can be saved with reduced drudgery to women folk.

Fig. 6 Power tiller in operation

Fig. 7 Seed drill and paddy transplanter in operation



a) S1 Falcon sickle; b) S2 CIAE sickle; c) S3 Pamico sickle; d) S4 Plain sickle

Fig. 8 Sickle and bruch cutter for harvesting

Fig. 9 Vegetable plucker

The other benefit of rotavator was better tilth and could also be used on custom hiring as entrepreneur.

Seed Drill/Paddy Transplanter

Manual drawn seed drills and multicrop planters (**Fig. 7**) were very good equipment for sowing maize, soybean, wheat and some other crops with precision and timeliness of operations. Similarly paddy transplanter could save labour and time with minimum drudgery. The results also indicated 10-15% higher production by using seed drill/planter.

Wheel Hoe

For inter-culture, wheel hoe was recommended for use in row crops of wheat, soybean, maize by farm women as this implement can cover five times more areas with less drudgery as compared to khuntee.

Sickle/Cutter

All serrated sickles and power operated cutter (**Fig. 8**) have 20-50% higher capacity than local plain sickle for harvesting of crops. Serrated sickle manufactured by Falcon Tools was found best among all the available serrated sickles. For harvesting maize crop, a power operated bush cutter cum crop reaper has been found three times better than traditional harvesting. The capacity of bush cutter was 0.028 ha/h.

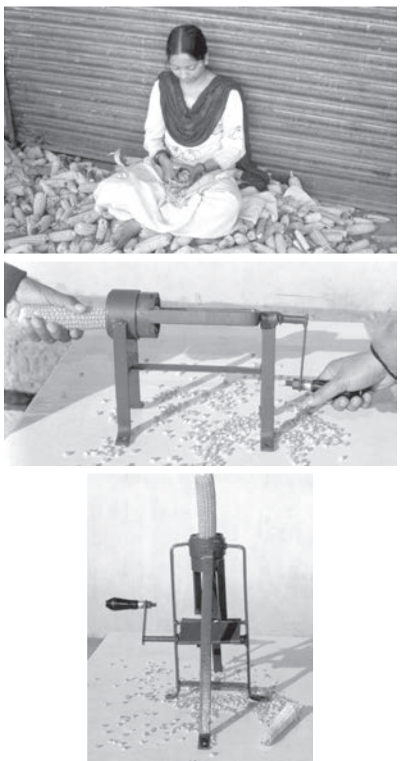


Fig. 10 Manually operated various maize shellers

Vegetable Plucker

The low cost tool for harvesting vegetable is liked by farm women. The plucker (**Fig. 9**) can save time, cost and reduce drudgery compared to traditional harvesting.

Paddy Thresher

Paddy threshing with the help of pedal operated paddy thresher has shown 50% higher capacity as compared to beating method and requires minimum labour with less drudgery.

Maize Sheller

Tubular maize sheller is a good tool for maize shelling. Farm women can easily adopt this tool because of low cost and high efficiency. However, the hand operated tubular maize sheller needs further modifications for firm grip mainly for use by the women. Horizontal and vertical cob shellers (**Fig. 10**) were also found 50% higher efficiency compared to tubular maize sheller.

Grain Cleaner

Hand and pedal operated grain cleaners developed by CIAE have been found good for cleaning of grain with 82 and 205 kg/h capacity respectively. This equipment can save 80% time of farm women.

Engineering and Ergonomical Intervention for Future Work

Women folk play a very significant role in carrying out different farming operations in the hills and from the human stand point, it is not desirable to subject them to a lot of drudgery in undertaking such tedious tasks. Certain suggestions for enhancing the output and reducing the drudgery of women and sustainable hill agriculture are enumerated below:

Light Weight Power Source and Equipment

The available power in hill agriculture is very low, about 0.9 kW/ha. Due to this, the farmers of the region are unable to complete the farm operations in time, particularly in the rainfed areas, which consequently affect the overall production of food. To select proper agricultural power source and matching machinery, planning at the macro level is required. In the limited valley areas where the economic condition of the farmers is good, use of the available power tiller can help in mechanisation of agriculture and reducing drudgery of farmers (Vatsa and Saraswat, 2003). Due to the prevalence of hilly terrain having undulating topography, total weight of any machine used in the agricultural sector is a major factor in determining its use and efficiency. Thus, while designing and selecting a power source and machines, its weight should be kept as low as possible so that it can be easily driven at the turns in the field and the transportation from one terrace to another having high vertical drop becomes less cumbersome.

Ergonomically Designed Machines for Women Folk

Women manage majority of the operations in hill farming and hence there is need to develop such tools, which can be efficiently used by women in reducing drudgery in agricultural operations. Application of ergonomical procedures used and interventions should be given consideration for the design and development of appropriate tools and equipment for hill women. Some studies have shown that improvements to tools can reduce occupational strain, require less energy to use and thereby lead to greater working efficiency and increase productivity (Dewangan *et al.*, 2008, Singh *et al.*, 2009). An exhaustive study is required to be undertaken to gather data on anthropometric measurements in respect of women belonging to different districts of the state of Himachal Pradesh. Establishment of an Ergonomics Laboratory is required to conduct study on such aspects.

Enhanced Use of the Available Bullock Power

Presently, the peasants of the hilly region generally use the bullock power for ploughing purposes only and the animals remain idle for most of the time during the year. On the basis of the implements in vogue in the plain areas, there is need to design new light weight implements for use in the hilly areas to enhance the utility of available bullock power. This would increase the agricultural productivity by conducting farm operations timely and reduce heavy work load.

Need of Sowing Through Seed Drill/Planter

There is need to design and develop a low weight two row animal drawn seed-drill/planter for sowing major crops of the region. Line-sowing technique would make the weeding/inter-culture operations less tiresome while using even the traditional tools like “Khuntee” and “Kudali” (Vatsa and Singh, 2010).

Carriage in an Easy Manner

The women generally carry big head loads of farm produce, manure, grasses etc. to transport such material from one place to the other. In the absence of a suitable carrier, these operations become time consuming and tiring. Taking into consideration the topography of the region, there is an urgent need to develop a suitable machine for transporting such loads.

Evaluation of Horticultural Tools

Apart from the agricultural sector, the women are also involved in conducting farm operations in the horticultural sector using the conventional hand tools. There is an urgent need for formulating and executing a project on design, development and evaluation of horticultural tools to refrain women from working too hard.

Setting-Up of Small Scale Industry and Strong Extension Net-Work

The demand of the farmers for traditional tools and implements is mostly met by the rural artisans/blacksmiths etc. spread throughout the state of the Himachal Pradesh. The Himachal Pradesh Agro Industries Corporation is also engaged in manufacturing certain tools and implements. However, there is no organised industry in the state to cater to the need of designing and fabricating improved tools/equipment and to further rationalize it, establishment of small scale manufacturing units should be encouraged.

Organization of Trainings/Demonstrations/Awareness Camps

Exposure cum training on use and operation of various machines/tools it is necessary to organize training programmes for skill up gradation of farm workers at block/village levels so that they can use new and improved tools in comfortable and safe manner.

Need for an Advanced Centre for Hill Mechanisation

Present infrastructure for farm engineering intervention is almost negligible in Himachal Pradesh. There is one agricultural university in the state where only one scientific man power is engaged in research and development work to meet out the demand of all the zones of hills.

Not only this, state government is also not having proper network for research and extension activities due to non-availability of suitable manpower. In light of the above, establishment of an Advanced Centre for Hill Mechanisation equipped with modern gadgets and suitable scientific manpower is the need of the hour. This would go a long way in reducing drudgery of women in hill agriculture.

To create awareness in the farming community regarding the use of modern drudgery reducing technologies on a larger scale at different locations are required.

Conclusions

From this paper, it is concluded that role of women in various agricultural operations is much higher i.e. 60-80% than men. Farm power available from different sources was 0.91 kW/ha in which the total contribution of animate power was a maximum of 60% in hill farming. Farm women using traditional tools and implements had reported that these tools gave too much fatigue and were not easy to operate. Few tools and equipment developed, evaluated and recommended for hills in different operations are animal drawn clod breaker, power tiller rotavator, seed drill/multi-crop planter, wheel hoe, serrated sickle, bush cutter, paddy thresher, maize sheller and grain cleaner for reduction of women drudgery.

This clearly indicate the importance of ergonomical and safety related issues of women in farm mechanization as due attention to this aspects may increase productivity by enhancing comfort and safety of women workers in the hills and reduce drudgery involved in agricultural operations. To reduce drudgery of women, certain long term strategies like introduction of mechanical power source and ergonomically improved farm tools and implements is the need for sustainable hill agriculture. This will be possible by establishing an Advanced Centre for Hill Mechanisation equipped with modern gadgets and suitable scientific manpower.

REFERENCES

Anonymous. 2015-16. Statistical Abstract of Himachal Pradesh 2015-2016. Department of Economics and Statistics. Government of Himachal Pradesh, Shimla.

Dewangan, K. N., C. Owary and R. K. Datta. 2008. Anthropometric data of female farm workers from north eastern India and design of hand tools of the hilly region. International Journal of Industrial Ergonomics, 38(1): 90-100.

Gite, L. P. 2012. Changing scenario of ergonomics in Indian agriculture. In Proceedings International Conference on HWWE "Ergo2012: safety for all at GBPUAT, Pantnagar Uttarakhand, India, 6-8 Dec 2012 .pg. 18

Singh, S. P. and D. K. Vatsa. 1998. Development and evaluation of farm tools and implements to reduce drudgery of women in hill agriculture. Ad-hoc Project Report of ICAR. Deptt of Agricultural Engineering. CSKHPKV, Palampur.

Singh, S. P., R. S. Singh. and N. Agarwal. 2009. Women Friendly Improved Farm Tools and Implements for Commercialization. Agricultural Engineering Today. 33(2): 20-25.

Singh, S. and D. K. Vatsa. 2015. Need of ergonomically mechanized interventions in selected farm operations in hills of Himachal Pradesh. Agril. Mechanisation in Asia, South Africa and Latin America. 46(2): 23-28.

Srivastava, N. S. L. 1999. Role of Agricultural Engineering in doubling food productions in next ten years. Agricultural Engineering Today. 23 (1-2): 37-49.

Thresia, C U. 2004. Women workers in agriculture. Gender discrimination, working Conditions and health status. Discussion paper No. 85. Kerala Research programme on local level development. Centre for Development Studies, Thiruvanathapuram

Vatsa, D.K. and Saraswat, D.C. 2003. Agriculture mechanization in hills of HP- a case study. Agricultural Mechanization in Asia, Africa and Latin America. 34(1): 66-70.

Vatsa D. K. and Singh Sukhbir. 2010. Sowing methods with different seed drills for mechanizing mountain farming. Agricultural Mechanization in Asia, Africa and Latin America. 41(1): 51-54.

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Analysis of the Stability and Cost of the Rice Harvest-transport Process as a Function of the Transportation Distances and the Number of Transport

by

Yanoy Morejón Mesa
Professor
Department of Engineering
Agrarian University of Havana
Mayabeque -32700
CUBA
ymm@unah.edu.cu

Ciro E. Iglesias Coronel
Titular Professor
Agricultural Mechanization Center
Agrarian University of Havana
Mayabeque -32700
CUBA
ciro@unah.edu.cu

Javier León Martínez
Assistant Professor
Department of Engineering
Agrarian University of Havana
Mayabeque -32700
CUBA
jleon@unah.edu.cu

Abstract

This research was undertaken on the EAIG Los Palacios, using the SAORCE-CTR system to the determination of rational composition mechanized resources involved in the process of harvest-transport. With five variants of transportation distances and two agricultural yields, the influence of the distance of transportation and the amount of transportation in stability and cost of the harvest process was determined with a brigade composed of three harvesters NEW HOLLAND TC-57. For fields with crop yields of 3.2 t/ha, the total economic losses were reduced when five transport were used in the transportation variants I, II and III in 1.88; 3.61 and 7.06 peso/h (1 CUC= 25 CUP = 0,97 USD) representing 3.2; 8.3 and 9.7% of the total economic losses according to the current composition of the EAIG and in transportation variants IV and V, the total economic losses were reduced to the six means of transport in 20.35 and 22.37 peso/h respectively, representing 22 and 23.6% of the total economic losses according the current compositions of the EAIG. In agricultural fields, with yields of 4.2 t/ha total economic losses were reduced when six transport were used in each variant of transportation in 5.51; 11.93; 19.69; 31.3 and 168.32 peso/h respectively representing 8.3; 14.8; 21.3; 30.4; 67.1% of the total economic losses when the current compositions of the EAIG were used.

Introduction

During the development of the grain harvest-transport process, showing a number of organizational issues that directly determine quality, among these, the folowing may be mentioned:

- The low productivity rates achieved by the harvesters machines;
- Poor road conditions presented when the harvested grain is moved;
- Deficiency transportation cycle of grain harvested
- The congestion or lack of transportation in the field and grain reception centers, which causes an increase in the cycle time for the loss of unproductive time like waiting, thus increasing process costs.

Based on the aforementioned organizational issues, the research was conducted to a lack of continuity in the flow of technological harvesting system, which even manages to be stopped; this is caused mainly by organizational deficiencies of the process.

To determine the influence of the distance of transportation and the amount of transportation in the stability and cost of rice harvest-transport process, evaluation of the harvester machine is necessary, because this predetermines the potential productivity of the process, at harvest time, quality cutting, threshing and cleaning the grain and the amount of transport to allocate harvest brigade, influencing both techniques in the total costs of this process.

One factor that directly influences the stability and cost of the process is the composition of harvest-transport complex, which should be determined considering technical and economic criteria that allow the rational organization of the process, taking into account the minimum costs per unit of time and/or unit of product harvested and transported ,considering the harvester machine productivity, the capacity of means of transport, the transportation distance , the type and road conditions, waiting times for product loading and unloading on the field and on reception centers [Server *et al*., 2002; Garcia, 2010; Iglesias, 2007a; Iglesias, 2007b; Izmailov,2007; Amu, 2010; Iglesias, 2012; Matos, 2012a; Matos, 2012b; Miranda, 2013; Matos, 2014; Yesin, 2013; Shepelyov *et al*.,2014].

Materials and Methods

To determine the influence of the transportation distances and the number of transport in stability and cost - transport of rice crop in the conditions of the Agro-industrial Grain Enterprise (EAIG) Los Palacios, the SAORCE-CTR system was used. It may be possible to determine the rational amount of transportation, taking as reference of a brigade composed of three harvesters machines NEW HOLLAND TC- 57 developing the rice harvesting operation in fields with crop yields averages of 3.2 and 4.2 t/ha and a link of transport formed by tractors NEW HOLLAND TS- 6020 each one with two trailers IMECA, considering five variants of transportation that are listed below :

- Variant I. transportation distance 6 km (4 km asphalt and embankment 2 km) ;
- Variant II. transportation distance 12 km (9 km asphalt and embankment 3 km) ;
- Variant III. transportation distance 18 km (13 km asphalt and embankment 5 km);
- Variant IV. transportation distance 24 km (17 km asphalt and embankment 7 km) ;
- Variant V. transportation distance 30 km (22 km asphalt and embankment 8 km)

The SAORCE -CTR system has among its features the use of the Queueing Theory and the economic criterion of minimum total costs per stops of the harvesters and transportation, from operating costs [Morejón, 2014a; Morejón *et al*., 2014b]

$S = (C_{PC} \cdot \lambda \cdot t_{esp} + C_{PT} \cdot n) \cdot P_{cola} \rightarrow \min$, peso/h ....(1)

Where: C_{PC}, C_{PT} - hourly cost for harvester machine stops and transportation , peso/h ; average number of servers (transportation) arriving the system of waiting line; t_{esp} average waiting time of each request harvester machine , h ; n-number of transport to a group of harvesters ; P_{queue} - probability that a unit arrives at the system and have to wait or probability that there is a queue of both transport by harvesters machine and harvesters machine for transportation.

Considering the expression (1), it is possible to determine the hourly cost for harvester machine stops as follows:

$C_{PC} = C_{exp} = C_{dc} + C_c + C_l + C_{mr} + C_{soc}$, peso/h ....(2)

Where: C_{exp} -Costs operating, peso/h ; C_{dc} - cost of harvesters machine depreciation , peso/h ; C_c- Cost of fuel consumed , peso/h ; C_l -Cost of lubricant consumed , peso/h ; C_{mr}-cost of maintenance and repair , peso/h ; C_{soc}- cost in salary of harvesters machine operator, peso/h.

Likewise, the hourly cost of means of transport downtime can be determined using the following expression:

$C_{PT} = C_{dt} + C_{mr} + C_{sot}$, peso/h ......(3)

Where: C_{dt} - cost of means of transport depreciation, peso/h; C_{mr} - cost of maintenance and repair, peso/h; C_{sot}- cost in salary of means of transport operator, peso/h.

By determining the probabilities attached to stochastic processes that occurs during the harvesting process, it is possible to determine the probability that a unit of the complex harvest-transport arrives at the system and have to wait or the probability that there is a queue of both transport for harvesters and harvesters for transportation, which is determined as follows:

$$P_{queue} = 1 - \sum_{C=1}^{n} P_C \quad ....(4)$$

Where: P_C- Probability of units (combine and/or transport) in the system.

Results and Discussion

Determination of Rational Composition of the Harvest-Transport Complex of Rice in Fields with Agricultural Yields of 3.2 t/ha

Based on theoretical and methodological basis it was possible to obtain that for all variants of transportation, when was used one and two transport the condition $\varphi > n$ is satisfied, so the system cannot accommodate requests and the queue grows indefinitely. Similarly, it also happens when three means of transport are used in transportation variants IV and V.

The results show that for harvesting brigades formed by three harvesters NEW HOLLAND TC- 57, in fields with crop yields of 3.2 t/ha; when considering the probability that a unit of harvester or means of transport arrives at harvest system and have to wait, it is rational allocation of three means of transport for transportation variants (I and II); however, for the rest of the variants of transportation (III, IV and V), it is rational use of four means of transport, but when considering the economic criterion of minimum cost of total economic losses stops on a time, that for variants of transportation (I, II and III), five means of transport were required and for variants (IV and V), six means of transportation were required.

This contradiction between the probability of arrival of a unit of harvest and/or transport the system and minimum cost of total economic losses stops in one hour is given by reducing the average time a unit in the system and mainly harvester machines because it is the main link in the process; therefore, to determine the rational amount of transport and economic losses by harvest-transport process is reduced. These proposed compositions are shown in **Fig. 1 (a ... e)** represented mathematical models that match the relationship between the probabilities that a unit arrives at the system and have to wait (Probability of queue) for each the transportation variants depending on the amount of transportation.

Analyzing the results of economic losses that the current composition employed by the EAIG "Los Palacios", in which four means of transport are used for the above three harvesters is possible to reduce the economic losses, if in transportation variants I, II and III representing 3.2 ; 8.3 and 9.7% of total economic losses stops when it was used with the composition employed by the EAIG. However, for variants of transportation IV and V, it is possible to reduce the total economic losses stops, when it was used with six means of transport in 20.35 and 22.37 peso/h respectively, representing 22% and 23.6% of the total economic losses from the current EAIG conformation .

Determination of Rational Composition of the Rice Harvest-transport Complex in Fields with Agricultural Yields of 4.2 t/ha.

Based on theoretical and methodological basis raised, it was obtained that for all variants of transportation, when it was used one and two means of transportation the condition $\varphi > n$ is satisfied, so that the system cannot accommodate the requests and queue will grow indefinitely. Similarly, it happens when three means of transport are used in transportation variants III, IV and V.

These results demonstrate that for harvesting brigades in which three harvesters NEW HOLLAND TC- 57 were used, in fields with agricultural yields of 4.2 t/ha; when considering the probability that a unit arrives at the system and have to wait, it is rational allocation of three means of transport for transportation variant (I) , for transportation variants (II and III), it is rational to use four transport and for the transportation variant (IV and V), it is rational to use six means of transport, but considering the minimum of total economic losses stops, it is obtained that for all variants of transportation six means of transport were required. This contradiction between the probability that a unit arrives at the system and have to wait and the minimum total economic losses stops, is given by reducing the average time of stay of a unit in the system and mainly the harvester machines as main elements in the process, hence as the amount of means of transportation increases, harvesters stops are reduced and thus the economic losses from the harvest-transport process stops and the total cost of the process decrease.

These proposed composition are shown in **Fig. 2 (a ... e)** representing the mathematical models that match the relationship between the probability that a unit arrives at the system and have to wait (Probability of queue) to each transportation variant depending on the amount of transport.

Similarly when the results of economic losses stops harvest - transport process were analyzed, it can be seen that the considered current composition employed by the EAIG " Los Palacios", in which four means of transport are used for the above three harvesters is possible to reduce the total economic losses stops when six means of transport were used in each transportation variant of in 5.51 ; 11.93 ; 19.69 ; 31.3 and 168.32 peso/h respectively , representing 8.3 ; 14.8 ; 21.3 ; 30.4 and 67.1% of total economic losses considering the current conformation of the EAIG.

Conclusions

- The raised theoretical and methodological basis to the rational composition mechanized resources involved in the rice harvest-transport process, confirmed its validity.
- The influence of transportation distances and the amount of transportation in stability and cost of the rice harvest?transport process was determined, using the SAORCE-CTR system, taking five variants of transportation in two different agricultural yields, obtaining the following results:
  - ♦ In fields with agricultural yields of 3.2 t/ha, the total economic losses for stops are reduced for the transportation variants I, II and III in 1.88 ; 3.61 and 7.06 peso/h when using five means

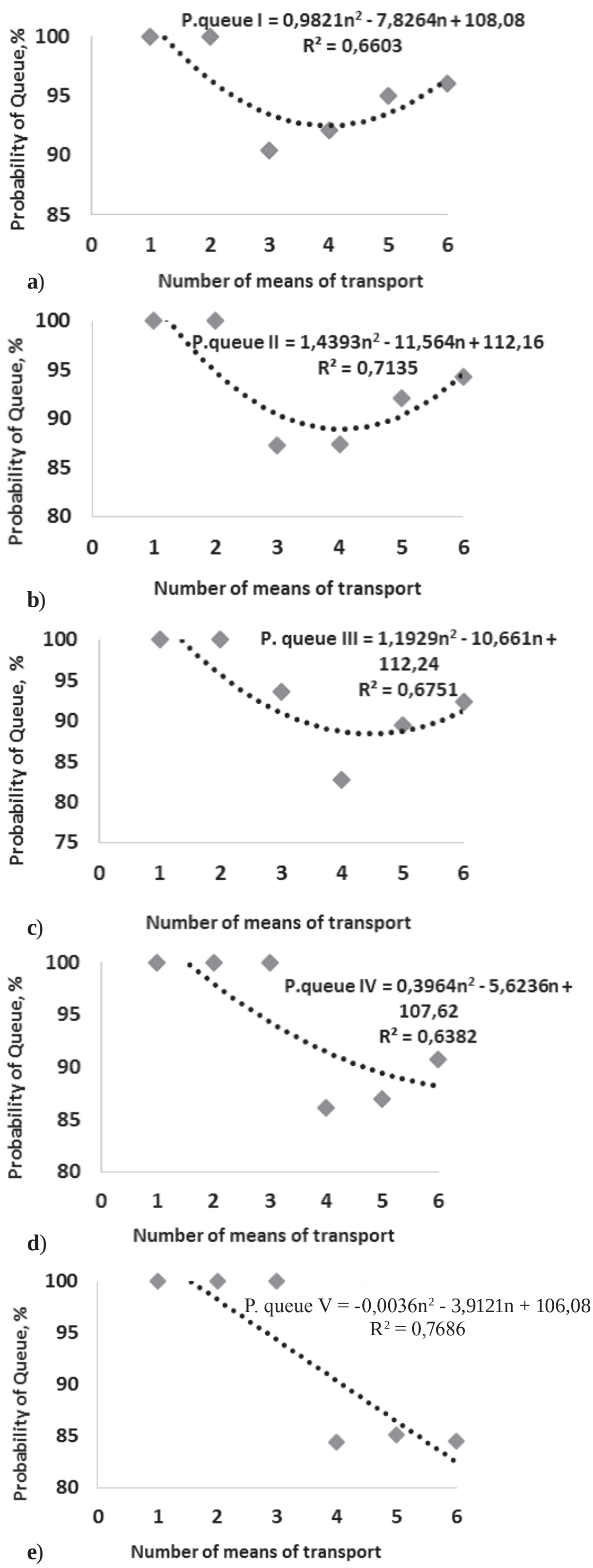

Fig. 1 Behavior of the probability that a unit arrives at the system and have to wait for each of the variants of transportation depending on the amount of means of transport, in agricultural fields with yields of 3.2 t/ha.

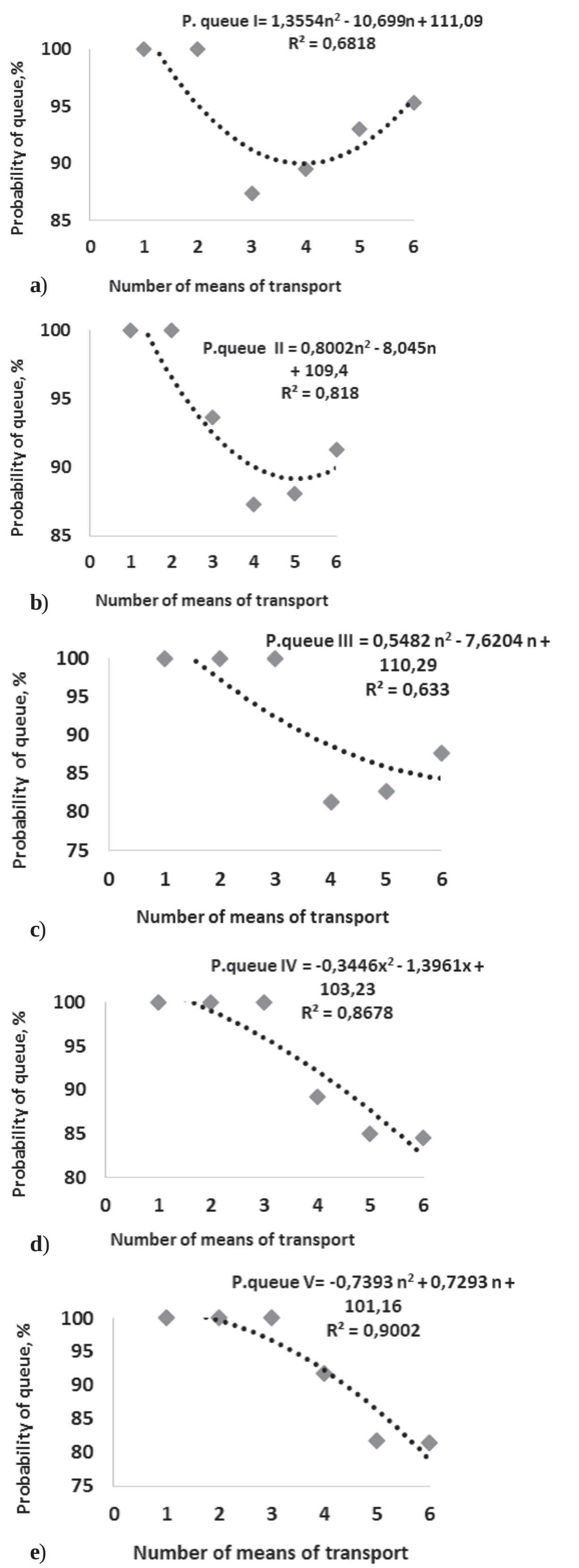

Fig. 2 Behavior of the probability that a unit arrives at the system and have to wait for each one of the variants of transportation depending on the amount of means of transport, in agricultural fields with yields of 4.2 t/ha.

of transport, representing 3.2 ; 8.3 and 9.7% of total economic losses for stops the current composition of the EAIG and to the transportation variants IV and V the total economic losses stops are reduced by 20.35 and 22.37 peso/h respectively, six means of transport, representing 22% and 23.6% of total economic losses stops according the current composition of the EAIG .

♦ In fields with agricultural yields of 4.2 t/ha total economic losses for stops are reduced in 5.51; 11.93; 19.69 ; 31.3 and 168.32 peso/h respectively, when six means of transport were used in each transportation variants, that represents 8.3 ; 148 ; 21.3 ; 30.4 and 67.1% of total economic losses stops when the current composition of the EAIG is used.

● The economic criterion of minimum cost per stops is more accurate than the probabilistic stability criterion for determining the rational structure of technological flow of the rice harvest-transport complex.

REFERENCES

Amu, L. G. 2010. Logística de cosecha. Evaluación de tiempos y movimientos. Indicadores y control. Revista Tecnicaña No.26. 25-30pp. ISSN: 0123-0409. Colombia.

García C, E. and F. León. 2010. Evaluación de la explotación de los medios técnicos en la cosecha transporte del arroz. Revista Ciencias Técnicas Agropecuarias. Vol.19. No.1. ISSN: 2071-0054. Cuba.

Iglesias, C. E., L. Shkiliova and A. Miranda. 2007a. Metodología para el cálculo de la productividad de las cosechadoras de arroz en función de la utilización del tiempo de turno. Revista Ciencias Técnicas Agropecuarias. Vol.16. No.1. ISSN: 2071-0054. Cuba.

Iglesias, C. E. 2007b. Carácter probabilístico del trabajo de los medios de cosecha de la caña de azúcar. Congreso Internacional de Ciencias Agropecuarias, Agrociencias. Edición magnética ISSN-978-959-282-053-1.Cuba.

Iglesias, C. E., Y. Morejón, R. Llanes. 2012. Determinación de la composición del complejo cosecha-transporte del arroz con la aplicación de la Teoría del Servicio Masivo. Revista Ciencias Técnicas Agropecuarias. Vol.21. No.2. ISSN:2071-0054. Cuba.

Izmailov, A. Y. 2007. Technologies and technical solutions to increase the effectiveness efficiency of transport systems of agriculture. M .FGNU "Rosinformagroteh", ISBN: 978-5-7367-0683-9.200p.

Matos, N. and C. Iglesias. 2012a. Modelo económico-matemático para la organización racional de los medios técnicos en la cosecha-transporte-recepción de la caña de azúcar. Revista Ciencias Técnicas Agropecuarias. Vol.21. No.3. ISSN:2071-0054. Cuba.

Matos, N. *et al*. 2012b. Optimización del proceso cosecha-transporte-recepción de la caña de azúcar. Revista Cubana de Ciencias Informáticas (RCCI). ISSN:1994-1536 Vol. 5. No. 3.

Matos, N. *et al.* 2014. Organización racional del complejo de máquinas en la cosecha-transporte-recepción de la caña de azúcar en la Empresa Azucarera “ARGENTINA”. Revista Ciencias Técnicas Agropecuarias. Vol.23. No.2. ISSN:2071-0054. Cuba.

Miranda, A. *et al*. 2013. Análisis de la utilización del tiempo de turno por las cosechadoras arroz CLAAS DOMINATOR. Revista Ciencias Técnicas Agropecuarias. Vol.22. No.4. ISSN: 2071-0054. Cuba.

Morejón, Y. and C. Iglesias. 2014a. Use of Queueing Theory to the organization of the complex rice harvest-transport on the Agroindustrial Rice Complex Los Palacios. Revista Ciencias Técnicas Agropecuarias. Vol.23, No. 2, pp.23-26.Cuba.

Morejón, Y. *et al*. 2014b. Sistema Automatizado para la organización racional del proceso cosecha-transporte de cereales (SAORCE). Revista Ciencias Técnicas Agropecuarias. Vol.23, No. 3, pp.89-93.Cuba.

Server, P., *et al*. 2002. El transporte de la caña de azúcar utilizando la modelación. Revista Universitaria. Ciego de Ávila. ISSN: 1607-6079. Vol. 3. No 1. Cuba.

Shepelyov, S. D. *et al*. Influencia del período de servicio a la cosechadora en la estructura tecnológica de línea espera. Revista Agro ingeniería. Chelyabinsk.ISSN:77-155498.2014. 4p. Pág. web: libr.orensau.ru.(en idioma ruso)

Yesin, K. S. 2013. Methods of selection of transport during grain harvesting, cultural Tour. World of Transport and Technological Machines. ISSN: 77-47352. №2 (41). - S. 95-102.

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Development of Solar Powered Evaporatively Cooled Tractor Cab

by

A. Sacikumar
PhD scholar
Division of Agricultural Engineering
Indian Agricultural Research Institute
New Delhi -110012
INDIA
saci.ask06@gmail.com

Adarsh Kumar
Principal scientist
Division of Agricultural Engineering
Indian Agricultural Research Institute
New Delhi -110012
INDIA
adarsh_iari@rediffmail.com

J. K. Singh
Principal scientist
Division of Agricultural Engineering
Indian Agricultural Research Institute
New Delhi -110012
INDIA
jksinghiari@gmail.com

Indra Mani
Head
Division of Agricultural Engineering
Indian Agricultural Research Institute
New Delhi -110012
INDIA
maniindra99@gmail.com

Abstract

In India, working on farm in peak summer is very drudgerous for farm workers. To reduce the drudgery of tractor driver, a low cost solar powered evaporative cooled cab was designed and fabricated with locally available materials and retrofitted on tractor. The system had provision to operate either with solar panel or tractor battery. Evaluation of cab was done for secondary tillage and transportation at different time interval in the summer forenoon. With evaporative cooled cab the temperature was significantly reduced from 43°C to 33°C and relative humidity increased from 11% to 39% for tillage operation and 42°C to 35°C with relative humidity of 12% to 41% for transportation operation. The dust concentration of PM 10 also reduced significantly from 18.5 mg m^{-3} to 0.35 mg m^{-3} in tillage operation and 4.4 mg m^{-3} to 0.2 mg m^{-3} in transportation. Physiological parameter of tractor operators improved with conducive working environmental conditions; heart rate reduced from 138 beats min^{-1} to 119 beats min^{-1} and overall discomfort score from 4 to 2.9 for tillage operation and 117 beats min^{-1} to 107 beats $min^{-1}$and overall discomfort score from 2.9 to 1.9 for transportation operation. The evaporative cooling efficiency of the cab was 80%. The developed system has a versatility of retrofitting on existing as well as on new tractors.

Introduction

The use of tractors as prime mover on Indian farms has increased from 0.53 million units in 1980s to 5.24 million units in the year 2013-14 (Singh *et al.*, 2015). In tractor operation, driver is subjected to harsh environmental stresses along with machine vibrations and noise (**Fig. 1**). These stresses accelerate the fatigue of the operator and affect the sensitivity and reaction of the operator.

Ambient temperature in tropical and subtropical countries like India ranges from 34°C to 45°C in the summer. It is very difficult for the farmers to work on the farm during daytime especially in northern part

Fig. 1 Tractor operator performing different agricultural operations under severe environmental condition

of India. The conditions become worse with added engine heat in tractor operation. In peak summer in order to maintain human body “core temperature” at 37°C, results in increase of blood to the skin which accelerate heart rate resulting in higher physiological demand (Kroemer *et al*., 1994). Therefore, it is desirable to reduce the operator's exposure from high environmental temperature and provide thermal comfort. Yadav *et al*. (1997) surveyed leading tractor manufacturers in India based on the comfort and efficiency of the drivers operating tractors with or without a tractor cab. It was observed that with small increase in the initial cost of the tractor, the tractor cab or enclosure could provide greater comfort and safety result in enhanced work capacity. A hydraulically operated collapsible enclosure frame with different configurations was designed (Bhoi *et al*., 2007). It was found that the collapsible enclosure configuration of open condition with all sides closed was able to provide comfort both during summer and winter condition. However, the comfort reduced during harsh outside environment conditions as there was no cooling or heating provision. In another study by Noren and Lindvall (1970), at an outside temperature of 30°C, inside temperature of the cab became unbearable for the operator. In dry climate areas, evaporative cooling by means of drawing the air through a gravity fed water trickle pad is the most economical approach (Herboldsheimer, 1967). However, many problems are encountered in obtaining efficient evaporative cooling. The major one is pitching and rolling of vehicle especially on undulated terrain. In gravity flow it is difficult to obtain even uniform distribution of the water in the trickle pad on undulating terrain which results in lower cooling efficiency. Gupta *et al*. (1995) designed a cab cooled by passing air over a wet evaporative surface, made with 40-mm-thick layer of shredded wood packaged between two 15-mm-thick layers of coconut fiber. The evaporative surface was continuously kept wet with recirculation of water by a low-capacity, submersible water pump installed at the bottom of a water tank operated by tractor battery. But they did not study the physiological aspect of operator. In developed countries air conditioned cabins are used for environmental moderation for operator comfort. Studies were conducted on combine cab equipped with air-conditioning unit with heating installation for operators comfort (Vogelaar, 1961). These solutions are not adoptable in countries like India due to economic reasons.

Another important environmental parameter is dust, generated during agricultural machine operations on the farm. Dust is not only responsible for occupational health problems but also results in higher heart rate (Christensen *et al*., 1992). It is, therefore, important to reduce dust exposure of farmers for better working conditions and health.

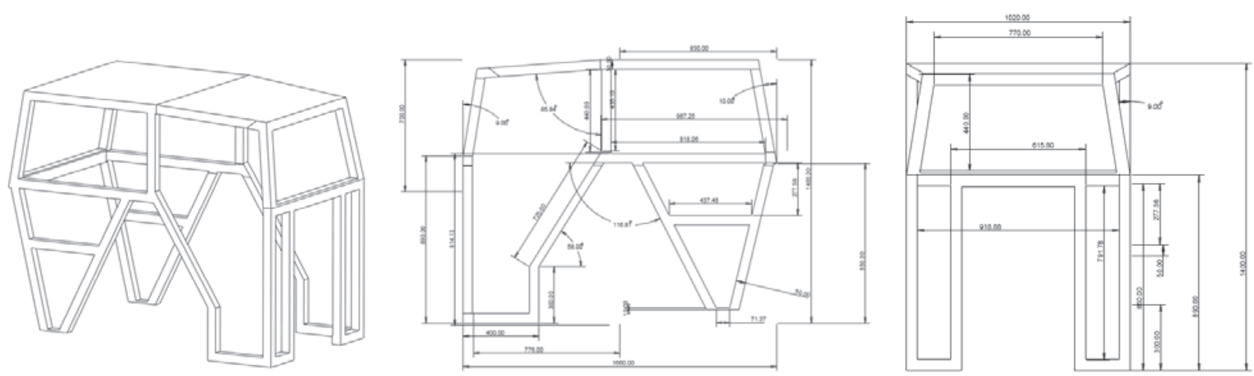
With the above background, a low cost solar powered evaporative cooled cab was designed, fabricated and retrofitted on the existing tractor. The system was powered with solar energy as well as tractor battery. The developed system was evaluated for environmental and comfort parameters of tractor- operator system.

Materials and Methods

Wind speed, temperature and relative humidity were recorded using a thermohygro-anemometer. Dust concentrations (mg m^{-3}) were measured using a handheld real-time environmental dust monitor, heart rate was measured by heart rate monitor and overall discomfort score were assessed subjectively at the end of every 15 minutes for one hour operation, using 5-point scale (Corlett and Bishop, 1976). The experiments were conducted in three sessions in the forenoon [10.00 AM -11.00AM (T1), 11.00AM-12.00 Noon (T2) and 12.00 Noon to 13.00 PM (T3)].

Related Design and Fabrication

Tractor Cabin Frame



Isometric view   Side view   Front view

Fig. 2 Tractor cabin structure

The main structural frame of the cab was fabricated with mild steel square hollow tube 37.5 × 37.5 × 3 mm. The square hollow section was selected because of high load bearing capacity, ease of welding and fabrication. The overall design and dimension of the structure are shown in **Fig. 2**. The cabin had a movable door for entry and egress. The covering material used was polycarbonate because of its visibility, strength and ease of fabrication.

Evaporative Cooling System

The most cost effective method of cooling in dry summer is evaporative cooling. Evaporative cooling has an added advantage of arresting dust as air passes through the wet surface, which acts as a water bath dust filter. The design calculations were done with the equations for heat gain through the walls, roof of the cab per unit time and total heat and cooling load. (Harris and Conde, 1974). The values computed are given in **Table 1**.

q_w or $q_r = A \times U \times (T_{ETD})$ ....(1)

Where:

q_w or q_r = Heat gain through walls or roof (W)

A = Area of wall/roof (m^2)

U = Overall heat transfer coefficient ($W\ m^{-2}\ {}^oK^{-1}$)

T_{ETD} = Total equivalent temperature difference (based on observed values)

$q_f = A\ (SC \times SHGF + U \times T_{ETD})$ ..(2)

Where:

q_f = Heat gain through fenestration (W)

A = Area of the fenestration (m^2)

SC = shading coefficient

$SHGF$ = solar heat gain factor calculated from the chart ($W\ m^{-2}$)

U = overall heat transfer coefficient ($W\ m^{-2}\ {}^oK^{-1}$)

Q = (Total sensible cooling load) / [(1.08) × (Temperature difference)] ....(3)

Where:

Q = Total quantity of air required

Duct size determination

Assuming an equal pressure drop in the duct throughout its length (2.54 cm of water per 30 m of duct length), equivalent diameter of duct to handle total air flow of 13 $m^3\ min^{-1}$ including allowance (13% allowance in total air quantity (ASHRAE, 1974)) was found to be 33 cm and duct size of 35 × 40 cm was used for fabrication based on ease of availability.

Cooling pad

A rectangular wire mesh box, 450 × 650 mm with khas-khas grass and shredded wood (Vetiveria Zizanoides) was used for evaporative surface for cooling (**Fig. 3**).

Water collecting tank

A plastic tank (600 × 450 × 450 mm) was used for water storage, mounted on the roof of the cab facilitated cooling of air through the pad as shown in **Fig. 3**.

Water re-circulating pump

A small D.C pump with flow rate of 6 l/min with maximum delivery head of 2 m was used for water circulation for even distribution on cooling pad. The pump was either operated with solar power input or 12-V DC tractor battery (**Fig. 3**).

Fan

An axial flow exhaust fan was used for better downstream distribution of air (**Fig. 3**). A fan size selected to deliver at least 11.8 m^3/min of air at maximum pressure level of 50 Pa was selected from the ASHRAE (1983) charts. A fan (320 mm diameter) was installed at the center of the cab roof for air flow to the operator.

Power supply

The system was powered with 60 W solar panel (maximum power voltage 17.0 V, maximum power current 3.53 A and maximum system voltage 1,000 V). The panel was mounted on the roof of the cabin (**Fig. 3**). Battery of tractor is also connected with cooling system.

Table 1 Calculated value for evaporative cooled cab design

Parameters	Values
Heat gain through walls (W)	175 W
Heat gain through roof (W)	50 W
Heat gain through fenestration	2,934 W
Sensible heat gain from inside space due to body heat	170 W
Total cooling load for the cab	3,328.32 W
The air requirement for the cooler	11.8 $m^3\ min^{-1}$

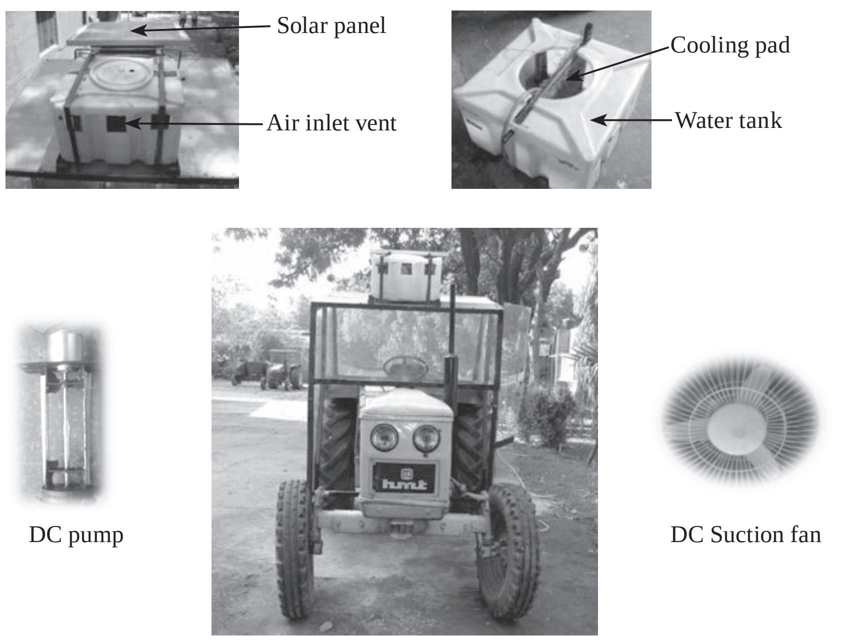


Fig. 3 Tractor cabin evaporative cooling system components

A selection switch was mounted for choosing power mode (solar or battery) depending upon requirement.

Testing of Developed Cab

Temperature and relative humidity

With cooled cab, temperature reduced from 43°C to 33°C and relative humidity increased from 11% to 39% during tillage operation and 42°C to 31°C with relative humidity of 12% to 41% during transportation (**Fig. 4a**). ASHRAE Hand Book (1989) has recommended that the summer comfort zone temperature should be 23°C and 25°C with relative humidity of 30% to 70%. However the achieved environmental conditions were close and relatively comfortable for operator (**Fig. 4b**).

Dust concentration

The dust concentration (PM 10 and PM 2.5) reduced in both the operation with cooling cab (**Fig. 5**). Maximum dust concentration of PM 10 was 18.5 mg m^{-3} reduced to 0.35 mg m^{-3} for tillage and 4 mg m^{-3} to 0.2 mg m^{-3} for transportation. With cab dust levels were within the permissible limits of NAAQS (2009), India and NAAQS (2012), US in secondary tillage and transportation.

Physiological parameter-heart rate

With cooling cab, heart rate reduced (**Fig. 6a**) resulting in shifting from work load category from "heavy" to "moderate" during tillage and "moderate" to "light work"

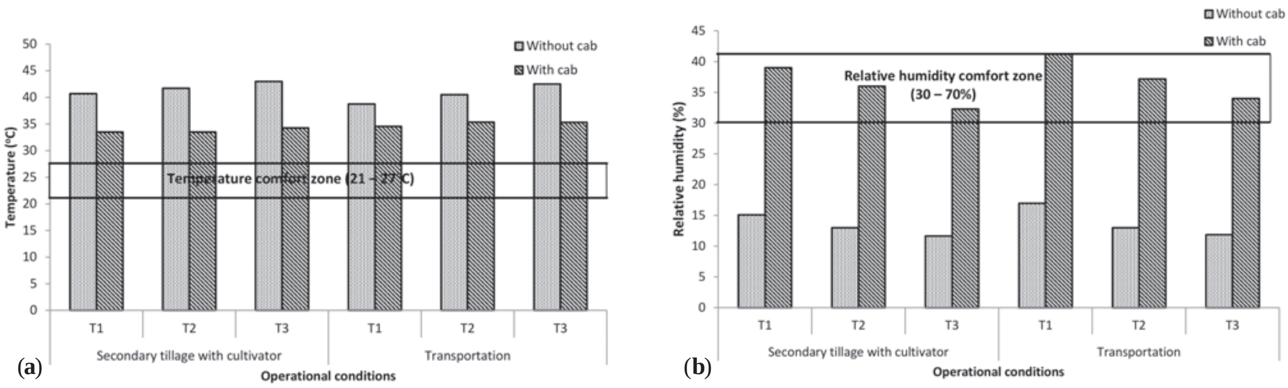


Fig. 4 Environmental parameters during secondary tillage (**a**) temperature (**b**) relative humidity

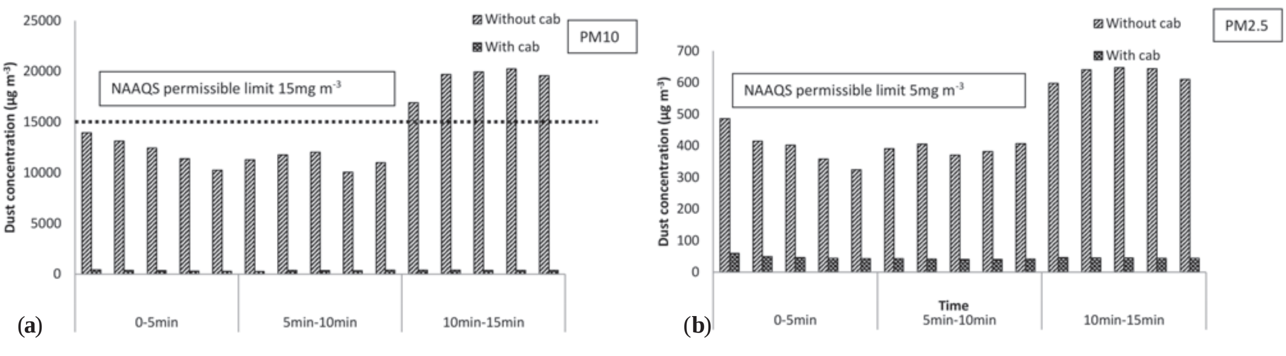


Fig. 5 Dust concentration for secondary tillage operation (**a**) PM 10 (**b**) PM 2.5

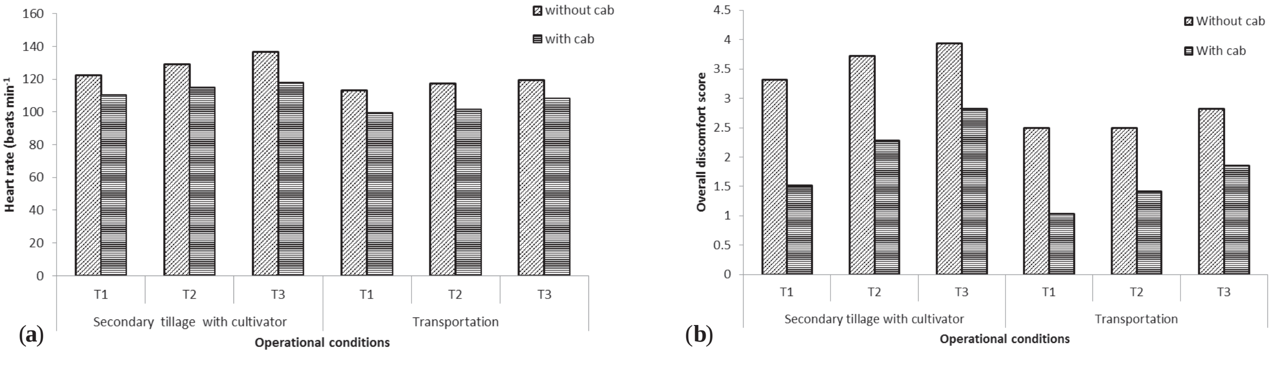


Fig. 6 Physiological parameters during different operational conditions (**a**) heart rate (**b**) overall discomfort scores

during transportation (Saha *et al.*, 1979). The maximum heart rate for tillage was 138 beats min^{-1} and 117 beats min^{-1} for transportation without cooling cab which reduced to119 beats min^{-1} and 107 beats min^{-1} with cooling cab resulting in lower physiological demand.

Overall discomfort score for different operational conditions without protective system

The maximum discomfort in the present study was observed in tillage operation (**Fig. 6b**). During transportation the discomfort and tiredness were lower as movement of tractor was on smooth road whereas in tillage, frequent looking back to monitor implement subjected operator to torsional stresses along with undulation of soil surface exposed operator to vibration and dust. The overall discomfort score reduced from 4.0 to 2.9 in tillage and 2.9 to 1.8 during transportation operation with cab.

Performance of the system

The human comfort zone is in temperature range of 22-25°C with relative humidity in the range of 30% to 70% (ASHRAE, 1995). The performance efficiency of cooling system was computed to be 80% under ambient conditions based on calculation given below.

$$Efficiency = 100\% \times [(T_{EDB} - T_{LDB}) / (T_{EDB} - T_{WB})]$$
$$= 100\% \times [(45 - 33) / (45 - 30)]$$
$$= 80\%$$

Where:

T_{EDB} = Entering air dry bulb temperature

T_{LDB} = Leaving air dry bulb temperature

T_{WB} = Wet bulb temperature

The developed system had advantage of simple design, ease of fabrication and use of locally available components and could be easily fitted on existing and new tractors.

Advantages

At higher temperature, body muscles dilate so that the optimum body temperature can be maintained. During this process work load increases even if human labor requirement is low. Therefore, there is a need to reduce temperature to comfortable range. Presently developed evaporative cooled system reduced temperature (10°C) and increased relative humidity (28%) providing comfort to the operator. Temperature reduced nearly to "summer comfort zone" as per ASHRAE Hand book (1995) which improved comfort and reduced physiological demand of operator.

The concentration of dust increases as the moisture content of topsoil reduces. The developed system reduced the dust concentration at operators' breathing zone as the evaporative cooler acted as water bath and filtered the air. It was found that with cooling cab the concentration of dust were lower than the threshold limit of NAAQS (2009) and NAAQS (2012) for both the work operations.

Retrofitting of the cabin modify climate resulting in comfort and improvement of physiological parameter and will enhancing operator efficiency. The total cost of developed system included cost of cab ($517) and the cost of 60 Wp solar panel ($37) as detailed in **Table 2**.

Table 2 Cost of evaporative cooling system

Materials	Quantity	Cost (Rs)
Mild steel square hollow tube (37.5 × 37.5 × 3 mm)	4	8,050
Polycarbonate sheet (1216 × 2432 × 4 mm)	3	15,000
G.I sheet (16 gauge) (1216 × 1824 mm)	2	2,000
Water collecting tank (600 × 450 × 450 mm)	1	650
Rectangular wire mesh box for cooling pad	1	100
PVC pipe of 25 mm diameter	1	50
12-V DC pump	1	350
12-V DC fan	1	450
Others (fasteners; latches etc.)		200
Solar panel 60Wp	1	2,410
Labor cost (25% of total cost)		6,712
Total		Rs.36,035
		$554

Conclusions

The designed evaporative cooled cab to moderate the micro-climate of tractor operator in summer month in northern India was successfully tested. The system was developed with available material in the local market and could be fabricated by local fabricator/mechanics in the rural areas. The mean temperature difference between with and without evaporatively cooled cab was 10°C. The mean relative humidity difference between with and without evaporatively cooled cab was 28%. Dust concentration level reduced from 18.58 mg m^{-3} to 0.35 mg m^{-3} in secondary tillage operation and 4.45 mg m^{-3} to 0.21 mg m^{-3} in transportation with developed system. Workers physical stress level reduced from "heavy" to "moderate" in secondary tillage operation and "moderate" to "light" category in transport operation. Overall discomfort score reduced from 4.0 to 2.9 in secondary tillage operation and 2.9 to 1.8 in transportation operation. The cooling system efficiency was 80 %. The developed protective intervention can be easily retrofitted on old as well as the on new tractors.

REFERENCES

ASHRAE. 1974. Evaporative air conditioning. In Systems Handbook, 39.1-39.11. New York: ASHRAE.

ASHRAE. 1983. Physiological principle, comfort and health. In Handbook of Fundamentals, 8.1-8.30. Atlanta, Ga.: ASHRAE.

ASHRAE. 1989. ASHRAE Fundamentals Handbook.

ASHRAE. 1995. ASHRAE Fundamentals Handbook.

Bhoi, P. K., V. K. Tewari, R. Dhar and K. N. Dewangan. 2007. The effect of an all season collapsible tractor operator enclosure of driver comfort in three adverse environmental conditions. International Journal of Industrial Ergonomics 37: 479-487.

Christensen, H., P. Vinzents, B. H. Nielsen, L. Finsen, M. B. Pedersen and G. Sjogaard. 1992. Occupational exposures and health among Danish farmers working in swine confinement buildings. Int. J. Industrial Ergonomics, 10, 265-273

Corlett., E. N. and R. P. Bishop. 1976. A Technique for Measuring Postural Discomfort. Ergonomics, 9: 175-182.

Gupta, C. P., A. Abbas andM. S. Bhutta. 1995. Thermal comfort inside a tractor cab by evaporative cooling system. Transactions of ASAE 38(6), 1667-1775.

Harris, N. C. and D. F. Conde. 1974. Modern Air Conditioning Practices. New York: McGraw-Hill Book Co.

Herboldsheimer, B. B. 1967. Evaporating cooler for vehicle mounting. United States pattern office filed, ser.no. 609, 451.

Kroemer, K. H. E., H. B. Kroemer and K. E. Kroemer-Elbert. 1994. Ergonomics: how to design for ease and efficiency. Englewood Cliffs, NJ: Prentice-Hall.

National Ambient Air Quality Standards. 2009. Central Pollution Control Board Notification. New Delhi.

National Ambient Air Quality Standards (40 CFR part 50). 2012. US Environmental Protection Agency.

Noren, O. and J. H. Lindvall. 1970. Heat relief in tractor cab, A project report. Uppsala: Swedish Inst, of Agricultural Engineering.

Saha, P. N., S. R. Datta, P. K. Banerjee and G. G. Narayane. 1979. An acceptable workload for Indian workers. Ergonomics, 22:1069-1071.

Singh, R. S., Singh Surendra and S. P. Singh. 2015. Farm Power and Machinery Availability on Indian Farms. Agricultural Engineering Today, Vol.39 (1).

Vogelaar, B. F. 1961. Characteristics of all-weather farm machine cabs. Journal of Agricultural Engineering, 14-17.

Yadav, R., V. K. Tewari and N. Prasad. 1997. Cab for Indian tractors: a case study. American Medical Association, 28 (2), 27-29.

New Co-operating Editor

Yakov Lobachevsky

Date of Birth: July 9th, 1955

Nationality: Russia

Present Position: Deputy director of Federal Scientific Agriengineering Center VIM

Education Background:

2001: Prof. Agricultural Engineering in Moscow State Agriengineering University.

2000: D.Sc. Agricultural Engineering in Moscow State Agriengineering University.

1987: Ph.D. Mechanization of Agriculture, Tillage Machinery in Moscow State Agriengineering University.

1977: M.Sc. Farm Machinery and Mechanization of Agriculture in Azov-Black Sea Agriengineering University, Rostov Region.

Professional Experience:

2016-present: Corresponding member of Russian Academy of Sciences.

2006-present:Deputy director of Federal Scientific Agriengineering Center VIM (Moscow).

2004-2006: Chief of Engineering and Melioration Department of Ministry for Agriculture of Russian Federation.

1998-2004: Chief of Tillage Machinery Department of Moscow State Agriengineering University (MSAU).

1990-1998: Director of Scientific - Technical Center "Agrospectr"(Moscow).

1986-1990: Chief of Farm Machinery Design Laboratory.

1983-1985: Researcher and Designer MSAU.

1980-1982: Post-Graduate Student and Researcher MSAU.

1977-1979: Engineer of North-Caucasion Test Station for Farm Machinery (Department of Tractors Tests), Rostov Region.

Scientific Experience: Research and design of agricultural machinery and technologies. Tests of tractors and units.

Email: lobachevsky@yandex.ru

Studies on Straw Management Techniques Using Paddy-Straw Chopper Cum Spreader Along With Various Tillage Practices and Subsequent Effect of Various Sowing Techniques on Wheat Yield and Economics

by
Surinder Singh Thakur
Research Engineer
Dept. of Farm Machinery and Power Engineering,
Punjab Agricultural University, Ludhiana
INDIA
ssthakur@pau.edu

Rupinder Chandel
Asstt. Prof. (Farm Machinery & Power Engineering)
Dept. of Farm Machinery and Power Engineering,
Punjab Agricultural University, Ludhiana
INDIA
rupinder26@gmail.com

Mahesh Kumar Narang
Agricultural Engineer
Dept. of Farm Machinery and Power Engineering,
Punjab Agricultural University, Ludhiana
INDIA
maheshnarang@pau.edu

Abstract

South-east Asia is the principal niche of rice crop and in this sub-continent rice and wheat occupy nearly 59.16 and 42.55 million ha, respectively and annual grain output is around 181.35 and 109.07 million tonnes, respectively. Rice-wheat system occupies a total of 13.5 million ha in 4 rice-wheat consortium countries (India, Pakistan, Bangladesh and Nepal with areas 10.0, 2.2, 0.8 and 0.5 million ha, respectively). Another 10 million ha of rice-wheat area is in China. With the introduction of combine harvesters, more than 75% of the rice area is harvested mechanically in north-western parts of the Indo-Gangetic Plains (IGP). Most farmers remove wheat straw for feeding the animals. However, management of the rice straw is a major challenge as it is considered to be a poor feed for the animals owing to high silica content. Combine harvester leaves behind a swath of loose rice residues, which interfere with operations of the seed drills used for planting wheat. To avoid this problem farmers resort to burning of crop residue, which not only lead to loss of huge biomass but also cause environmental pollution. A study was conducted on different paddy straw management practices to manage paddy crop residue and to reduce its burning, which included various machines being used like Paddy straw chopper cum spreader, Spatial drill, Happy Seeder, Zero till drill, Conventional drill, Roto Seeder. It was found that there was significant increase in yield of wheat after either sowing directly in paddy stubble field or sowing after incorporating paddy straw in the field. Wheat yield increase with chopper and spatial drill varied from 5.0-10.25%, with Happy seeder varied from 2-5%, with chopper and conventional drill varied from 14.28-17.80%, with chopper and broadcasting method varied from 4.92-11.27%, varied from 2.18-16.67% for chopper and zero till seed cum fertilizer drill combination. Wheat yield with Roto seeder machine was found to be same or lesser than conventional method. The mean total number of operations involved for straw management and field preparation per hectare for wheat sowing for Spatial drill and Happy seeder were 2 and for Conventional drill, Roto seeder, Broadcasting method and Zero till seed cum fertilizer drill were 6, 3, 6 and 6 respectively. In case of Chopper along with Spatial drill and Happy seeder, there was saving in time, labour and cost of operations involved, for paddy straw management and sowing of wheat. The benefit cost ratio was worked out for all the practices and it was highest and same for Happy seeder and sms combination as well as for chopper and spatial drill combination as 2.73:1. Saving for chopper with spatial drill combination and Happy seeder with SMS combination in Rs. per acre were 24,943.11 and 24,624.19 respectively (1 US $ = 68 Indian Rupees). The benefit cost ratio was minimum for Traditional method (partial burning) and broadcasting method as 2.29:1 and 2:30:1 respectively

Keywords: Chopper, happy Seeder, zero till drill, spatial drill, conventional drill, wheat.

Introduction

Burning of paddy straw is a serious issue worldwide, which has several ill effects like environment pollution i.e. smoke produced due to burning of paddy straw contains harmful and deadly gases like carbon monoxide, carbon dioxide etc., harm to soil fertility, harm to trees in fields and on roadsides, danger to birds as due to burning of paddy straw, the nests of birds on the trees in the fields and on road side and their eggs in them are burnt. When paddy straw is burnt in the fields, thick dark smoke is spread widely all around which reduces visibility to a great extent, almost to zero leading to accidents on roads. Due to smoke and soot suspended in the air, many diseases like cough, fever, cold, T.B., cancer, irritation in eyes, allergy, choking of lungs, and problem in breathing and other respiratory problems are increased in these days. When paddy straw is burnt, temperature in the nearby areas increases several degrees above the normal leading to environmental changes.

Rice residues are important natural resources, and recycling of these residues improves the soil physical, chemical and biological properties. Management of rice straw is a major challenge as it is considered to be a poor feed for the animals due to high silica content. This paper reviews the potential of rice residues and its management options, residue effects on soil properties and crop productivity. On the basis of reported research results by different researchers, an analysis has been made. A rice-wheat sequence that yields 7 t ha^{-1} of rice and 4 t ha^{-1} of wheat removes more than N 300, P 30 and K 300 kg ha^{-1} from the soil; the residues of rice and wheat amount to as much as 7-10 t ha^{-1} yr^{1}. South Asian farmers need to manage 5-7 t ha^{-1} of rice residues and overcome the problems for planting wheat. Management options are: burning, incorporation, surface retention and mulching, and baling and removing the straw. Despite some advantages like killing of deleterious pests and clearing the piles before wheat planting, burning results huge losses of N (up to 80%), P (25%), K (21%) and S (4-60%), air pollution (@ CO2 13 t ha^{-1}) depriving soils of organic matter (SOM). This loss of SOM is one of the recognized threats to sustainability. Incorporation leads to build up of SOM, soil N, P and K. The major disadvantage of incorporation is the immobilization of inorganic N. However, N at 15-20 kg ha^{-1} as starter dose with straw incorporation increases yield of wheat and rice compared to burning. Surface retention of residues increases soil NO3- by 46%, N uptake by 29%, and yield by 37% compared to burning. Residue management practices affect soil physical properties viz. soil moisture, temperature, aggregate formation, bulk density and hydraulic conductivity. Soil temperature is influenced through the change in radiant energy balance and insulation. Rice crop residues are highly siliceous, and have the potential of transforming electrochemical properties of acidic soils that reduces P fixation; improving base retention and increasing the soil pH. Rice straw incorporation coupled with organic manure increases grain yield of wheat and improves soil physical condition. Residue incorporation results more microbial activity than residue removal or burning. Thus, if residues are managed properly, then it can warrant the improvements in soil properties and the sustainability in crop productivity (Mandal *et al*., 2004).

Paddy straw management practices may include manual removal of straw from field to use it as animal feed, collection of straw with help of rakes and balers to use it as biofuels in power plants, chopped into small pieces with help of choppers, and use it as mulch over subsequent crop or incorporate the straw in soil with rotavator, subsoiler and disc plough. However, rakes and balers have limited use, due to high cost and little end use of paddy straw.

No tillage or zero tillage farming can help in reducing burning. Zero tillage implies planting crops in previously unprepared soil by opening a hole, narrow slot, trench or band of the smallest width and depth needed to obtain proper coverage of the seed. Zero till is also known as no till and direct planting. Zero tillage of wheat after rice generates significant benefits at the farm level, both in terms of significant yield gains particularly due to more timely planting of wheat and cost savings (particularly tillage savings) and also it helps control obnoxious weeds like Phalaris minor, improves soil health.

The spread of no-tillage systems on more than 110 million ha worldwide shows the great adaptability of the systems to all kinds of climates, soils and cropping conditions. The Indo-Gangetic-Plains include four countries in South Asia, India, Pakistan, Nepal and Bangladesh. In 2005 about 1.9 million ha were reported under no-tillage in this region. This refers only to the wheat crop in a double cropping system with rice. For rice, virtually all farmers plough the land or use intensive mechanical tillage practices to puddle the soil. The adoption of no-tillage practices by farmers in India has occurred mainly in the rice-wheat double cropping production system and has been adopted primarily for the wheat crop. The main reason is that tillage takes too much time resulting in delayed seeding of the wheat crop after rice. It is well established that for each day of delayed sowing beyond the optimum date wheat yields are reduced by 1 to 1.5%. This timely planting of wheat after rice is critical and that is the reason for the quick uptake of no-tillage wheat. The uptake of the technology was rapid in the north-western states which are relatively better endowed with respect to irrigation, mechanization and where the size of holdings is relatively large (3-4 ha) compared to the eastern region which is less mechanized and where the average land holding is small (1 ha). (Derpsch *et al*., 2010). Most of the zero and reduced tillage adoption is concentrated in the Northwest Indo-Gangetic plains. The Indian States of Haryana, Punjab and Western Uttar Pradesh account for more than 90% of the area under this technology (Erenstein and Laxmi, 2008). Zero-till drilling saves times for sowing wheat after paddy harvesting in paddy-wheat rotation. It reduces cost of production, controls soil erosion, weeds, conserve soil moisture also increase the quantity of organic matter in soil but also, presence of crop residues on the soil surface makes seedling establishment difficult. Direct drilling of wheat in combine harvested field with conventional drills faces the problems of accumulation of straw in drill's furrow openers, traction problem in the ground wheel due to the presence of loose straw and non-uniform depth of seed placement due to frequent lifting of the machine under heavy trash conditions (Shukla *et al*., 2002). Tractor drivers usually use an angle close to maximum in order to decrease the tillage depth, consequently decreasing power requirements, without considering the tillage quality and the impact on the soil properties. the result shows that increasing tilt angle of the mounted disk plough when operated at a speed of 6 km.h^{-1} in light clay soil significantly ($p < 0.05$) increased the bulk density, mean weight diameter and field capacity while significantly decreases the tractor wheel slippage and soil volume disturbance (Osman *et al*., 2011). A study revealed that operating depth for the primary and secondary implements was about 250 and 100 mm, respectively. Implements included moldboard plow plus chisel plow as primary and disk harrow plus field cultivator as secondary implements. In another study done in clay loam soil Draft measurements were compared to those predicted by ASABE Standard D497.5 (ASABE Standards, 2006) and were found to vary. It was found that draft force of moldboard plow and field cultivator was about 2.14 and 1.8 times as much as the chisel plow and disk harrow, respectively. The large difference in implement draft indicates that substantial energy savings can be readily obtained by selecting energy-efficient tillage implements (Askari and Khalifahamzehghasem, 2013). Rice occupied 2.808 million hectares with total production of 11.236 million tonnes during 2009-2010 in Punjab. The average grain yield of rice was 4.01 t/ha and average yield in terms of paddy was 6.033 t/ha (Anonymous, 2011). The total yield of paddy straw in combine-harvested field is about 12.5 t/ha and the yield of standing stubbles and loose straw are about 7 t/ha and 5.5 t/ha, respectively (Singh, 2002). Zero-till drilling saves times for sowing wheat after paddy harvesting in paddy-wheat rotation. It reduces cost of production, controls soil erosion, weeds, conserve soil moisture also increase the quantity of organic matter in soil but also, presence of crop residues on the soil surface makes seedling establishment difficult. Direct drilling of wheat in combine harvested field with conventional drills faces the problems of accumulation of straw in drill's furrow openers, traction problem in the ground wheel due to the presence of loose straw and non-uniform depth of seed placement due to frequent lifting of the machine under heavy trash conditions (Shukla *et al*., 2002). A combo happy seeder was developed. This machine can be operated with tractor above 45 hp and has capacity of 0.3-0.4 ha/h. It consists of two units namely straw management unit and sowing unit. It cuts the standing stubbles and loose straw, throws it backwards and simultaneously sows the field. Germination of seed affected if straw load was more than 7 t/ha. To reduce the straw load over modification was done in flail rotor to cut standing stubbles for 7.5 cm width in front of furrow openers and leaving standing stubbles in other 12.5 cm strip between two furrow openers as such. This modification resulted in 30% straw load reduction (Sidhu *et al*., 2005). Results show that, cutting edge thickness and cutting edge curve had significant effects on cross-sectional area of furrow (A_f) and disturbance of surface straw; the rake angle had a significant effect on soil bulk density. Soil types and operating depth had significant effects on soil disturbance caused by tine furrow openers. The concave type tine furrow opener produced the lowest soil disturbance and soil bulk density of seed furrow, the highest surface straw disturbance and the greatest content of WSA (>0.5 mm). With increasing rake angles of tine furrow opener, the width of seedbed (W_{sb}) and the A_f decreased first and then increased, respectively, while the width of soil throw (W_{st}) and the height of ridge (H_r) increased. The W_{sb} and A_f created by tine furrow opener with 60° rake angle were significantly lower than that with others, respectively. The tine furrow opener with rake angle ranged from 45° to 60° created the lowest soil bulk density. As the penetration clearance angle increased, the content of WSA (>0.5 mm) decreased, but the effect of penetration clearance angle on the content of WSA (<0.5 mm) was not significant. The cutting edge thickness (<2 mm) had no significant effects on soil properties of seedbed. This study could provide a reference for optimal design of the tine furrow opener to create more suitable seedbed environment, and promote the application of the light no-till planters (Xiangcai *et al*., 2016). Previous works has shown (Singh and Singh, 1998) that incorporation of paddy straw is the best available option for improving soil health. However, this process takes about two-three week period for puddled soil to settle prior to wheat sowing after chopping. But, it was reported that wheat yield affected adversely if crop is not sown in time. It has been reported that wheat yield decreases by 35-40 kg/ha per day, when wheat is not sown before November 30. A lot of work has been done in PAU in developing Paddy straw chopper cum spreader machine for chopping of paddy straw. Straw chopping-cum-spreading machine was developed which cut the stubbles left after combining, chop it into pieces and spread in the field, in a single operation. Capacity of the machine is about 2.4-3.2 ha/day and can be operated by a 50 hp tractor and it consumes 6.0-6.5 l/h fuel. The chopped straw size varied between 7-10 cm and spread on the field which can be easily incorporated in the soil by the use of rotavator. Subsequently, wheat sowing could be done by the use of conventional seed drill (Garg, 2004). A Paddy straw harvester cum chopper was developed which consisted of a cutter bar of 1.85 m length, a reel, an auger for feeding harvested paddy residue to chopping unit (Thakur, 2004). A field survey conducted in Tarai region of Uttaranchal has revealed the presence of compacted layer at the depth between 30 and 60 cm which could be alleviated by using proper subsoiling equipment. Experiments were conducted at three different locations during 2000-04 at the research farms of the Pantnagar University to observe the changes in soil properties and crop response to subsoiling. The yields of wheat after rice, maize crop and potato increased significantly in subsoiled plots in comparison to other tillage treatments. The yield of wheat increased by 7-13% in subsoiled plots. In tillage operation where rotavator as well as subsoiling was performed, the increase in wheat yield of 15-26% was found over zero-till plot. The subsoiling for maize crop resulted in about 16.50% increase of yield with 'winged subsoiler with shallow leading tines' over conventional method of harrowing and planking. Similarly, in case of potato crop, the yield increase of 11.70% was obtained over conventional method of seed bed preparation (Thakur *et al*., 2005). A equipment was designed and developed for deep soil volume loosening, fertilizer metering with deep placement and clod crushing with minimum disturbance at the level of a field. Deep soil volume loosening unit consisted of a pair of specially designed V-shaped tines mounted on a rectangular frame and positioned exactly behind the tractor rear wheels. The V-shaped tines could deform the soil and place it at almost same location without inversion, thereby maintaining original level of the field after soil loosening. The fertilizer placement unit consisted of two fertilizer boxes, each of 75 kg capacity with independent metering system and a ground drive wheel for power transmission. Metered quantity of fertilizer (250 to 1000 $kg.ha^{-1}$) could be placed in soil with four inverted-T openers with attachment for fertilizer conveying. Two floating armed spiked roller clod crushing units were positioned behind each V-shaped tine for soil pulverization and consolidation of tilled soil for moisture conservation. Laboratory and field evaluations indicated that the developed equipment performed its intended functions with coefficient of uniformity of more than 94% for fertilizer application rates up to 1,000 $kg.ha^{-1}$. The equipment was designed for performing general tillage in laser levelled fields, but can be used in row crop cultivation, especially for sugarcane ratoon management, as it could perform all the desired operations in a single pass (Kumar and Thakur, 2013). A chisel plough, disk plough and ridger were tested to evaluate their effect on selected soil physical properties along with their performance and power requirements. Implement type had a consistent significant effect ($P \leq 0.01$) on soil moisture content (%), whereas, bulk density (g/cm^3) and porosity (%) showed inconsistent response. However, the chisel plough recorded the highest moisture content and basic infiltration rate values as compared to the ridger and disk plough. The chisel plough had the highest power requirement and fuel consumption. The ridger had the lowest power requirement and fuel consumption, but recorded the highest field capacity and efficiency (Makki and Mohamed, 2008). The findings of another study show that plow-tillage practice can reduce soil bulk density and penetration resistance at the tillage zone, which can lead to greater root weight density, root length density and root surface density and greater evapotranspiration from tillering to flowering stage. This can increase plant population and cause greater water use efficiency and grain yield under rainfed condition (Guan *et al*., 2015). There are many benefits of conservation agriculture like less soil erosion, improvements in soil structure and an increase in organic matter content and crop yields. Overall tillage practices combined with conservation techniques are very useful for managing crop residues for conserving moisture and nutrients and controlling weeds as well as moderating soil temperature and are economical and environmentally safe options. Therefore present study was planned to study the effect of of paddy straw chopper cum spreader with various combination of tillage practices, soil type on paddy straw management and subsequent effect of various sowing practices/machines on wheat yield sown. The study was focused to find a suitable approach for paddy straw management in different soil conditions using chopper, tillage implements and sowing technique and their effect on wheat yield.

Material and Methods

The various straw management practices and wheat sowing techniques were used for sowing of wheat after paddy straw management. The study included cultivation practices and machines used for incorporation or spreading of paddy straw after combine harvesting of paddy, area covered, thereafter sowing practice/machine used for sowing of wheat and yield of the wheat crop with straw management practice and conventional practice. Various tillage practices were used for paddy straw management after paddy straw chopper cum spreader operation for incorporation and various wheat sowing machines were used and all the data was collected. Different machines used for straw management and for sowing of wheat were Paddy straw Chopper cum spreader (flail type), Paddy straw chopper cum spreader (combine header type), Straw management system (SMS), Happy Seeder (*in-situ*), disc harrow, cultivator, rotavator, Spatial drill, Zero till seed cum fertilizer drill, Conventional drill, Roto seeder and broadcasting method. The data for different machines in Punjab is shown in **Table 1**.

Table 1 Status of various machines in Punjab

Year	Name of Machine	Number*
2010-11	Disc Harrows	210,000
2011	Zero till seed cum fertilizer drill	10,300
2014	Happy Seeder	580
2014	Tractors	476,835
2014	Conventional Seed cum fertilizer drill	175,362
2014	Straw Reapers	38,684
2014	Paddy straw chopper cum spreader	55

*Agricultural Handbook Punjab, 2011, 2013, and 2014 Punjab Agricultural University, Ludhiana, Co-operative societies and Department of Agriculture, Punjab

Straw Load and Moisture Content of Straw and Soil

To measure straw load in the field a 1 m × 1 m square section frame (**Fig. 1**) made of iron rods was used. It was placed randomly at 3-4 locations in the field. Then loose straw and standing stubbles were collected and weighed on electronic balance. The moisture content of loose straw and standing stubbles was also measured by standard oven drying method. Similarly samples of soil were filled from various locations for determining soil type and moisture content. Detail of various machines used in present study is given below:

Fig. 1 A view of collection of straw sample from a unit area

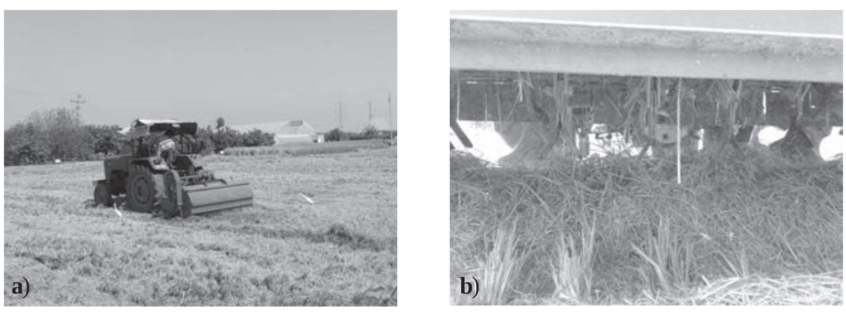


Fig. 2 **a**) Paddy straw Chopper cum spreader (flail type) **b**) Its rotor drum.

The Paddy Straw Chopper Cum Spreader

The Paddy straw chopper cum spreader machine has been developed by Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana (**Fig. 2**). This machine cuts, chops and spreads the paddy straw left (standing and loose straw) in the field after the combine harvester operation. This chopped straw can be used as a mulch or it can be incorporated in the soil and sowing of different crops like, wheat, vegetables (carrot, potato, sugarbeet), berseem etc. can be done using different tillage practices and sowing techniques. The size of chopped straw lies between 7-10 cm (**Fig. 3**). Paddy straw chopper cum spreader is now commercially available in two types of models (**Fig. 4**). In one type of model flail blades are mounted on a drum which cuts and chops the paddy straw and spread them in the field (**Fig. 1**).


Fig. 3 A view of paddy straw field after chopper operation

It consists of a rotary shaft mounted with blades named as flails for harvesting and chopping the paddy straw. Two counter rows having serrated blades are mounted on the concave of front portion of straw bruising which further assists in chopping the straw. The rotary shaft has two rows of flails. Each row consists of 20 numbers of flails. The shape of the flail is inverted gamma type. One counter row each having 21 serrated knives is fixed on the inside of the concave. Machine is operated by a 45-50 hp tractor. Field capacity of the machine is 0.3 $ha.h^{-1}$ and approximately 70% straw is chopped in the size less than 10 cm.

In the second type combine header has been used (**Fig. 4**). It includes cutter bar (1.85 m long), reel, auger for conveying cut straw into chopper and a secondary chopping unit for further reducing the straw size. Thus in second type paddy straw passes two times through chopping unit and it spreads chopped straw at the rear end. The combine harvester type blades are fixed on two rotating drums (chopper units) in combine header type chopper. This machine can be operated by a 45-50 HP tractor and their field capacity varies between 0.6-0.75 $acre.h^{-1}$. In year 2013 chopper machine was used over an area of 2000 acre in Punjab and various practices for incorporating paddy straw were used without burning it. After operating this machine wheat sowing was done either of the following methods.

Incorporation

One light irrigation after operation of paddy straw chopper was applied and chopped straw was mixed in soil with the help of rotavator (**Fig. 5**). The paddy straw was also mixed in soil using disc plough/cultivator/disc harrow by the farmers.

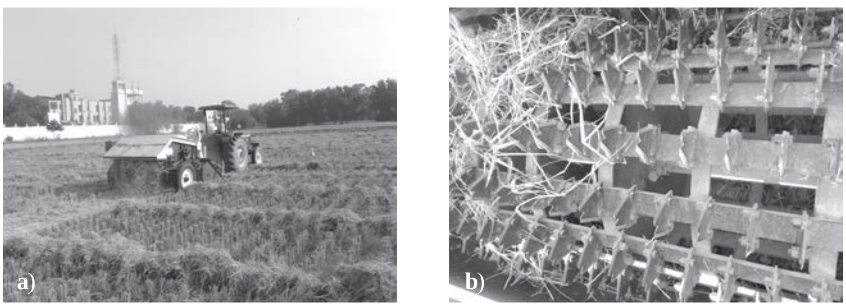


Fig. 4 **a**) Cutter bar type Paddy straw chopper cum spreader **b**) rotor drum


Fig. 5 Wet Mixing of chopped paddy straw with rotavator


Fig. 6 Wheat sowing with Zero till drill (After paddy straw chopper and wet mixing operation)


Fig. 7 Incorporation of chopped straw with disc harrow and cultivator

The paddy straw is fully incorporated by this method and it decays at much faster rate after its contact with soil. For increasing the decaying rate urea@20 kg.acre^{-1} can be broadcasted. Depending upon soil type the optimum moisture in field is obtained after 2-3 weeks. After the optimum moisture is obtained the wheat sowing can be done using zero or conventional drill (**Fig. 6**). To use this technique the irrigation should be stopped a few days before harvesting of paddy with combine as the same water can be used for incorporation of paddy straw after chopping paddy straw with paddy straw chopper. This reduces the delay in wheat sowing. The dry mixing of chopped paddy straw was also done using disc harrow, cultivator, disc plough etc. (**Fig. 7**).

Sowing With Spatial Zero Till Drill

Spatial drill is similar to zero till seed drill. This is a technology introduced by Department and its field evaluation is in process. This machine has inverted T-type furrow openers. In this machine the furrow openers have arranged in three rows instead of two rows (**Fig. 8**). Thus the spacing between furrow openers is increased 1.5 times greater than conventional drill and height of furrow opener is kept 0.60 m which is higher than conventional zero till drill which helps to prevent choking of chopped paddy straw between furrow openers. The spacing between furrow openers is 0.20 m as in conventional drill. This machine can be used for sowing of wheat after chopper operation or after baler operation in the field. There is no need for incorporation of paddy straw for sowing wheat by this machine. The field capacity of this machine is 0.6-1.0 acre.hr^{-1} and it can be operated by a 45 HP tractor.

Happy Seeder

Happy seeder machine combines the stubble mulching and seed drilling functions into the one machine. Happy seeder sows wheat directly in paddy residue in combine harvested field hence prevents residue burning thus reduces air pollution. An attachment called straw management system (SMS) can be attached behind the combine which spreads the loose straw falling at rear during harvesting operation (**Fig. 9**). The strip of stubble in front of the sowing tynes is cut, picked up and placed on the side of the drilled seed as mulch by flail blades (**Fig. 10**) mounted on rotor. The furrow openers cut the furrow slice (**Fig. 11**) for proper placement of wheat seed. The sowing tynes therefore engages bare soil. A view of Happy seeder ma-chine in operation is shown **Fig. 12**.

This machine has inverted T-type furrow openers. This PTO driven machine can be operated with 45 HP tractor and covers 0.2-0.3 ha.h^{-1}. Weed matter was nearly 50% lesser on Happy seeder plots as compared with conventionally sown plots. As wheat sown with Happy seeder machine grows, straw starts decaying. Mulched crops residue improved the soil health and added organic matter to the soil. This machine can also be used for sowing subsequent moong crop in wheat residue. Farmers have started growing wheat with Happy seeder and number and area under Happy seeder machines is increas-

Fig. 8 Wheat sowing with Spatial drill

Fig. 9 Straw Management System for spread-ing loose straw behind combine

Fig. 10 A view of flail blades in front of tines

Fig. 11 A view of cut furrow slice

Fig. 12 Different views of Happy Seeder during field operation

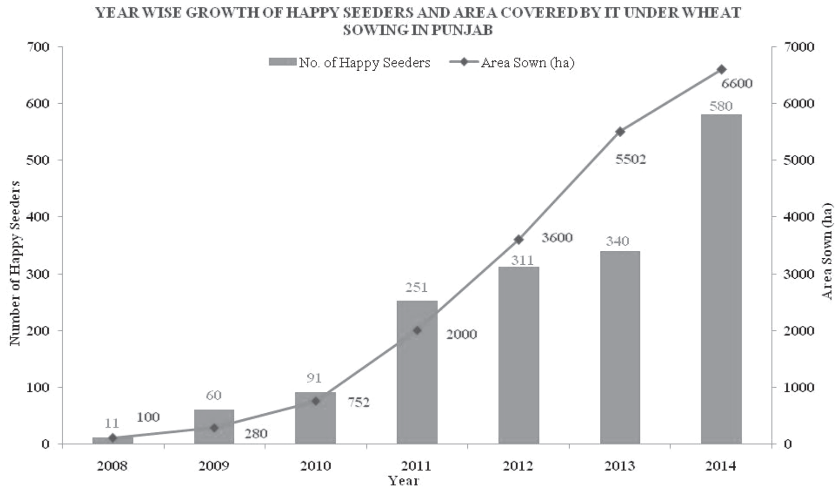


Fig. 13 Year wise growth of Happy Seeder in Punjab

ing every year (**Fig. 13**).

Zero Till Seed Cum Fertilizer Drill

Zero till drill machine is used for no tillage system requiring no previous seed bed preparation after harvesting paddy and sowing of wheat crop effectively in one operation (**Fig. 14**). This machine has inverted T-type furrow openers in place of shovel type furrow openers. The drill performance of the no-till drill was found to be most effective when operated in the fields where the loose straw after the combine harvesting of paddy has been dealt with. It can be operated by a 35 hp or above tractor. Its effective output is about 0.35 to 0.4 $ha.h^{-1}$. Its use saves 60-70% diesel and time and cost of operation in comparison to traditional method.

Conventional Drill

Conventional drill has shovel type furrow openers (**Fig. 15**). This machine can be operated in well prepared field. The field capacity of this machine is 0.3-0.4 $ha.h^{-1}$ and it can be operated by 35 HP tractor. This machine was used for sowing of wheat either after chopper operation along with incorporation or burning of loose straw alongwith field preparation.

Roto Seeder

Another machine used for sowing of wheat is rotoseeder (**Fig. 16**). It can be operated in paddy stubble fields. The wheat seed is dropped by flutted roller mechanism in plastic tubes in front of machine and rotavator mixes it in the soil. Therefore the seed is placed at different depths randomly in the field soil. The field capacity of this machine is 0.3-0.4 $ha.h^{-1}$ and it can be operated by 45-50 HP tractor. Some farmers follow manual broadcasting of seed and then they run only rotavator in the field.

Manual Broadcasting Method

This method was used by few farmers. The paddy straw was incorporated in the soil after chopper operation. The wheat sowing was done manually and was mixed in soil with the help of cultivator or rotavator.

Conventional Method

The conventional method adopted by most of farmers included burning of loose straw and standing stubbles causing a lot of pollution, then preparation of field using disc harrow, cultivator, planker and sowing of wheat using conventional or zero till seed cum fertilizer drill.

Effective Field Capacity

The effective field capacity of various machines/implements was calculated using following formula (Kepner *et al*., 1978):

$C = SW/10 \times E_f/100$ ....(1)

C - effective field capacity, $ha.h^{-1}$.

S - speed of travel, $km.h^{-1}$

W- rated width of implement, m

E_f - Field efficiency, in percent

$E_f = 100\ T_o/T_e + T_h + T_a$

T_o - theoretical time per hectare (per acre)

T_e - effective operating time = $T_o \times 100/K$

K - percent of implement width actually utilized

T_h - time lost per acre due to interruptions that are not proportional to area. At least part of Th usually

Fig. 14 View of wheat sowing with zero till drill

Fig. 15 View of wheat sowing with conventional drill

Fig. 16 View of wheat sowing with Roto seeder machine in the field

tends to be proportional to T_e

T_a - time lost per acre due to interruptions that tend to be proportional to area.

Estimation of Fuel Consumption

For measuring the fuel consumed during the sowing, a fuel consumption meter was attached with tractor. The fuel consumption reading at the start and end of field experiment was observed and fuel consumption was measured as

$F = 3.6 \times L/T$ ....(2)

where F is the fuel consumption in $l.h^{-1}$, L-fuel consumption meter readings difference (i.e. L_f - L_i) in ml for a particular length and T is time for particular length in seconds, L_f, L_i-Fuel consumption meter readings at finish and start of experiment respectively.

Working Width And Depth

Depth of various implements were measured after operating them in the field with the help of a scale and working width was measured using a measuring tape/scale. The standard row to row spacing in case of sowing drill was adjusted to 200 mm.

Fig. 17 Wheat sown with spatial drill after chopper operation

Fig. 18 Different stages of wheat sown with Happy seeder machine

Results and Discussion

The mean moisture content of loose straw varied between 22-28 %(w.b.) and of standing stubbles varied between 60-70% (w.b.). The straw load at various locations varied between 5-9 $Mg.ha^{-1}$. The moisture content of soil varied between 12.78-18.11% (d.b.) during different field experiments. The various specifications, power requirements, fuel consumption, field capacity of machines and implements used were measured and are shown in **Table 2** (see the end of this paper).

It was found that there was significant increase in yield of wheat after either sowing directly in paddy stubble field or sowing after incorporating paddy straw in the field. The data for soil type, wheat variety sown, area covered and yield obtained with straw management practices and conventional practices are shown in **Table 3** (see the end of this paper). Wheat yield increase with chopper and spatial drill combination (**Fig. 17**) varied from 5.0-10.25%, with Happy seeder (**Fig. 18**) varied from 2.0-5.0%, with chopper and conventional drill combinations varied from 14.28-17.80%, with chopper and broadcasting method varied from 4.92-11.27% and with chopper and zero till seed cum fertilizer drill varied from 2.18-16.67% with sowing. However in case of Roto Seeder the yield was either equivalent or lesser than conventional practice. The effect of different sowing machines/techniques/practices used for straw management and for sowing of wheat was found to be significant on mean% increase in wheat yield as compared with conventional method at 5% level of significance. The mean total number of operations involved for straw management and field preparation per hectare for wheat sowing for Spatial drill and Happy seeder were 2 and for Conventional drill, Roto seeder, Broadcasting method

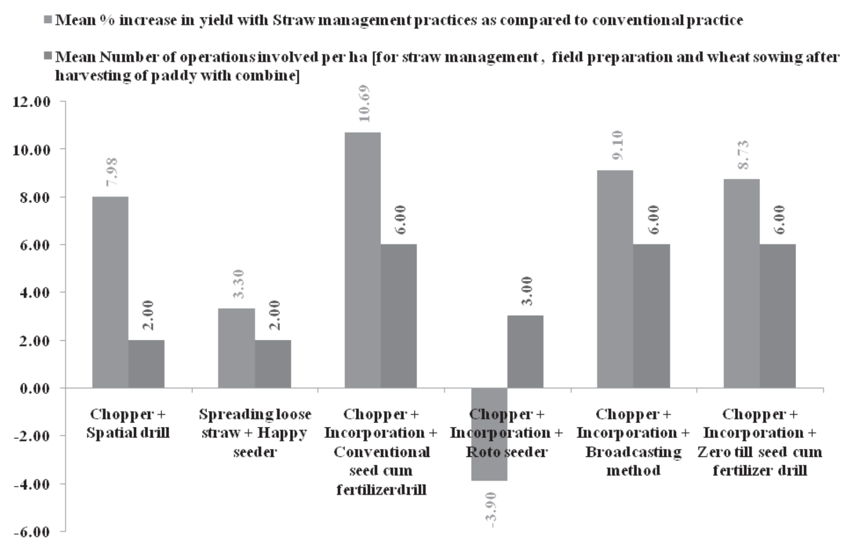


Fig. 19 Effect of straw management practices/machines on % increase in wheat yield and total number of operations involved for straw management and field preparation for subsequent wheat sowing

and Zero till seed cum fertilizer drill were 6, 3, 6 and 6 respectively (**Fig. 19**) . Thus cost of operations per hectare was also less in case of wheat sowing with spatial drill and happy seeder machines as compared to other machines/practices.

Economic Analysis

The economic analysis of various straw management practices alongwith wheat sowing by various machines was carried out and is shown in **Table 4** (see the end of this paper). Here the practices were considered that are mostly followed by farmers. In economics calculations, for the sowing machines, sprayers, straw management machinery, tillage implements and harvesting machinery fixed and variable costs were included. The Diesel cost, fertilizers and weedicides cost, labour cost, irrigation cost and harvesting cost were also included. Yield benefit and straw benefit were also calculated. The average straw yield was 4.0 t/ha and cost of diesel was taken as Rs.57/litre. The urea, DAP, NPK, MOP costs per were taken as Rs./- 5,410, 21,200, 23,200 and 10,000 per tonne. The benefit cost ratio was worked out for all the practices and it was highest for Happy seeder and sms combination and chopper and spatial drill combination as 2.73:1. The benefit cost ratio was minimum for Traditional method (partial burning) and broadcasting method as 2.29:1 and 2:30:1 respectively.

Conclusions

The mean % increase in wheat yield with chopper and spatial drill combination was 7.98% as compared to conventional method and mean number of operations required per hectare were only 2 for sowing of wheat after harvesting of paddy with combine. The mean % increase in wheat yield for Happy seeder machine with practice of spreading loose straw was 3.30% as compared to conventional method and mean number of operations required per hectare were only 2 for straw management sowing of wheat after harvesting of paddy with combine. The mean % increase in yield for wheat sowing practice with chopper operation along with incorporation of chopped paddy straw and conventional seed cum fertilizer drill combination was 10.69% as compared to conventional method and mean number of operations required per hectare were 6 for straw management and field preparation for sowing of wheat after harvesting of paddy with combine. Thus cost of sowing/ha for wheat also increased for this practice. There was no increase or decrease in yield for wheat sowing practice with chopper operation along with incorporation of chopped paddy straw and roto seeder combination and mean % decrease in yield was found to be -3.90% as compared to conventional practice. This might be due to uneven placement of seed with Roto seeder as compared to seed drills, non-uniform depth of seed placement and compaction of soil layer beneath. The mean number of operations required per hectare were 3 for straw management and sowing of wheat after harvesting of paddy with combine. The mean % increase in yield for wheat sowing practice with chopper operation along with incorporation of chopped paddy straw and Broadcasting method combination was 9.10% as compared to conventional method and mean number of operations required per hectare were 6 for straw management and field preparation for sowing of wheat after harvesting of paddy with combine. In this practice alongwith higher cost of operations involved, cost of seed per hectare was also high because farmers put more seed per hectare than recommended in this practice. The mean % increase in yield with for wheat sowing practice with chopper operation along with incorporation of chopped paddy straw and Zero till seed cum fertilizer drill combination was 8.73% as compared to conventional method and mean number of operations required per hectare were 6 for straw management and field preparation for sowing of wheat after harvesting of paddy with combine. The benefit cost ratio was worked out for all the practices and it was highest and almost same for Happy seeder and SMS combnation and for chopper and spatial drill combination as 2.73:1. Savings for chopper with spatial drill combination and Happy seeder with SMS combination.in were 24943.11 Rs.acre^{-1} and 24624.19 Rs.acre^{-1} respectively. General observation in field was that if the chopper was operated as soon as after combine harvesting of paddy (i.e. 1-2 days after combine harvesting, this time for sun drying of paddy straw) the tractor runs under load. As the paddy straw was allowed for more time in field after combine harvesting it became hard to chop and then tractor runs overload.

The paddy straw burning problem can be resolved using these different machines/practices and also farmers can be benefitted through increase in subsequent crop yield, reduction in cost of fertilizers, which in turn increase their economy. The effect of sowing wheat in paddy stubbles field along with chopper combination was found to be effective in almost all the machines except Roto seeder. In case of Chopper along with Spatial drill and Happy seeder, there was saving in time, labour and cost of operations involved, for straw management and sowing of wheat.

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REFERENCES

Askari, M. and S. Khalifahamzehghasem. 2013. Draft Force Inputs for Primary and Secondary Tillage Implements in a Clay Loam Soil. World Applied Sciences Journal 21, 1789-1794.

Anonymous. 2011. Package of practices for crops of Punjab, Kharif-2011, Punjab Agricultural University, Ludhiana, India, 1.

Derpsch, R., T. Friedrich, A. Kassam and H. Li. 2010. Current status of adoption of no-till farming in the world and some of its main benefits. Int. J. Agric. and Biol. Engineering , 3 (1), 1-26.

Erenstein, O. and V. Laxmi. 2008. Zero tillage impacts in India's rice-wheat systems: A review. Soil and Tillage Research, 100 (1-2), 1-14.

Garg, I. K. 2004. Design and development of rice straw chopper-cum-spreader. J Res. Punjab Agric. Uni. 41(1), 130-138.

Guan, D., Y. Zhang, M. M. Al-Kaisi, Q. Wang, M. Zhang and Z. Li. 2015. Tillage practices effect on root distribution and water use efficiency of winter wheat under rain-fed condition in the North China Plain. Soil & Tillage Research 146, 286-295.

Kumar, M. and T. C. Thakur. 2013. Design, development and evaluation of deep soil volume loosener-cum-fertilizer applicator. Journal of Agricultural Engineering. 50, 1-9.

Makki, E. K. and A. E. A. Mohamed. 2008. Tillage implements performance and effect on some soil physical properties. Agricultural mechanization in Asia, Africa, and Latin America. 39, 9-13.

Mandal, K. G., A. K. Misra, K. M. Hati, K. K. Bandyopadhyay, P. K. Ghosh and M. Mohanty. 2004. Rice residue-management options and effects on soil properties and crop productivity Food, Agriculture and Environment Vol.2 (1): 224-231. 2004

Osman., A. N., L. Xia and Z. Dongxing. 2011. Effects of tilt angle of disk plough on some soil physical properties, work rate and wheel slippage under light clay soil. Int J Agric & Biol Eng. 4, 29-35.

Shukla, L. N., H. S. Sidhu and V. Bector. 2002. Design and development of loose straw thrower attachment for direct drilling machines. Agricultural Engineering Today 26(3-4), 23-29.

Sidhu, H. S., J. Blackwell, V. Bector, L. N. Shukla and M. Singh. 2005. Development of combo happy seeder for direct drilling in a combine harvested paddy field. Proc. 39th annual ISAE convention, held at ANGRAU, Hyderabad, India during March 9-11, 2005.

Singh, R. K. P. and S. Bachan. 1998. Effect of different tillage systems in soil properties and yield of wheat (Triticum Aestivum). Agricultural Engineering Today. 22(5-6), 1-8.

Singh, S. 2002. Annual report of project, "Mechanization of Rice-Wheat Cropping System for Increasing the Productivity" 2001-2002, Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana.

Thakur, S. S. 2004. Studies on management of paddy straw by chopping for sowing wheat in combine harvested field. Published Ph.D. dissertation, Punjab Agricultural University, Ludhiana, India.

Thakur, T. C., A. Kumar and S. S. Papal. 2005. Proceedings of the Project Workshop on Accelerating the Adoption of Resource Conservation Technologies in Rice-Wheat systems of the Indo-Gangetic plains held on June 1-2, 2005 at Hisar (Haryana), India, 183-192.

Xiangcai, Z., L. Hongwen, D. Ruichen, M. Shaochun, H. Jin, Q. Wang, W. Chen, Z. Zheng and Z. Zhang. 2016. Effects of key design parameters of tine furrow opener on soil seedbed properties. Int J Agric & Biol Eng. 9, 67-80.

*(**Table 2, 3, and 4** are shown on the next pages)*

Table 2 Specifications and operational parameters of various sowing machines / Implements used in the study

Machine/Implement Particulars	Cost	Required Tractor power	Seed metering device	Mean working width	Operational depth	Weight	Speed rpm		No. of blades/ tynes/ disks/ furrow opener	Fuel consumption	Effective field capacity
	Rs./unit	KW		mm	mm	kg	PTO	Rotor		l./h	ha./h
Happy seeder (reversible straight γ-type blades, 10 tines, Inverted T- type furrow opener)	125,000.00	37.30 (CAT I and II)	Aluminium type flutted roller	1800	63.5-80.0	500-550	540	1250-1350	10	5.75-6.25	0.25-0.35
Zero till seed cum fertilizer drill (11 tines, Inverted T- type furrow opener), seed capacity 95 kg, fertilizer capacity, 90 kg	40,000.00	29.84 (CAT-1)	Aluminium type flutted roller	2000	50.0-60.0	250-300	--	--	11	4.50-5.50	0.30-0.40
Conventional seed cum fertilizer drill (11 tines, shovel type furrow opener) 1575 × 2210 × 1300	40,000.00	29.84 (CAT I)	Aluminium type flutted roller	2000	50.0-60.0	250-300	--	--	11	4.50-5.50	0.30-0.40
Roto seeder (L-type blades) 2435 × 1370 × 1055, 42 blades	125,000.00	37.30 (CAT II)	Aluminium type flutted roller	1828-1905	75.0-88.9	425-576	540	180-270	42	6.00-7.00	0.25-0.30
Spatial drill (9 tines-Inverted T-type furrow opener)	50,000.00	33.57 (CAT-I/II optional)	Aluminium type flutted roller	1600	63.5-80.0	280-300	--	--	9	5.20-5.80	0.25-0.35
Cultivator (11 tines, reversible shovel type)), 2457 × 2287 × 585 mm Spring (mm): 10 WD, 50 OD (28.5 coils), Tynes, mm: 50/2” × 25/1” (Forged), Shovel: 8 mm (T) EN-42	25,000.00	33.57-37.3 (CAT I and II)	--	2350	90-110	255-345	--	--	11	4.75-5.25	0.30-0.35
Disk harrow (16 disks, Φ 609.6 mm), disc diameter 500 × 4T (22 inch), disc spacing 570 mm, 75 × 10 angle frame with 100 × 50 channel, gang bolt-31 mm (solid sq rod) with split gangs, distance between discs 228 mm, bearing hubs-6	36,000.00	33.57 (CAT-I/II optional)	--	1840	110-130	500	--	--	16	5.40-5.60	0.30-0.35
Rotavator (L-type blade), flanges 8-9, multi gear box, 42 blades	95,000.00	37.3 (CAT II)	--	1828-1847	75.0-88.9	425-475	540	180-270	42	6.00-7.00	0.30-0.35
Planker: 3 channel (3060 × 510 × 100 mm)	15,000.00	33.57 (CAT-1)	--	3060	--	150-200	--	--	--	4.00-4.50	0.40-0.50
Paddy straw chopper cum spreader (Inverted γ-type flails), 48 blades,	100,000.00	37.3	--	1830	--		540	1250-1350	111	5.50-6.00	0.28-0.35
2 × 1.10 × 0.95 m, cylinder dia: 600 mm, 2-3 rows of serrated blades on inside concave and 17-21 blades on each row , PTO driven ,mounted type		(CAT II)									

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Paddy straw chopper cum spreader (cutter bar type), main cylinder-14 rows, secondary cylinder: 7 rows (21 serrated blades each row), concave bar: 5 rows (41 blade each row), PTO driven, Trailed type.	240,000.00	44.76 (CAT II)	--	2180	--	2000-2300	540	900-1000	646	4.50-7.00	0.25-0.32
Ridger (3-bottom), overall width 2928 mm	12,000.00	33.57 (CAT-I/II optional)	--	2483 (adjustable)	250.0-300.0	200	--	--	--	4.90-5.10	0.25-0.30
Mounted Disk plough (2 disk blades, (Φ660 × 6T (26”)), Coulter disc 508 × 5 mm, disc spacing 570 mm	65,000.00	41.03 (CAT II)	--	500-550	225-250	310	--	--	2	5.75-6.25	0.24-0.30
Straw reaper combine, 3680 × 2470 × 2100, 2-3 blowers, Multi gear box, thresher drun diameter 677 mm, length 1380 mm, Blower 2, blades per blower 4	240,000.00	44.76	--	2100-2150	--	1950-2250	540	750-1000	238 basket blades 33, channel blade-18	3.15-5.00	0.24-0.30
Cutter bar blade-28 no., Width: 2190 mm,		(CAT II)									
Spray pump (Knap sack type), 16 l capacity	3,000.00	Manual		--	--	20-25	--	--	--	0	0.28-0.30

Table 3 Comparison of different straw management techniques on different crops yield as compared to traditional method

Machine/ technique used for wheat sowing	Straw managment/ Tillage machine/ practice for paddy straw management and field preparation	Type of soil	Variety of wheat sown	Area covered	Wheat yield with straw management practices	Wheat yield with conventional method	% Increase in yield with Straw management practices as compared to conventional practice	Mean % Increase in yield with straw management practices as compared to conventional practice	Mean Number of operations involved per ha [for straw management and field preparation after harvesting of paddy with combine]
				ha	Mg./ha	Mg./ha			
Spatial drill	Chopper	Loam	HD-2967	0.30	6.00	5.50	9.09	7.98	2
	Chopper	Loam	HD-2967	0.45	5.25	5.00	5.00		
	Chopper	Loam	HD-2967	0.50	5.38	4.88	10.25		
	Chopper	Sandy loam	HD-2967	0.60	5.25	4.88	7.580		
Happy seeder	Manual spreading of loose straw/Straw Management System	Sandy loam	HD-2967	0.80	5.75	5.50	4.54	3.30	2
	Manual spreading of loose straw/SMS	Sandy loam	HD-2967	0.40	5.12	5.00	2.40		
	Manual spreading of loose straw/SMS	Sandy loam	HD-2967	0.40	5.10	5.00	2.00		
	Manual spreading of loose straw/SMS	Sandy loam	HD-2967	0.60	5.25	5.00	5.00		

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	Cutter bar type Chopper cum spreader	Sandy clay loam	HD-2967	2.50	5.25	5.12	2.54		
Conventional drill	Chopper +Incorporation with disc plough (2)	Sandy clay loam	HD-2967	3.50	5.89	5.00	17.8	10.69	6
	Partial Burning + disc harrow(2) + cultivator(2) + planker	Sandy clay loam	HD-2329	64.00	4.88	4.88	0.00		
	Chopper (1 day after combine) + one irrigation + rotavator (1) + cultivator (2) + planker	Loamy Sand	HD-2967	2.00	6.00	5.25	14.28		
Roto seeder	No practice	Loam	DBW-17	6.00	5.75	5.75	0.00	-3.90	3
	No practice	Loam	PBW-621	12.00	6.00	6.00	0.00		
	Chopper (after 5-7 days of combine) + Irrigation + 25 kg Urea/acre + disc harrow (1) + cultivator	Sandy loam	HD-2967	6.00	4.75	5.38	-11.71		
Broadcasting + Ridges (ridger)	Chopper + one irrigation + disc harrow (3) + cultivator (2)	Sandy clay loam	HD-2967	1.60	6.12	5.50	11.27	9.10	6
Broadcasting +cultivator (1)	Chopper (3-4 days after combine) + rotavator + irrigation + Field left for 7-10 days + disc harrow (low depth)	Sandy loam	HD-2967	0.20	5.00	4.50	11.11		
Broadcasting + Rotavator	Chopper+Incorporation with rotavator	Sandy loam	HD-2967	10.00	5.12	4.88	4.92		
Zero till seed cum fertilizer drill	Chopper +disc harrow(2) + cultivator (2) + planker (2)	Sandy loam	HD-2967	4.00	5.62	5.50	2.18	8.73	6
			PBW-621	9.00	6.00	6.00	0.00		
	Chopper (after 20-30 days as straw was dry) + rotavator + Flood Irrigation + 20-25 days field free + disc harrow (2) + planker	Sandy	HD-2967	1.20	5.75	5.00	15.00		
	Chopper (12 days after combine operation) + rotavator + flood irrigation + at optimum moisture rotavator	Sandy loam	HD-2967	4.00	5.25	4.50	16.67		

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	Chopper (Next day after combine operation) + rotavator + one irrigation + disc harrow (2) + planker (2)	Sandy loam	HD-2967	0.80	5.75	5.50	4.54		
	Cutter bar type chopper cum spreader (Next day after combine operation) + Field left for 3 days + disc harrow (2) + Cultivator (1) + planker (3)	Sandy loam	HD-2967	44.00	5.50	5.00	10.00		
	Chopper + Incorporation with rotavator	Sandy loam	HD-2733	2.00	5.50	4.88	12.70		
							CD (5 %)	S	--

Table 4 Economic analysis of various paddy straw management and wheat sowing techniques

Detail of Paddy straw management technology/tillage practices/sowing method applied	Straw Management, field preparation, sowing operation cost Rs.acre^{-1}	Cost of seeds, fertilizers, weedicides, insecticides, labour, irrigation Rs.acre^{-1}	Harvesting and threshing charges Rs.acre^{-1}	Transportation and marketing costs Rs.acre^{-1}	Total variable costs Rs.acre^{-1}	Interest on variable costs@ 9% for half crop period Rs.acre^{-1}	Total Variable costs Rs.acre^{-1}	Gross returns (from grain and straw) Rs.acre^{-1}	Net returns over variable costs Rs.acre^{-1}	B:C ratio
	[1]	[2]	[3]	[4]	[5] = [1]+[2]+[3]+[4]	[6] = [5]*0.09	[7] = [5]+[6]	[8]	[9] = [8]-[7]	[10] = [8]/[7]
Chopper + Spatial drill	1813.93	6719.00	4000.00	700.00	13232.93	1190.96	14423.89	39367.00	24943.11	2.73:1
Happy seeder + sms or manual spreading	1405.41	6799.00	4000.00	700.00	12904.41	1161.40	14065.81	38330.00	24624.19	2.73:1
Chopper (4 days after combine) + one irrigation + rotavator (1) + cultivator (2) + planker + Conventional drill	3944.15	6904.00	4000.00	700.00	15548.15	1399.33	16947.48	40099.00	23151.52	2.37:1
Chopper (after 5-7 days of combine) + Irrigation + 25 kg Urea/acre + disc harrow (1) + cultivator + Rotoseeder	3712.29	7040.00	4000.00	700.00	15452.29	1390.71	16843.00	39550.00	22707.00	2.35:1

(Continued on the next page)

(Continued from the previous page)

Chopper + one irrigation + disc harrow (3) + cultivator (2) + Broadcasting/ Ridger	3967.68	6904.00	4000.00	700.00	15571.68	1401.45	16973.13	39001.00	22027.87	2.30:1
Chopper (12 days after combine operation) + rotavator + flood irrigation + at optimum moisture rotavator + Zero till drill	3496.01	6904.00	4000.00	700.00	15100.01	1359.00	16459.01	40343.00	23883.99	2.45:1
Traditional Method (Partial burning + disc harrow (2) + cultivator (2) + planker (1) + conventional drill)	2919.68	6719.00	4000.00	700.00	14338.68	1290.48	15629.16	35768.00	20138.84	2.29:1

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Evaluation of Different Primary Tillage Equipment for Soil Cultivation in Laser Levelled Fields

by
Manoj Kumar
Manoj Kumar
Scientist, Agricultural Mechanization Division, ICAR-Central Institute of Agricultural Engineering, Nabi Bagh, Berasia Road, Bhopal - 462038 (MP)
INDIA
dreamweaver.manoj@gmail.com

T. C. Thakur
Former ICAR National Professor
Deptt. of FMPE, College of Technology
Govind Balliabh Pant Univ. of Agril. & Technology
Pantnagar-26314, Distt. U S Nagar, Uttarakhand
INDIA

Abstract

This study was conducted to access the suitability of "Pant-ICAR-Deep Soil Volume Loosener-cum-Fertilizer Applicator" as a precision equipment developed for soil cultivation in laser levelled field. The equipment was developed for deep soil loosening, deep application of fertilizers and clod crushing without altering the level of the field surface after operation. The equipment was compared with disk plough and ICAR-Pant subsoiler in respect of changes in the level of soil surface. The results indicated that the developed equipment create minimum field surface level disturbance in single pass, hence extending the benefits of laser land levelling for many years and was recommended for soil cultivation in laser leveled fields.

Keywords: Deep soil loosening, deep fertilizer placement, laser leveller, tillage in laser leveled fields.

Introduction

A precisely levelled field is a prerequisite for an efficient surface irrigation system, in-situ conservation of rain water and introduction of resource conservation technologies such as zero tillage, raised bed planting etc. The laser aided precision land smoothening equipment which have been used for decades in many developed countries were imported in India in the year 2002. The laser land levelling is a process of smoothing the land surface (± 20 mm) from its average elevation using laser equipped drag buckets. According to an estimate over 5000 units of laser land levellers are now available in India which have levelled over 1 Mha of land mainly in the States of Punjab, Haryana, U.P. and Uttarakhand (RWC, 2009). Results of several hundred participatory field trials in these states have brought out several tangible benefits of this technology which include irrigation water saving of about 24.5, 24.5, 31.66, 26.5, 33, 31 and 17% for wheat, sugarcane, rice, maize, potato, sorghum and ladyfinger, respectively in comparison to unlevelled field (Ahmed *et al*., 2001). In addition to this, an increase in nutrient utilization efficiency by 10-15%, enhanced field efficiency of farm equipment by over 10%, increased net cultivable area by reduction of bunds/ridges and irrigation channels by 2-5%, and yield advantage of 15 to 30% in different crops have also been reported (Jat *et al*., 2006). The field capacity of laser guided land leveller, both in terms of area covered and volume of soil handled per hour was less as compared to conventional levelling/grading by drag scraper of same size. The cost of levelling by laser guided land leveller has been found about 50% higher in case of land levelling operation and nearly double in case of land grading operations as compared to conventional levelling and grading (Chaudhuri *et al*., 2007). It is recommended that laser leveller should be used after 2-3 years. The area under laser levelling is increasing at an exponential rate but for tillage operations in these fields the same old equipment such as mouldboard/disc plough, harrow, cultivator etc. are being used thereby causing frequent changes in the level of fields. In fact, there is a need for tillage equipment which could cultivate not only the top soil but also the subsoil without soil inversion so that the biomass in different soil layers are maintained in the same zone and at the same time, the level of field is disturbed to a bare minimum (Thakur, 2008). Thus, keeping these points in view, a new equipment (Manoj Kumar, 2010) which was developed for soil cultivation in laser levelled fields without disturbing its original level was compared with existing tillage equipment i.e. disk plough and Pant-

ICAR subsoiler.

Materials and Methods

The experiments were conducted at crop research centre of the G. B. Pant University of Agriculture and Technology, Pantnagar during 2010 i.e. a two bottom disc plough, Pant-ICAR subsoiler-cum-differential rate fertilizer applicator and Pant-ICAR deep soil volume loosener-cum-fertilizer applicator were selected for study (**Fig. 1**).

The first one was a two bottom disk plough which was selected because it is mostly used by the farmers as primary tillage equipment. Second one was Pant-ICAR subsoiler-cum-differential rate fertilizer applicator. This modern agricultural equipment is used for breaking of hard pan and deep soil cultivation up to depth of 500 mm, and produce lesser soil surface disturbance and is capable of band application of fertilizers in root zone of crops at two different depths. Last one was Pant-ICAR deep soil volume loosener-cum-fertilizer applicator and first prototype of this equipment was developed in Farm Machinery and Power Energy Department above said university. It consisted of three main units i.e. a deep soil volume loosening unit, fertilizer application unit and clod crusher unit. The deep soil volume loosening unit consisted of mainly a rectangular frame, two V-shaped tines and a hitching system. The fertilizer application unit consisted of two fertilizer boxes with metering system for each inverted-T opener tines, a ground drive wheel for power transmission and its accessories. The clod crusher unit consisted of two floating type spiked rollers hinged exactly at the rear of main V-tine. It can loosen soil up to 300 mm depth, apply fertilizers in bands up to 200 mm depth with minimum disturbance of the level of field surface (Manoj Kumar and T C Thakur, 2011).

For experimental study, a plot size of 45 m × 30 m was selected and the field was marked by grid of 2.5 m × 2.5 m sizes. Further, initial elevations at all the grid points were noted with the help of a dumpy level and thereafter, the field was marked in three equal strips of 30 m × 15 m (**Fig. 2**) for operation of different equipment.

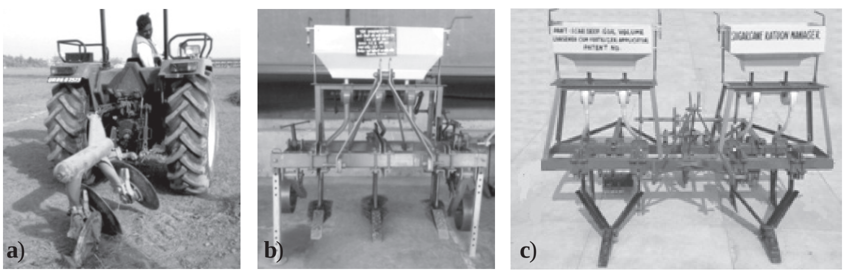


Fig. 1 Different equipment used in the experiment
a) Two- bottom disk plough
b) Pant-ICAR subsoiler-cum-differential rate fertilizer applicator
c) Pant-ICAR deep soil volume loosener-cum-fertilizer applicator

The disk plough, Pant-ICAR deep soil volume loosener-cum-fertilizer applicator and Pant-ICAR subsoiler cum-differential rate fertilizer applicator are operated in first, second and third strips, respectively, and again the elevation of same grid points were noted. The difference of these elevations indicated the change in the level of field due to the operation of a equipment. The difference in the level of the field due to the operation of developed equipment was also compared with that of a disk plough and Pant-ICAR subsoiler-cum-differential rate fertilizer applicator. Moreover, to the Levelling Index (LI) and Land Uniformity Coefficient (LUC) were also calculated to assess the smoothness of the land surface. The LI was taken as the average numerical variation between the proposed or designed levels and the existing average field level as follows:

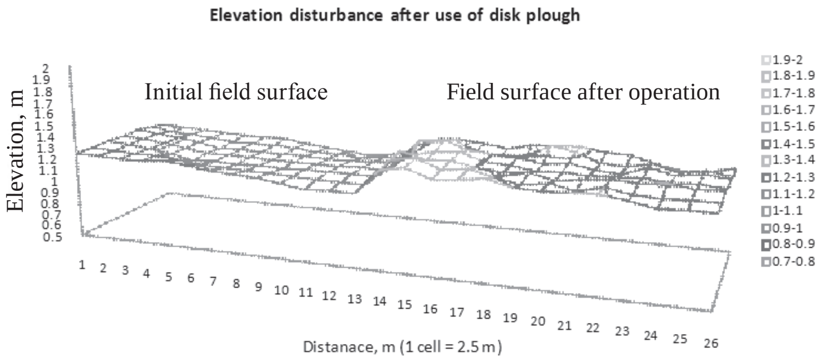
$$LI = (\sum|DLi-ALi|) / N \quad (1)$$

Where, DLi = designed grid level at point i, cm; ALi = existing grid level at point i, cm; and N = total number of grid points

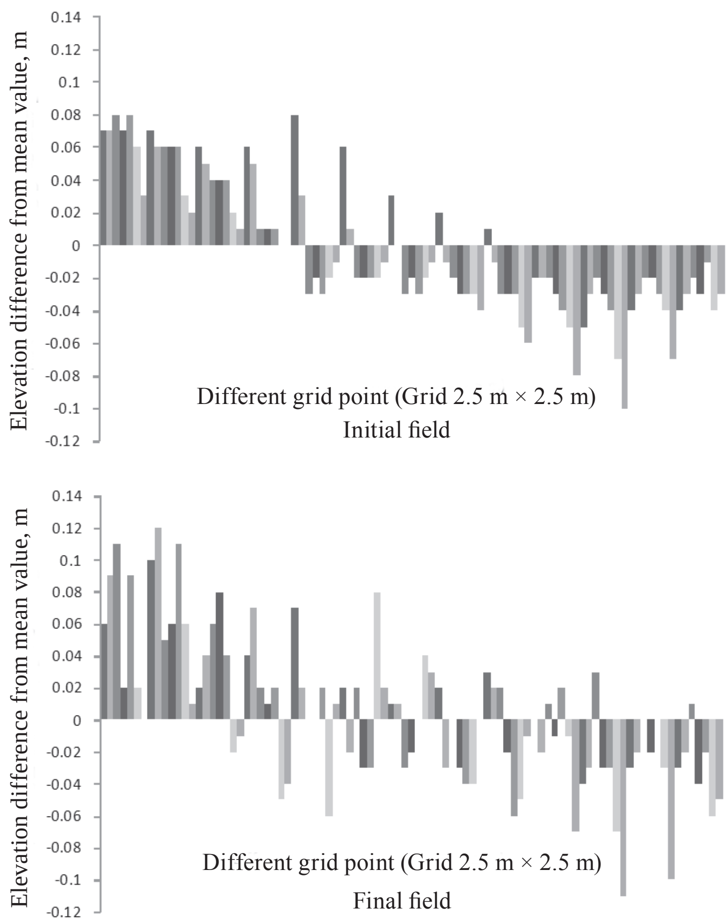
The lower limit of LI is zero, and LI of zero indicates to perfect levelling of the field. Increasing values of LI reflect poorer quality of field levelling which results in low irrigation efficiency. The second levelling index selected for the study was Land Uniformity Coefficient (LUC). The

Fig. 2 A view of levelling, grid formation and elevation measurement of test plot
a) Levelling of the field, **b**)Grid forming, **c**) Grid elevation

a) Disk plough in operation



b) Graphical representation Surface level disturbance after use of disk plough



c) Variations in field surface level with respect to mean elevation

Fig. 3 Details of disk plough operated field

LUC represents the magnitude as well as the frequency of occurrence of successively larger undulations in the field. The highest value of LUC is 1.0, which reflects a perfectly level surface. Decreasing values of LUC represent successively poorer quality of land levelling. The LUC is defined as:

$$LUC = \{1 - (\sum|DLi\text{-}ALi|) / (\sum DLi)\} \quad \text{.........................(2)}$$

Further, the field slope calculated with the help of formula given below:

$$S = (\sum(DH) - (\sum D)(\sum H) / n) / (\sum(D^2) - (\sum D)^2 / n) \quad \text{.....................(3)}$$

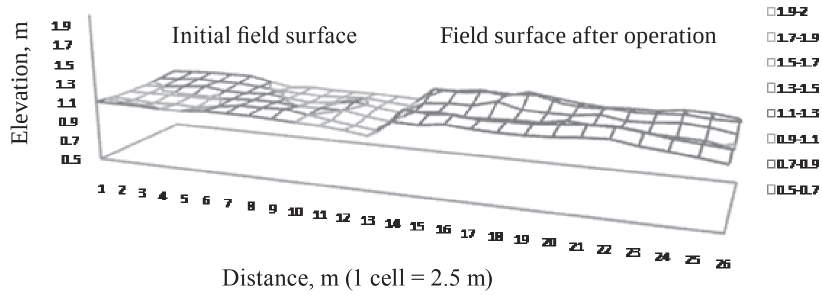
Where, S = slope of line in a plane, dimensionless; D = distance from the reference line, L; H = elevation of the grid point, L; and n = number of grid points.

Results and Discussion

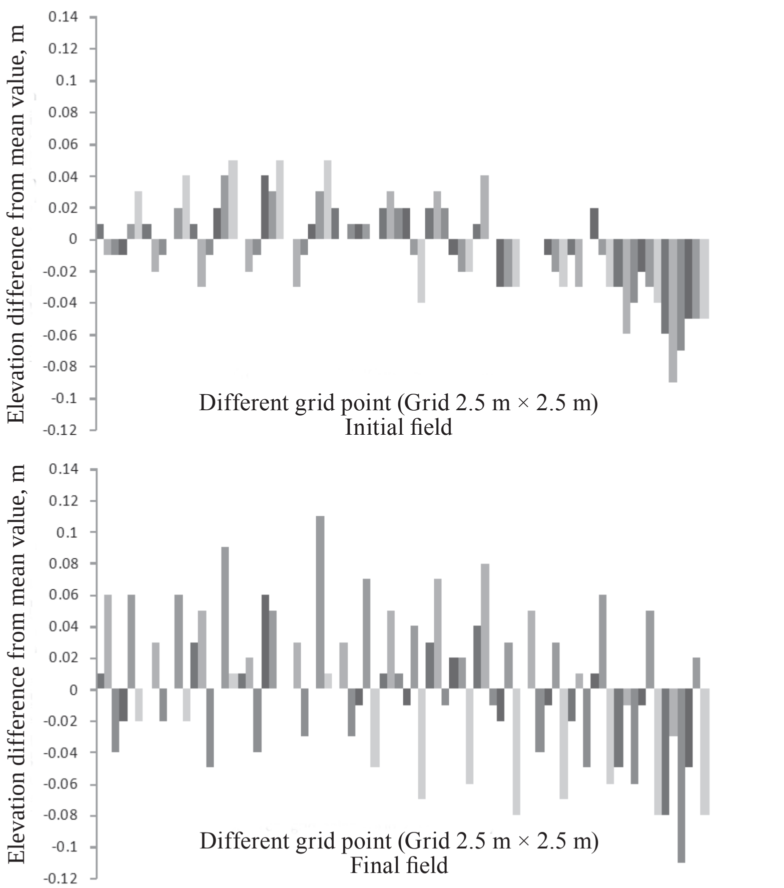
The field surface condition after the operation of a disk plough is shown in **Fig. 3a** and the digital representation of the field surface level before and after the operation of equipment is shown in **Fig 3b**. Initially the mean level of field was found to be 1.17 m and after the operation of a disk plough, it was 1.28 m. The increase in field surface level was found to be 110 mm due to loosening and inversion of the soil. It is clear that the final (S_x = 0.314, S_y = 0.307) slope of the field after disk ploughing did not differ much from its initial (S_x = 0.350, S_y = 0.304) slopes. The land surface smoothness index i.e. LI in case of disk plough was found 0.0351 and 0.356 for initial and final field conditions, respectively. Also the land surface smoothness index LUC for disk ploughing was 0.970 and 0.972 for initial and final field conditions, respectively. Further, the variations in the field surface after operation (**Fig. 3c**) was more than that of before the operation in respect of corresponding mean level of the field.

The field condition after the operation of Pant-ICAR subsoiler-cum-differential rate fertilizer applicator is shown in **Fig. 4a**. The digital representation of field surface level before and after operation of the equipment is shown in **Fig. 4b**. Initially the mean level of field was found to be 1.10 m but after the subsoiler operation it was

a) Equipment in operation



b) Graphical representation of surface level disturbance after the operation of equipment



c) Variation in field level with respect to mean elevation

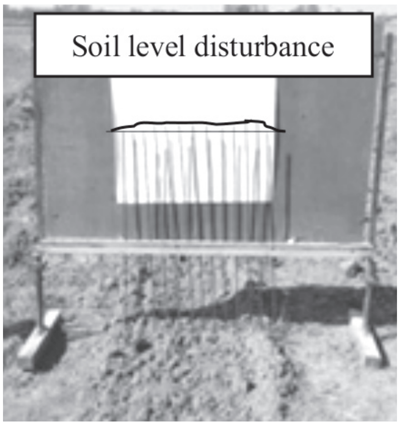
Fig. 4 Details of Pant-ICAR subsoiler-cum-differential rate fertilizer applicator operated field

1.19 m. The subsoiler produced the maximum undulated surface due to maximum upheaval of soil by its leg after every 1.5 m spacing. It is clear that the final (S_x = 0.178, S_y = 0.04) slope of the field after subsoiling operation did not differ much from its initial (S_x = 0.167, S_y = 0.137) slope. The land surface smoothness index (LI) in case of subsoiler was found to be 0.0233 and 0.0362 for initial and final field conditions, respectively. Further, the land surface smoothness index (LUC) for subsoiler operation was 0.980 and 0.972 for initial and final field conditions, respectively. It is evident that the variation in the field surface after operation (**Fig. 4c**) was more than before the operation of equipment in respect of corresponding mean level of the field.

The field surface condition after the operation of Pant-ICAR deep soil volume soil loosener-cum-fertilizer applicator is shown in **Fig. 5 (a)** and the soil surface level after a single pass is shown in **Fig. 5 (b)**. The digital representation of field surface level before and after the operation of equipment is illustrated in **Fig. 5 (c)**. Initially the mean field level was found to be 1.12 m, which changed to 1.16 m after one pass of equipment and 1.18 m after cross pass of equipment. It is clear that the slope (S_x = 0.292, S_y = 0.080) after one pass and slope (S_x = 0.298, S_y = 0.06) after cross pass did not differ much from the initial slope (S_x = 0.294, S_y = 0.099). The land surface smoothness index (LI) was found to be 0.0270, 0.0278 and 0.0286 for initial, one pass and cross pass, respectively. Moreover, the land surface smoothness index (LUC) was found as, 0.9758, 0.976 and 0.9758 for initial one pass and cross pass of field, respectively. The variations in the field surface after operation (**Fig. 5d**) and cross operation were almost same to that of before operation in respect of corresponding mean level of the field.

It is clear from **Fig. 6** that the maximum surface level upheaval was produced by the disk plough whereas the subsoiler produced the maximum undulated surface due to maximum upheaval of soil by its leg after every 1.5 m spacing. The difference in mean elevation of the field before and after the operation of equipment was found to be maximum with disk plough and minimum for Pant-ICAR deep soil volume loosener-cum-fertilizer ap-

a) Level of the field after operation of equipment



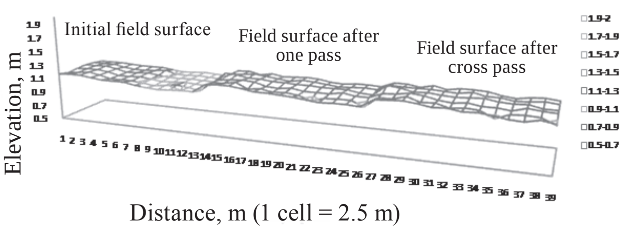
b) Soil surface after operation (one pass)

plicator. The difference in slope of the field before and after operation in x and y directions was found minimum for newly developed equipment and maximum for the subsoiler. Further, the levelling index was found to change minimum in case of disk plough operation, little higher in case of newly developed equipment operation and maximum for subsoiler operation. Another index for smoothness i.e. LUC was found best for the developed equipment followed by disk plough and subsoiler, respectively.

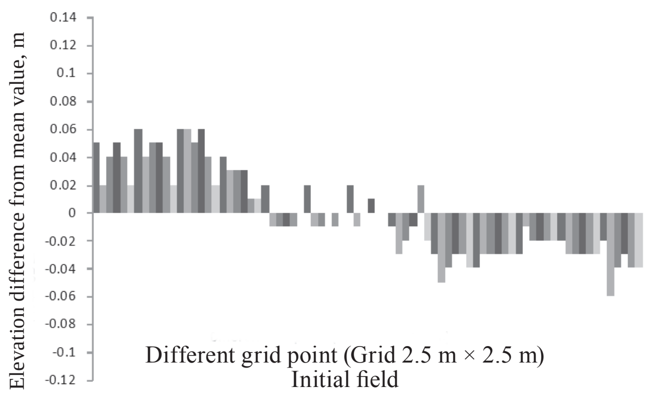
The developed equipment produced a levelled field surface in comparison to other equipment after operation because it cuts, lifts and leaves the soil almost at the same place without inversion. The clod crushers mounted behind the main V-shaped tines further pulverize and consolidate the soil, resulting in completely levelled field surface.

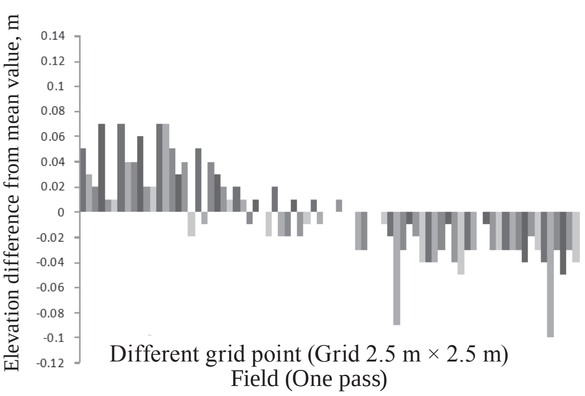
Conclusions

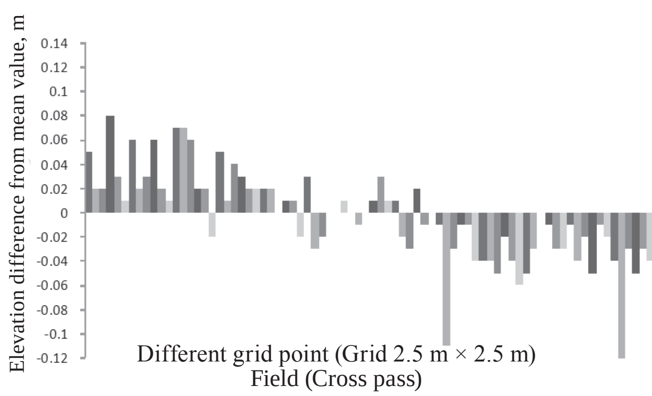
The comparison of field surface level after operation of developed equipment along with two bottom disc plough and Pant-ICAR subsoiler-cum-differential rate fertilizer applicator revealed maximum elevation difference with disk plough followed by subsoiler and deep soil volume loosener-cum-fertilizer applicator. The land profile after the operation of the developed implement was quite flat compared to the ploughed field by other two equipments. Therefore, the developed equipment can be used for cultivation in laser levelled field for maintaining the level of field and sustaining the benefits of laser leveling over a long period. In addition to this, it can simultaneously perform deep soil volume loosening, off-barring operation in sugarcane ratoon, fertilizer application in deeper soil profile, pulverization of clods and intercultural operation in



c) Graphical representation of surface level disturbance after operation of equipment







d) Variation in field level with respect to mean elevation

Fig. 5 Details of Pant-ICAR deep soil volume loosener-cum-fertilizer applicator operated field

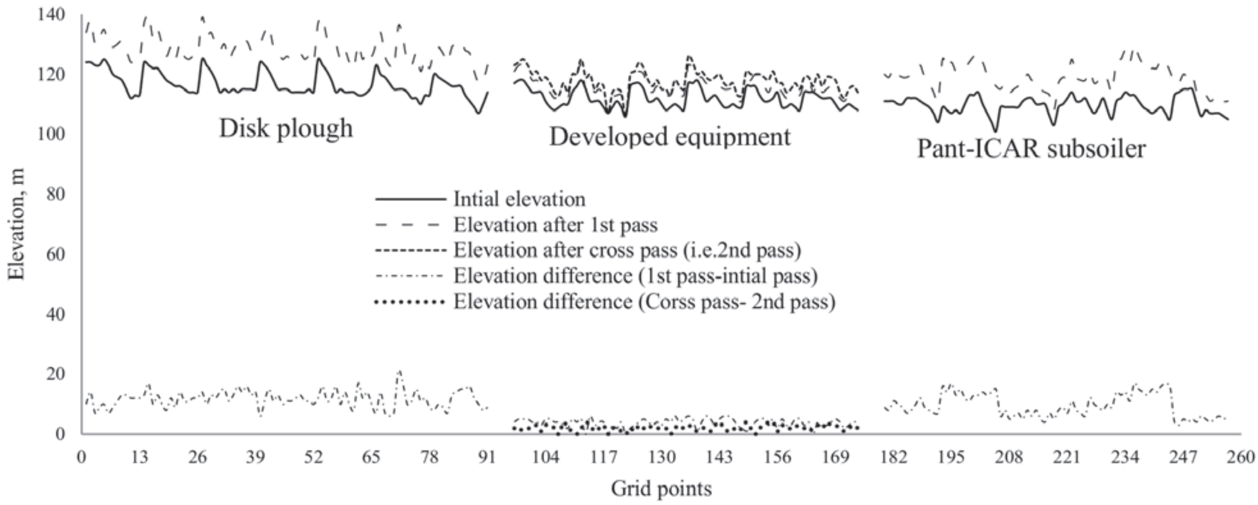


Fig. 6 Comparison of elevation difference in field level before and after the operation of different equipment

row crops. The control traffic based design concept reduces re-compaction of tilled field and higher level of levelling of field which ultimately saves fuel and time.

Acknowledgments

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REFERENCES

Ahmad, B., S. B. Kholhar, H. Badar. 2001. Economics of laser land levelling in district Faisalabad. Pakistan Journal of Applied Sciences, 1(3): 409-412.

Chaudhuri, D., S. K. Mathankar, V. V. Singh, N. A. Shirsat, U. C. Dubey. 2007. Performance evaluation of laser guided land leveller in vertisols of central India. Journal of Agricultural Engineering, 44(2) (source: Indian Journal. com).http://www.indianjournals.com/ijor.aspx?target=ijor:joae&volume=44&issue=2&article=001

Jat, M. L., S. K. Sharma, K. K. Singh. 2006. Conservation agriculture for sustainable farming in India. Paper presented in Winter School Training at the Department of Agronomy, TNAU, Coimbatore.

Kumar, M. 2010. Design, development and performance evaluation of deep soil volume loosener-cum-fertilizer applicator and its response on sugarcane ratoons. Unpublished Ph.D. Thesis, G. B. Pant University of Agriculture and Technology, Pantnagar, Pp1-249.

Kumar, M. and T. C. Thakur. 2011. Design and Development of Deep Soil Volume Loosener-cum-Fertilizer Applicator. Under Communication with JAE.Pp 1-13, Fig. s 1-10, Tables 1-3.

RWC. 2009. Rice-wheat consortium for the Indo-Gangetic plains. http://www.rice-wheat consortium welcome.htm

Thakur, T. C. 2008. Soil compaction and response of sugarcane to subsoiling. Proceedings of national seminar on varietal planning for improving productivity and sugar recovery in sugarcane. G.B.P.U. A.T., Pantnagar, India. Pp 88-97.

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Design, Development and Evaluation of Small Scale Maize Kernel Degermer

by
Sukreeti Sharma
sharmasukreeti@gmail.com

Gagandeep Kaur Sidhu

M. S. Alam

Department of Processing and Food Engineering
Punjab Agricultural University, Ludhiana-141004
INDIA

Abstract

Maize is considered a promising option for diversifying agriculture in upland areas of India. The laboratory size maize degermer was designed, developed and fabricated in the engineering workshop for separation of germ without crushing it. An AUTOCAD was used for the design of maize kernel degermer in 3D-model, based on the design considerations like durability, strength, corrosiveness and machinability at low cost to ease the construction work and maintenance. The machine component comprised of horizontal rotating shaft having wooden pieces fixed at regular intervals providing desired shearing and rubbing action for the separation of germ due to density difference. A one hp, 3-phase electric motor was used to rotate the shaft at an output speed of 7, 14 and 21 rpm. The maize kernels were pretreated (steeping at 50 ±2°C for 72 hrs.) to a specific gravity of 7.5-9° Baume prior to feeding into the machine. The machine was evaluated at 7, 14 and 21 rpm for various responses i.e. efficiency, recovery, power consumption, uniformity index, fineness modulus and average particle size of separated germ. The machine optimum capacity was found to be 20 kg/h with an investment of Rs 35,000 (≈ $520.00 US) on its fabrication. Results showed that the machine works efficiently at 7 rpm with germ separation efficiency of 71.6%, germ recovery of 7.16% and power consumption of 0.545 kW. The maximum germ retained (82.29%) was on sieve size of 1.4 mm witnessing average particle size of 1.85 ±0.01 mm with uniformity index of 1.465:8.514:0.017.

Keywords: Maize germ, maize kernel degermer design, steeping, separation efficiency

Introduction

Degermination of maize is an essential and required unit operation for the extraction of corn oil through a combination of chemical and mechanical processes. Maize (Zea Mays) has been referred to as "the cereal of the future" due to its high nutritional value and the wide utilization of its products and by products (Milazzo, 1986). Worldwide, 60-70% of maize production is used domestically as livestock feed, and the remaining 30-40% is used for production of items for human consumption (Anon, 2013). By cultivating maize, farmers can protect the worsening quality of soil, save 90% of water and 70% of power as compared to paddy and earn far more than they earn through paddy and wheat (Anon, 2014).

Maize is generally processed by two distinct processes, namely wet milling and dry milling. The separation of corn constituents through dry milling is not as ideal as in wet

Nomenclature

D	Diameter of shaft (mm)
K_B	Combined shock and fatigue factor applied to bending moment
K_T	Combined shock and fatigue factor applied to torsional moment
S_s	the allowable stress= 47 MN/m^3
M_B	Maximum bending moment (Nm)
M_T	Maximum torsional moment (Nm)
dF_D	Drag force
ρ	Density of mixture
C_d	Drag coefficient = 1.05
x	Width of wooden piece
ω	Angular velocity
L	Length of wooden piece
t	Thickness of wooden piece
D_1	Diameter of driver pulley
D_2	Diameter of driven pulley
C	Central distance between driving and driven pulley
T_1	Tension of the belt on the tight side
T_2	Tension of the belt on the slack side
k	Coefficient of friction between the belt and the pulley
θ	Angle of contact between the pulleys
V	Velocity of the belt (m/s)
P	Power transmitted by belt (watts)

milling. Kent and Ronald (2005) reported that the germ obtained from dry milling has lower oil content (26% db) due to attachment of small amounts of pericarp and endosperm than germ from wet milling (35 to 45% db). The wet milling process involves the use of different steeping procedures (Anderson *et al*., 1961; Roushdi *et al*., 1979; Krochta *et al*., 1981; Hassanean and Abdel-Wahed 1986; Caransa *et al*., 1988; Steinke and Johnson, 1991; Steinke *et al*., 1991; Fox and Eckhoff, 1993; Shandera *et al*., 1995; Biss and Cogan, 1996) which play significant role in the determination of germ separation efficiency. Cox *et al*. (1944) reported that when corn is steeped for 48-50 h in SO_2 aqueous solution, disintegration of protein matrix occurs that encapsulates the starch granules in the endosperm and removes soluble, mainly from the germ, to increase germ recovery. Due to such operating conditions maximum germ separation and lactic acid production is achieved (Watson *et al*., 1955). The presence of lactic acid in steeping water makes the cell walls easier to break, hence better simulating the industrial steeping process at laboratory level (Mac Masters, 1962 and Echoff *et al*., 1993).

A degerminating process involves the separation of germ from grain kernels without damaging it. Maize germ constitutes 5-14% of the weight of kernel and is a good source of key nutrients especially 18-41% of oil (Johnston *et al*., 2005 and MPOC 2008). The available degerminating equipment for dry milling i.e Beall degerminator, granulator and disk mills reffered as the attrition mills have been used for germ separation (Brekke and Weinecke, 1964). In the beall type degerminator which is extensively used in North America, the grain kernels are rubbed more against one another than against the metal of the machine. As a consequence, even though relatively good separation of the germ is achieved, a large quantity of fines is generated and the fines are high in fat content since they contain much germ. Impact type degerminators are used where finished products having high fat content are acceptable and where smaller granulation of the finished products is involved but the separation of the germ achieved with impact machines is poor and for this reason they have not been used much. Also, the germ separation through hydro-cyclones adds cost to the wet milling method. As a result, the separation of germ obtained from endosperm is either inefficient or costlier process.

Machines made in the developing country, need to be relatively simple, low cost, and easy to operate. Therefore, the overall objective of this study was to design, develop and evaluate the performance of simple and compact equipment for separation of germ from maize by using appropriate steeping procedure.

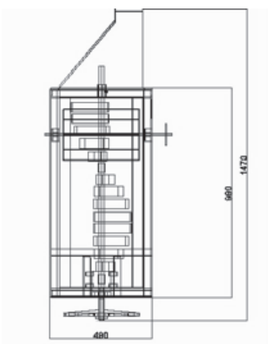
Materials and Methods

Description of Machine Components

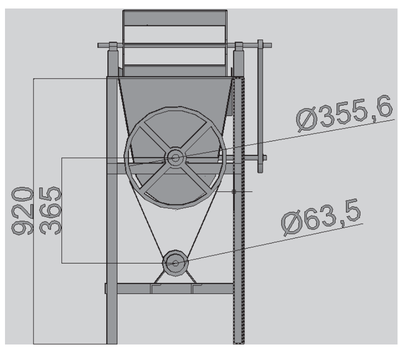
The maize kernel degermer machine consists of five major components: frame, degermer unit, skimmer, germ discharge spout and slurry discharge spout (**Fig. 1**). The main frame supports the entire weight of the machine. The material is directly fed into the U-shape trough. The trough is fabricated from 2 mm thick mild steel sheet which has carbon ranging from 0.10-0.20%. The trough consists of wooden pieces on horizontal shaft driven through a belt drive by a 1 hp, 1,500 rpm three-phase electric motor. The wooden pieces are arranged in spiral form (like a screw conveyor) with uniform spacing within the trough. The skimmer is mounted at the top end of hopper to skim off the germ through germ discharge spout. The remaining slurry is collected through discharge spout with 40 mm diameter installed at one lower end of the trough.

Design Considerations

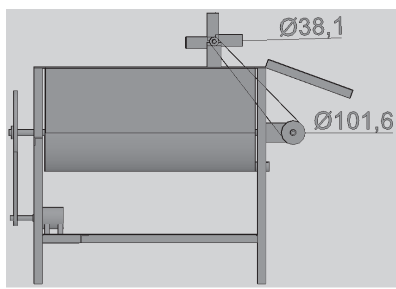
The mechanics of maize kernel degermer include shearing and forward action. The design analysis was carried out with a view to evaluate the design parameters, strength and size of materials for consideration in the selection of the various machine parts in order to avoid failure by excessive yielding and fatigue during the required working life of the machine. The material of adequate strength and stability



a) Top view



b) Front view



c) Side view

Fig. 1 CAD drawings of maize kernel degermer was used for fabrication i.e. mild steel. The machine was designed to process about 300 kg of maize per twelve-hour shift. The materials that are locally available were used in the fabrication of the machine components. Consideration was given to the cost of items and materials of fabrication with the ultimate aim of utilizing the cheapest available materials, yet satisfying all strength requirements.

Design of Maize Kernel Degermer Machine

The machine was conceived as a low cost and easy to fabricate device for separating germ from whole maize kernel. Basic considerations were given to the design for the size and capacity of components that includes belt and pulley system, the speed of operation, machine power rating of shaft, shaft carrying wooden pieces and the bearing.

The Main Frame

The frame of 990 × 475 × 920 mm was chosen to support the entire weight by the machine. The total weight carried by the machine is weight of U-shape trough, weight of shaft carrying wooden pieces, skimmer, bearings and pulleys. The two design factors considered in determining the material required for the frame are weight and strength. The angle steel bar of 35 × 35 × 5 mm thickness was used to give the required rigidity.

The Degermer Unit

The degermer unit consists of U-shape trough with wooden pieces fixed on horizontal shaft. The unit was to provide effective means of removal of germ from the whole maize kernel. This operation was achieved through shearing and forward actions. The wooden pieces create the shearing effect on the treated maize kernel and the clearance between the horizontal shaft and the attached wooden pieces creates the desired rubbing action for the separation of germ due to density difference. The degermer unit was designed on the basis of angle of inclination of trough, shaft diameter and drag force due to wooden pieces.

Angle of Inclination

The trough design is based on the angle of repose. Angle of repose is the maximum slope at which the heap of any loose or fragmented bulk material will stand without sliding. It is also called as angle of friction of rest (Eugene and Theodre, 1986). The recommended angle of inclination for agricultural materials is 8° or more, than the angle of repose. The angle of repose of maize is 27° (Richey *et al*., 1982). Further, the u-shaped trough with 895 × 405 mm dimensions was decided to hold about 30 kg of treated maize at a time.

Therefore, from the right angled triangle of **Fig. 2**.

$x = [(50)^2 - (2.5)^2]^{0.5} = 49.93$ mm

$Tan\ Ø = 280/49.93 = 5.60$

$Ø = 79.8°$

Design of shaft: A shaft is a rotating or stationary member, usually of circular cross-section having such elements as gears, pulleys and other power transmission units mounted on it (Shigley 1986). The shaft of this machine has each wooden piece of 175 × 45 × 25 mm dimension, fixed at 15 mm distance from each other and a pulley mounted on it. It is supported on bearings. Shaft design consists primarily of the determination of the correct shaft diameter to ensure safety strength and rigidity when the shaft is transmitting power under various bending and torsion conditions. The length of the shaft has been pre-determined at 1,200 mm.

Calculation of vertical loading (Fig. 3)

The vertical load on shaft is mainly due to pulley weight, bevel gear, bearings and wooden pieces fixed on shaft itself.

Therefore, vertical force due to pulley,

$V_p = T_1 \cos\beta + T_2 \cos\beta = 446.76\ N$

Here,

β = *angle of wrap in pulley and belt* = 9.06°

Further, drag produced by wooden pieces will affect the force requirement of bearings. Hence drag force produced by wooden pieces can be calculated by the relationship given by (Cengel and Cimbala, 2013). Hence integrating from 0 to width of wooden piece;

$dF_D = \int_0^{0.175} \rho\, C_d\, t\, x^2\, \omega^2\, dx$

Moment due to wooden pieces,

$dM = \int_0^{0.175} x\, dF_D \times 15 = 23.03\ Nm$

Also, vertical force due to bevel gear,

V_B = *(Torque required by bevel gear) / (radius of bevel gear)* = 55.53 N

Taking moment about B,

$R_A \times 990 = 446.762 \times 1095 + 55.353 \times 105$

$R_A = 500.01\ N$

Also,

$R_A + R_B = 446.762 - 55.353 = 391.40\ N$

Therefore,

$R_B = -108.6\ N$

Calculation of horizontal loading

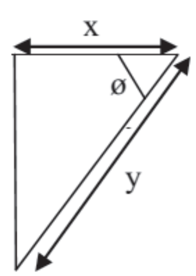


Fig. 2 Right angle triangle (trough)

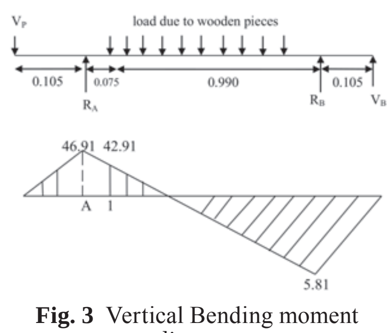


Fig. 3 Vertical Bending moment diagram

(Fig. 4)

The horizontal force on shaft is due to wooden pieces and bearings.

Therefore,

horizontal force $= T_1 \sin\beta - T_2 \sin\beta = 23.55$ N

Now, Taking moment about B,

$R_A \times 990 = 23.558 \times 1095$

$R_A = 26.08$

Also,

$R_A + R_B = 23.55$

Therefore,

$R_B = -2.53$

Calculation of maximum bending moment (M_B) of shaft:

$M_B^2 = M_{BV}^2 + M_{BH}^2$

Calculation of torsional moment (M_T) of shaft:

$M_T = P/2\pi N$

Determination of Shaft Diameter

The required diameter for solid shaft having combined bending and torsional loads is obtained from ASME code equation (Hall *et al*., 1983):

$D^3 = 16/\pi Ss \times \sqrt{(K_B MB)^2 + (K_T M_T)^2)}$

Where,

D = diameter of shaft

$Ss = 47\ MN/m^3$

$K_t = 1$ *and* $Kb = 1.5$ *for gradually applied loads*

Design of the Pulley and Belt Drive

The nominal pitch length of the electric motor to degermer unit was determined in order to know the actual belt size that is required to transfer power from the motor to the degermer unit. The design and selection of appropriate power requirement for the rotation of the shaft in degermer unit was selected based on the speed of the driving motor, speed reduction ratio, centre to centre distance between the driving pulley and driven pulley at the condition under which the degerming action must take place. An electric three phase motor with 1,500 rev/min was used with a pulley diameter of 63.5 mm. A low speed of shaft rotation is expected during germ separation operation since the degerming section must be operated within a fluid medium. The length of belt was determined by using equation given by (Avallone and Baumeister 1997):

$L = \pi/2\ (D_1 + D_2) + [(D_1 - D_2)^2 / 4C] + 2C$

The angle of contact between the driver and driven pulley was determined in order to know the tensions between the belt and the pulleys. The tensions on the belt is determined so as to ascertain the power transmitted by the driver pulley to the driven pulley, therefore the tension on the two sides of the open belt was calculated from the formula given by (Gupta and Khurmi 2005):

$T_1 / T_2 = e^{k\theta}$

The power transmitted by an open belt drive is given by

$P = (T_1 - T_2)V$

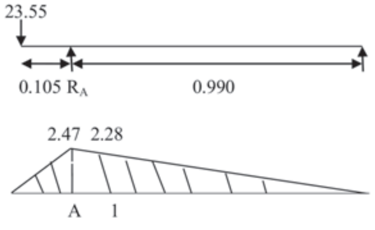


Fig. 4 Horizontal Bending moment diagram

Fabrication Process

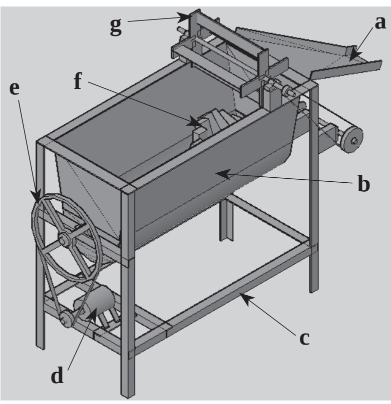
The construction processes were carried out in the workshop of local manufacturer. The basic manufacturing processes which include cutting, primary shaping and joining processes were undertaken. The U-shape trough was made from 2 mm thick mild steel sheet. The outer trough was marked out consisting of 990 × 475 mm dimensions and 895 × 495 mm for inner trough. A 25 × 2500 mm mild steel shaft was cut and turned on a lathe machine to serve as the main shaft that carries the wooden pieces, pulley and bearings. The 15 wooden pieces of 175 × 45 × 25 mm dimension each were cut and fastened firmly using 2 bolts and nuts per piece. The skimmer of 50 × 5 mm dimension was fixed at top end of machine to skim off the germ through triangular discharge spout. The 40 mm hole serves as the slurry—draining outlet. Slurry draining outlet pipe, 40 mm diameter, 200 mm long and 3 mm thickness was welded to the 40 mm at the base plate. The end of the pipe is fitted with a gate valve which serves as an opening for the discharge of remaining slurry from the underflow. The supporting components consist of the main frame and electric motor base. An electric DC three phase motor was used as the prime mover. The dc motor is mounted on the electric base support and fastened firmly using four bolts and nuts.

Sample Preparation

The maize kernels, having 96% purity were used for experiment. After cleaning, steeping of maize was done to soften the kernels, hence disintegrating the protein matrix that encapsulates the starch granules in the endosperm and removing soluble, mainly from the germ, to increase germ recovery. Three step steeping process was followed. In the first step, one kg of maize per 2 litres of distilled water was steeped with a solution composed of 30 ml of SO_2 and 12 ml of lactic acid at a temperature of about 55°C. After 24 hours, the initial steeping medium was discarded and replaced with fresh solution at same levels of SO_2, lactic acid and distilled water for another 24 hours. In the final step, same procedure was followed for another 24 hours. Further, the two step degermination process was done to decrease germ damage by doing coarse grinding. The objective of the first grind was to make softened maize pulpy so that separation of germ becomes easy in the second step of maize degermination. After the first grind, germ was separated from the rest of the slurry in the developed maize kernel degermer based on density difference, with the lighter germ floating in the overflow and heavier material settling in the underflow. A specific gravity range of 7.5-9° Baume of the slurry was made using 90 gram of salt in 1 litre of water for germ separation (Anderson 1963). The floating germ was skimmed by the skimmer from the overflow and the material from the underflow was drained, dried and milled into flour. Sample of weight 20 kg was fed into the machine and retention time was recorded.

Performance Evaluation of Maize Kernel Degermer

The maize kernel degermer machine was assembled after its various components were fabricated and evaluated for operation performance and separation process performance. The photograph of the fabricated machine is shown in **Fig. 5**. The maize kernel degermer machine was operated at three different operating speeds of the degermer unit. On the preliminary trial basis the shaft was fitted with three different pulleys to generate three different levels of the operating speed of 7, 14 and 21 rpm. A tachometer was used to determine the rotating shaft speed. The electric motor was connected directly to the shaft through a flat belt. A 1 hp, 3 phase electric motor was used for this. This was undertaken to ascertain the durability of the machine components. The performance of the machine at loaded condition was investigated for about an hour for each of the combination of the operating conditions.



a. Germ discharge spout
b. U-shaped trough
c. Main frame
d. DC motor
e. Pulley and belt drive
f. Wooden pieces mounted on shaft
g. Skimmer

Fig. 5 Isometric view of maize kernel degermer

After separation of germ at different speeds sieve analysis was done using macro rotap machine to determine the fineness modulus, uniformity index and average particle size as shown in **Table 1**. Calculation of fineness modulus, uniformity index and average particle size is described below:

Fineness modulus = Total of fineness number / 100

Uniformity index = x / 10 : y / 10 : z / 10

Average particle size = $0.0104 \times 2^{F.M.}$ *mm*

Where,

x = sum of coarser sized particle

y = sum of medium sized particle

z = sum of fine sized particle

F.M. = fineness modulus

Process performance of the machine was undertaken to test the process performance of germ recovery efficiency, germ separation efficiency and power consumption. The economic analysis of the developed maize kernel degermer has been done to estimate the feasibility of the machine. The process performance was evaluated on the basis of the following indices:

Germ separation efficiency (ηg) = Actual weight of germ obtained / Theoretical germ content in whole maize

Germ recovery (%) = weight of germ obtained in kg / weight of input sample in kg

Power consumption = $2\pi NT / (60 \times \eta)$

Where

N =Motor rpm at fixed rpm

T = Torque exerted by motor in N-m

η = Motor efficiency = 75% (Assumption)

Data obtained from the tests were subjected to analysis of variance (ANOVA) and test of significance using SPSS.

Results and Discussions

Results of the analyses carried out indicate that there were significant differences ($p \leq 0.05$) in the magnitude of power consumption, germ separation efficiency and germ recovery at all speeds tested. The effect of rotational speed on selected parameters i.e. power consumption, germ recovery and germ separation efficiency are discussed below:

Effect of Rotational Speed on Power Consumption

ANOVA given in **Table 2** reveals that the effect of speed on power consumption was statistically significant at 5% level of significance.

Table 1 ANOVA to study the effect of different speeds on power consumption, germ recovery and germ separation efficiency

Paramete	Source	Sum of Squares	Degrees of freedom	Mean Square	FCalculated
Germ recovery	Between groups	1.495	2	0.748	43.108*
	Within groups	0.104	6	0.017	
	Total	1.599	8		
Power consumption	Between groups	220.383	2	110.191	19.734*
	Within groups	33.503	6	5.584	
	Total	253.886	8		
Germ separation	Between groups	149.941	2	74.971	42.947*
	Within groups	10.474	6	1.746	
	Total	160.415	8		

*Significant at 5% level

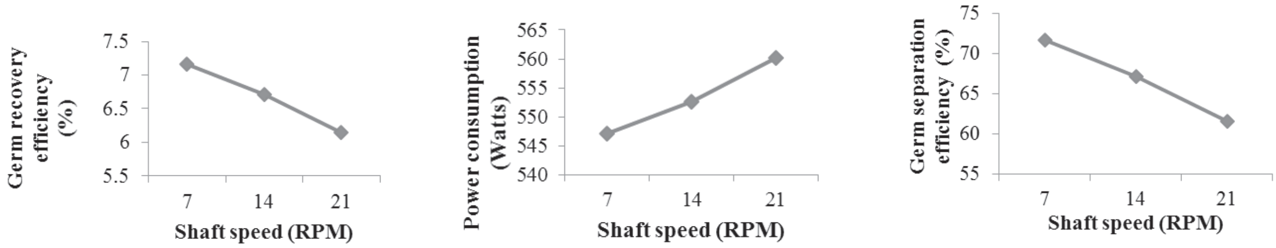


Fig. 6 Effect of rotational speed on selected parameters

It can be observed from the **Fig. 6** that the power consumption increased with the increase in shaft speed. The power consumption was lowest at 7 rpm (548 W) and highest at 21 rpm (560 W). This is because at higher peripheral speeds, there is greater compression between wooden pieces and the fed material during separation process. This result was supported by (Sudajan *et al*., 2002 and Sharma, 1994).

Effect of Rotational Speed on Germ Recovery

It was clear from the **Fig. 6** that with the increase in shaft speed, the germ recovery decreased. The germ recovery was found to be significant at 5% level of significance (**Table 2**). As the shaft speed increased, the germ recovery decreased between 7.25% and 6.04% respectively. The maximum germ recovery was found at the shaft speed of 7 rpm i.e. 7.16% while minimum at 21 rpm (6.16%). This decrease in germ recovery clearly indicated that a low speed of shaft rotation is expected during germ separation operation since the degerming section was operated within a fluid medium. Similar results were studied by (Olaoye, 2011).

Effect of rotational speed on germ separation efficiency: The germ separation efficiency was achieved at three different speeds of 7, 14 and 21 rpm. The germ was easily separated on density basis under the influence of wooden pieces attached on rotating shaft. It was found from the **Fig. 6** that the germ separation efficiency decreased with the increase in shaft speed. The effect of shaft speed was found significant at 5% level of significance (**Table 2**). At the shaft speed of 7, 14 and 21 rpm, the germ separation efficiency decreased between 72.5% and 60.4% respectively. The maximum germ was separated at the shaft speed of 7 rpm i.e. 71.6% while minimum at 21 rpm (61.5%).

Conclusion

The maize kernel degermer has been designed, developed and fabricated keeping in mind the difficulties faced during the separation of germ from hard kernel (**Fig. 7**). The developed machine works efficiently at 7 rpm with germ separation efficiency of 71.6%, germ recovery of 7.16% and power consumption of 0.545 kW. The maneuverability of the machine is quite good and the handling is quite simple. The germ can be separated and collected simultaneously. This machine can be used at small scale level for oil extraction from obtained germ and the byproduct i.e. degermed flour can be beneficial as it has better keeping qualities than whole maize flour. Thus, this machine can be very helpful to small scale farmers and atta chakis.

REFERENCES

Anderson, R. A. 1963. Wet-milling properties of grains: bench-scale study. Cereal Science 8, 190-95 221.

Anonymous. 2014. India maize summit 2014. Online source culled from (http://www.ficci.com /spdocument/20386/India-Maize-2014_v2.pdf).

Anonymous. 2013. Punjab produces record wheat rice and maize Crop (http://www.agricorner.com).

Avallone, E. A. and T. Baumeister. 1997. Mark's Standard Hand book

Table 2 Performance evaluation of maize degermer

Parameters	Speed of maize degermer (7 rpm)	(14 rpm)	(21 rpm)
Capacity/batch (kg/hr)	20	20	20
Power Consumption (KW)	0.548 ±0.002	0.552 ±0.002	0.56 ±0.002
Germ recovery (%)	7.1 ±0.15	6.71 ±0.04	6.1 ±0.14
Fineness modulus	1.00	0.95	0.90
Average particle size (mm)	1.843	1.821	1.801
Uniformity Index (Coarser: Medium: Fine)	1.465:8.514:0.017	1.720:8.251:0.027	1.760:7.687:0.025
Germ separation efficiency	71 ±1.5	67.1 ±0.4	61 ±1.4

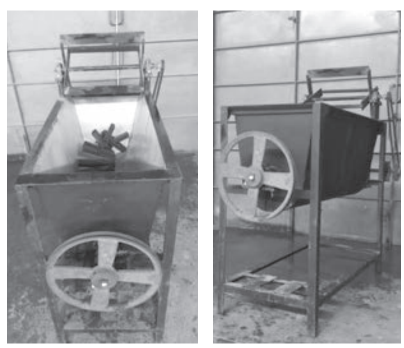


Fig. 7 Fabricated degermer machine

for Mechanical Engineers (Eds,) (pp 132-37). McGraw Hill International: Mechanical Engineering Series.
Barnwal, P., Kore, P. and A. Sharma. 2013. Assessment of Storage Stability of Whole and degermed maize flour Journal of Food Safety, 15: 83-87.
Biss, R. and U. Cogan. 1996. Sulfur dioxide in acid environment facilitates corn steeping. Cereal Chemistry, 73: 40-44.
Brekke, O. L. and L. A. Weinecke. 1964. Corn dry milling: A comparative evaluation of commercial degerminator samples. Cereal Chemistry, 41: 321-328.
Caransa, A., M. Simell, A. Lehmussaari, M Vaara and T. Vaara. 1988. A novel enzyme application for corn wet milling. Starch/Starke 40: 409-411.
Cengel, Y. A. and J. M. Cimbala. 2013. Fluid Mechanics: Fundamentals and Applications (Eds.), McGraw-Hill.
Cox, M. J., M. M. MacMasters and G. E. Hilbert. 1944. Effect of sulfurous acid steep in corn wet milling. Cereal Chemistry, 21: 447-465.
Eckhoff, S. R., K. D. Rausch, E. J. Fox, C. C. Tso, X. Wu, Z. Pan and P. Buriak. 1993. A laboratory wet milling procedure to increase reproducibility and accuracy of product yields. Cereal Chemistry, 70: 723-727.
Eugene, A. A. and B. Theodore. 1986. Standard Handbook for Mechanical Engineering. McGraw Hill Book Company, pp 8-57
Fox, E. J. and S. R. Eckhoff. 1993. Wet milling of soft-endosperm, high-lysine corn using short steep times. Cereal Chemistry, 70: 402-404.
Gupta, J. K. and R. S. Khurmi. 2005. Machine design (Eds.), (pp. 434-960). S. Chand and Company Ltd, Ram Nagar, New Delhi - 110055.
Hall, A. S., A. R. Hollowenko and H. G. Laugh. 1983. Theory and Problems of Machine Design Schaum's Outline Series. McGraw-Hill International Book Company. Singapore, pp 113-130.
Hassanean, A. and A. Abdel-Wahed. 1986. A new method to short the steeping period of corn grains. Starch/Starke 38: 417-419.
Johnston, D. B., A. J. McAloon, R. A. Moreau, K. B. Hicks and V. Singh. 2005. Composition and economic comparison of germ fractions derived from modified corn processing technologies. Journal of the American Oil Chemist Society, 82: 603-608.
Krochta, J. M., K. T. Look. and L. G. Wong. 1981. Modification of corn wet-milling steeping conditions to reduce energy consumption. Journal of Food Processing and Preservation, 5: 39-47.
MacMasters, M. M. 1962. Important aspects of kernel structure. Trans ASAE, 25: 247-249.
Malaysian Palm Oil Council (MPOC). 2008. Global oils and fat business magazine, 5: 33-34.
Millazo, A. 1986. Corn milling profile. Association of Operative Millers Bull, 4651-4662.
Olaoye, J. O. 2011. Development of small scale equipment for depulpping locust bean seeds. International Journal of Engineering and Technology, 11(6): 145-54.
Richey, C. B., L. Johnson and C. W. Hall. 1982. Agricultural Engineering Handbook McGraw Hill Book Company, pp 650.
Roushdi, M., Y. Ghali and A. Hassanean. 1979. Factors improving the steeping process of corn grains. I. Effect of steeping process, artificial drying, scratching and storage. Starch/Starke 31: 78-81.
Shandera, D. L., A. M. Parkhurst and D. S. Jackson. 1995. Interactions of sulfur dioxide, lactic acid, and temperature during simulated corn wet milling. Cereal Chemistry, 72: 371-378.
Sharma, R. 1994. Study on selected design and operational parameters on the performance of serrated tooth type wheat threshing system. M.Tech. Thesis, Punjab Agricultural University, Ludhiana, India.
Shigley, J. E. 1986. Mechanical engineering design (Eds,) S I (metric) McGraw-Hill, New York, NY, USA.
Steinke, J. D. and L. A. Johnson. 1991. Steeping maize in the presence of multiple enzymes. I. Static batchwise steeping. Cereal Chemistry, 68: 7-12
Steinke, J. D., L. A. Johnson and C. Wang. 1991. Steeping maize in the presence of multiple enzymes. II. Continuous countercurrent steeping. Cereal Chemistry, 68: 12-17.
Sudajan, S., V. M. Salokhe and K. Triratanasirichai. 2002. Effect of type off drum, drum speed on feed rate on sunflower threshing. Biosystems Engineering, 83: 413-421.
Watson, S. A., Y. Hirata and C. B. Williams. 1955. A study of the lactic acid fermentation in commercial corn steeping. Cereal Chemistry, 32: 382-394.
Watson, S. A. 1991. Structure and composition. In S A Watson and P E Ramstad (ed) Corn: Chemistry and technology. St Paul, MN: American Association of Cereal Chemists, pp 53-82

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Design and Development of Tractor Operated Carrot Digger

by
Naresh
Assistant Agricultural Engineer
Dept. of Farm Machinery and Power Engineering
College of Agricultural Engineering & Technology
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana)
INDIA
sihag.hau@gmail.com

Vijaya Rani
Associate Professor
Dept. of Farm Machinery and Power Engineering
College of Agricultural Engineering & Technology
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana)
INDIA

Mukesh Jain
Assistant Professor
Dept. of Farm Machinery and Power Engineering
College of Agricultural Engineering & Technology
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana)
INDIA

Anil Kumar
Assistant Professor
Dept. of Farm Machinery and Power Engineering
College of Agricultural Engineering & Technology
Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana)
INDIA

Narender
Ph.D Scholar
Jawaharlal Nehru Agricultural University
Jabalpur (Madhya Pradesh)
INDIA

Abstract

In India, the cultivated area of carrot in 2013-14 was 62.41 thousand ha with production of 1,073.71 thousand tonnes and in Haryana, it was 17.86 thousand ha with production of 276.81 thousand tonnes. Harvesting is a most critical operation in carrot cultivation. It requires 350-450 man-hours per hectare for digging and pulling out carrots which is very costly, tedious and time consuming for farmers. Thus,study was undertaken to design and develop atractor operated carrot digger.The carrot digger consisted of digging unit, conveying unit, de-topping unit, collecting unit, main frame and power transmission system. Power was transmitted from tractor PTO to conveying and de-topping unit through chain sprocket system, universal shafts, gear box and bevel gears. The overall transmission ratio was 3.6. The transmission ratio of gear box and bevel gears was 1.8 and 2, respectively. A sweep type blade was used for digging the carrots and two triple pitch roller chains rotating in opposite direction were used to hold the leaves of carrots digged by the digging blade. De-topping unit was provided to cut the leaves of carrots by the two serrated discs rotating in opposite direction, provided below the conveying unit. Crateholding frame was provided for placing crates, used for collecting the de-topped carrots. Digging efficiency, picking efficiency and cutting efficiency of de-topping unit were 100%, 61.56% and 100%, respectively.Effective field capacity of the digger was 0.11 ha h^{-1} with field efficiency of 61.70%.The time and cost saving was found to be 94% and 63.36%, respectively with the developed carrot digger in comparison to manual method of harvesting.

Keywords: design, development, picking efficiency

Introduction

Vegetables play an important role in improving the economic condition of farmers. In production of vegetables, India ranks 2nd in the world, next to China and has achieved annual growth rate of 2.6 per cent in total vegetable production. It has been recorded during the last 10 years the average yield of vegetables in India is still lower than many Asian countries. This is due to the reason that the farmers use traditional tools and methods for cultivation of vegetable crops (Srivastava *et al*., 2009). There is lot of scope for increasing yield in most of the vegetables by growing high yielding varieties and adopting improved production technologies. Vegetables are highly perishable and need harvesting within a narrow time span, along with careful handling and proper storage before consumption or processing. Carrot (*DacusCarota L*.) belong to family *Umbelliferae*, has been cultivated for over 5,000 years. According to historians, this root vegetable has its origin in ancient Afghanistan. It was first cultivated for their aromatic leaves and seeds, not for the roots. Today, China is the leading producer of carrot in the world, followed by Russia and India ranks 14th in production of carrot, among more than 125 countries those cultivating this vegetable. The major carrot growing states in India are Uttar Pradesh, Assam, Karnataka, Andhra Pradesh, Punjab and Haryana. In India the cultivated area of carrot in 2013-14 was 62.41 thousand hectare with production of 1,073.71 thousand tonnes and in Haryana it was 17.86 thousand hectare& 276.81 thousand tonnes, respectively (www.nhb.gov.in).

Harvesting is the one of the critical operation for carrots.Carrots can be harvested when they are about a half inch in diameter. At this point of time, they are about finger size. Carrots of this size are 60 to 80 days old and from this point forward, carrots can be harvested at any stage. The older the carrots get, the woodier their texture will be and higher their natural sugar content.

In traditional method of harvesting, cost of cultivation is high and there are huge loses ranging between 30-40 per cent of the total produce due to damage caused during harvesting, handling, storage, transport and processing (Srivastava, 2000). For digging and pulling out one hectare area of carrots, on an average, about 350-450 man-hours are required which is very costly for farmers (Shirwal and Mani, 2014). The labour has to stoop forward while digging/pulling carrot from the bed and also during picking up. Stooping posture results in a lot of bio-mechanical stresses in the back and has higher energy consumption as compared to other working positions (Hagen *et al*., 1993). Continuous use of bare hands for pulling out carrots may cause bruises on hands leading to infection. Both stooping and squatting working positions are not ergonomic and therefore, carrot harvesting operation involves considerable human drudgery and discomfort. Due to this, the crop is cultivated on small scale and is one of the main bottlenecks in increasing the area under the carrot cultivation. The large scale diversification and reduction in cost of cultivation in carrot crop is only possible through mechanization of carrot sowing and digging process. So, there is a need to develop a carrot digging machine that can harvest the crop.

Mechanical harvesting of carrots is a real challenge. Although tractor-drawn elevator type potato diggers have been developed but biometric properties of carrot crop are entirely different from the potato. So a mechanized carrot harvester would be a one which could dig the carrot, detach soil and mixture, detop leaves and finally windrow the harvested crop which can be picked up manually or collected in collector. Generally, the root harvester consists of digging blade and a soil separator. The tool geometry of the blade effects the digging efficiency of the harvester and draft required. The tool geometry is governed by rake angle of the blade and friction angle of the soil (Agbetoye, 1998). Horia *et al*. (2008) developed a machine to harvest carrot crop and tested it at a constant speed of 0.3 m s^{-1}. It had three main components namely; pulling unit, transmission system and frame. This machine lifts the carrots with the help of pulling unit and cut the leaves. There was no digging and collecting unit. The optimum parameters of the carrot harvesting machine were belt speed 0.5 m s^{-1}, belt inclination angle 450 and height of branch catch 5 cm. The best root quality, root damage and lifting efficiency were 99.5%, 0.5% and 86.46%, respectively. Yulan *et al*. (2012) developed a digging-pulling style cassava harvester which looses the soil, pull out the cassava tuber to a certain height by a clamping conveyor, cut the leaves by cutter and windrow on the ground surface. Although efforts have been made to develop carrot digger, limited information is available on machine crop parameters influencing the design of various machine components of a carrot digger. Moreover, presently there is no carrot digger developed in India which is efficient in working. It was therefore, proposed to study various machine crop parameters and to develop a suitable carrot digger.

Materials and Methods

In traditional method of carrot harvesting, carrots are first digged with a spade and then pulled manually along with their leaves. Carrot harvester needs a digging device to loosen the soil around carrot,after the soil is loosened, the carrots need to be pulled out and transported to a certain height to separate from soil by conveying unit. The conveyed carrots then need to be detached from leaves with a detopper and finally carrots need to be collected. Thus the functional units of digger are namely a digging blade,conveying unit, de-topping unit, collecting unit, main frame and power transmission system (**Fig. 1**).

Digging Unit

A digging unit was required to dig the carrot.It was developed to loosen the soil around carrot and was positioned below the conveying unit. The loosened carrots are then caught by the conveying unit with carrot leaves and are conveyed to the de-topping unit.

A sweep type blade (**Fig. 2**) was used for efficient digging with minimum energy requirement (Khura *et al.*, 2011).

Blade Width

The width of blade was calculated as

Effective zone of sweep type blade is given by following formula

$Z_f = W + 2d \tan \phi S$ (Sharma and Mukesh, 2013)

Z_f = *Effective zone of blade, cm (56 cm, the bottom width of ridge)*

W = Width of blade, cm

d = Depth of operation, cm (Assumed 30 cm, on the basis of carrot depth)

ϕ_S = *Angle of internal friction which depend upon soil type (100-300), assumed 200*

Therefore, width of blade was calculated as

$56 = W + 2 \times 30 \times \tan 200$

$56 = W + 60 \times 0.36$

$W = 56 - 21.6$

$W = 34.4$

The blade was designed keeping W = 35 cm (**Fig. 2**)

Apex Angle of the Blade

The apex angle (2Θ) is the included angle formed between the two cutting edges.

$\Theta = 90° - \varphi w$

Where φw = angle of friction between soil and cutting edge and it range between 30° to 56°

Assuming (φw = 32°)

$\Theta = 90° - 32° = 58°$

Therefore, apex angle = 2 × 58° =116° (**Fig. 2**)

Design of Shank

The maximum draft on the tip of the sweep was considered as = 600 kgf, (Narender, 2012)

Taking factor of safety to be 2 and taking 2 times of maximum force for impact loading, The bending load on the sweep will be = 600 × 2 × 2 = 2400 kg.

Assuming height of link supporting the blade from the tip of blade be 400 mm

So, the maximum bending moment (M) for a cantilever of 400 mm = 2400 × 400

= 960000 kg-mm

Using the formula,

$f_b = MC / I$ *(Sharma and Mukesh, 2013)*

where,

f_b = *bending stress, kg/mm²*

M = bending moment, kg-mm

C = distance from the neutral axis to the point at which stress is determined.

I = moment of inertia of section, mm⁴

So

$Z = I / C = M/f_b = 960000 / 30 = 32000$

Moreover,

$Z = b^3 / 6$

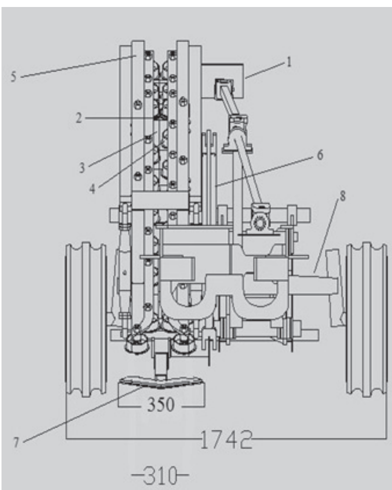
$b^3 = Z \times 6 = 32000 \times 6$

$b = \sqrt[3]{32000 \times 6)}$

$= 57.68$

Therefore, hollow square section of side 60 mm (on availability) was used for fabrication of shank.

The digging blade (**Fig. 3**) was fabricated from carbon steel of thickness 5 mm. It was welded in front of a MS hollow square section



Note: All dimensions are in mm

1	Gear box
2	Cutting discs
3	Conveying chain
4	Idlers
5	Conveyor
6	Hydraulic pump
7	Digging blade
8	Axle

Fig. 1 Structural schematic of carrot harvester

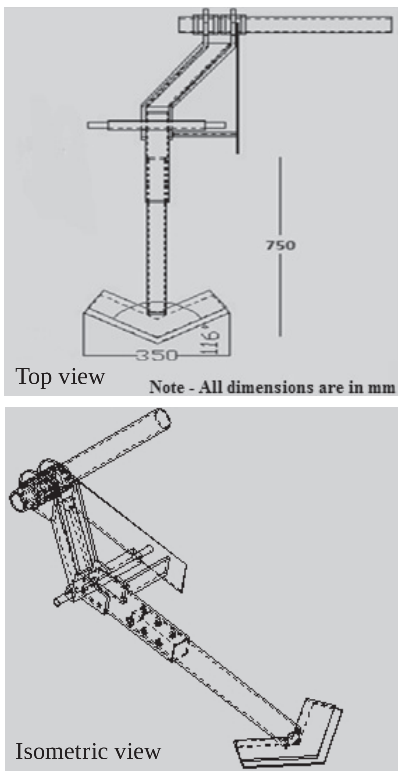


Fig. 2 Top and isometric view of the digging unit

Fig. 3 Digging blade of developed carrot digger

of side 60 mm and thickness 5 mm. The length of blade could be varied as the blade with hollow square section (60 mm) was fitted with nut & bolt in a hollow square section of side 74 mm. Details of the digging unit are included in **Table 1**.

Table 1 Specification of the constituent components of the prototype carrot digger

Component	Specification
1 Complete carrot digger	
Length, mm	6,011
Width, mm	1,742
Height, mm	1,610
2 Main Frame	
Length, mm	5,555
Width, mm	929
Height, mm	1,212
Material	M.S.
3 Digging unit	
Length, mm	750
Width of blade, mm	350
Apex angle of blade, degree	116
Diameter of supporting shaft, mm	600
4 Conveying unit	
Number of idlers	18
Diameter of idlers, mm	115
Width of conveyor, mm	310
Length of conveyor, mm	2,800
Diameter of chain drive sprocket, mm	95
Centre to centre distance between idlers, mm	300
Pitch of chain, mm	12
5 De-topping unit	
Diameter of cutting discs, mm	135
Overlapping of discs, mm	15
Thickness of disc, mm	3
Diameter of sprockets, mm	80
6 Collecting unit	
Width of frame, mm	1,130
Length of frame, mm	400
Height of frame from ground, mm	195
7 Power transmission system	
Number of teeth on PTO sprockets	16
Distribution ratio of gear box	1.8
Transmission ratio of bevel gears	2
Speed of clamping chain sprockets, rpm	150

Conveying Unit

The main function of the conveying unit (**Fig. 4**) was to hold and pull the leaves of loosened carrot (by digging unit) and convey it to the de-topping unit. The conveying unit was located above the digging blade. The developed conveying unit comprised offrame, idlers (30 cm apart), chains tightner, two endless triple pitch roller chains and chain drive sprockets. The conveying unit is the most critical component of the carrot digger as performance of the digger would largely depend on the design of the conveying unit. The important parameters determining the conveying efficiency and picking efficiency of the conveying unit were its conveying angle, conveyor length, speed and clearance between the triple pitch roller chains for holding the leaves of carrot without clogging. Provision was provided to vary the angle of conveying unit with the help of two top links attached to the frame of digging blade. Taking conveying unit angle as 450 (Horia *et al.*, 2008), keeping in view the number of carrots per meter row length and the location of crates to collect the de-topped carrots, the length of conveying unit was optimized as 280 cm on basis of preliminary trials. Crank system was provided on one side idlers to adjust the clearance between the triple pitch roller chains.

Fig. 4 Conveying unit of the developed carrot digger

The linearvelocity of the triple pitch roller chains was taken equal to forward speed of the operation which was taken as 2.7 km h^{-1}. The main frame of the conveying unit was fabricated from M.S. hollow square section of side 60 mm. Details of the conveying unit are shown in **Fig. 5** and included in **Table 1**.

De-topping Unit

The de-topping unitwas provided to cut the leaves of the carrot, which were conveyed by the conveying unit. It was designed to de-top the carrot with no damage to the carrot and with less energy requirement. The unit was positioned below the conveying unit toward the rear end. When the carrot with leaves reached to the rear end of the conveying unit, the leaves get de-topped by two serrated circular discs rotating in opposite direction (**Fig. 6**). Serra-

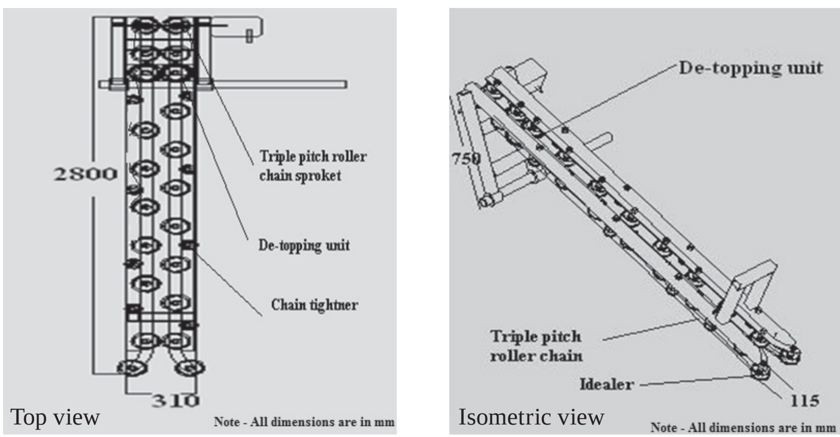


Fig. 5 Top and isometric view of the conveying unit

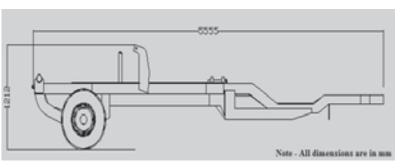
tions were provided on the discs in order to avoid slippage of the leaves of carrot. The spacing between the serration of disc was kept less than the diameter of the carrot leaves at top of the carrot. These two cutting discsoverlapped at cutting edge. Each disc was bolted below a sprocket which took drive from the conveying chain.

Though for efficient cutting of unsupported stalks, the cutting speed is recommended between 6 to 10 m s^{-1} (Klenin *et al*., 1985). But in this case the leaves of the carrot were held by the triple pitch roller chain when being de-topped. The linear velocity of de-topping discs was kept more than linear velocity of conveying unit. The discs were made up of carbon steel. Details of the de-topping unit are included in **Table 1**. The rotating discs were able to cut the carrot leaves efficiently when tested.

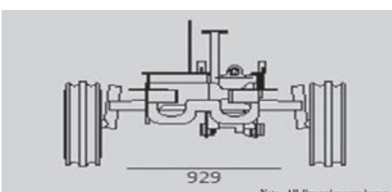
Main Frame

It is the main supporting unit of the designed carrot digger. It was fabricated from MS sheet I-section of thickness 16 mm and width 177 mm for mounting the conveying unit, digging unit, power transmission system and collecting unit. The length, width and height of the frame were 5,555, 929 and 1,212 mm, respectively. The conveyingunit and digging unit were mounted on the side of the frame with the help of circular rod of diameter 60 mm.The function of the frame is to provide a durable support to different parts of the machine.Details of the main frame are included in **Table 1** and **Fig. 5**. The overall length, width and height of the machine were 6,011, 929 and 1,610 mm, respectively.

Fig. 6 De-topping unit of the developed carrot digger
a) Triple pitch roller chain, **b**) Sprocket, **c**) Cutting discs



Side view



Front view

Fig. 7 Side and front view of the main frame of developed carrot digger

Power Transmission System

The conveying unit and de-topping unit were provided motion for catching and de-topping the leaves of the carrot by the power transmission system. The triple pitch roller chains needed certain speed to clamp carrot leaves smoothly in order to convey the carrot to the de-topping unit without clogging. Thesetwo triple pitch roller chains rotated in opposite direction. Power was provided from the tractor PTO (540 rpm) to the conveying unit through chain sprockets system to the counter shaft,universal shafts, gear box, bevel gears and finally to the triple pitch roller chain. The power train of the transmission system is shown in **Table 2** and **Fig. 8**.

Determination of Total Transmission Ratio of the Transmission System

Linear speed of the triple pitch roller chain was taken equal to the forward linear speed of the tractor, $v_1 = 0.75\ m\ s^{-1}$ (2.7 km h^{-1}), (Narender, 2012)

According to the formula

$v_1 = \pi dN / 60$

where, N is the rotational speed of sprocket of triple pitch roller chain, rpm

d is the diameter of sprocket of triple pitch roller chain

Taking d = 9.5 cm (on availability)

Thus, required rotational speed of

Table 2 Power train of the conveying unit

From	Through	To
Tractor PTO	Chain sprockets system	Counter shaft
Counter shaft	Universal shafts	Gear box
Gear box	Pinions mounted on gear box output shaft	Bevel gear's pinion
Bevel gear's pinion	Bevel gear's ring	Sprockets of triple pitch roller chain

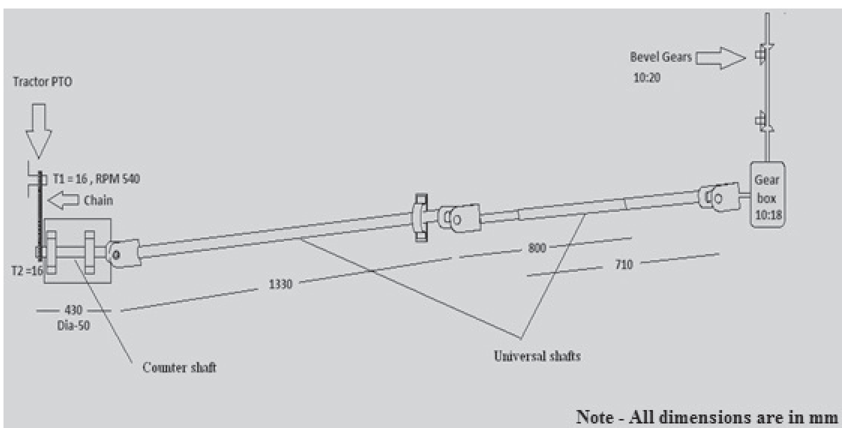


Fig. 8 Power transmission system

sprocket of triple pitch roller chain, N = 150 rpm

The tractor PTO speed, N_1 = 540 rpm

The total transmission ratio I was calculated as

$I = N_1 / N$

$= 540 / 150$

$= 3.6$

Transmission ratio of tractor PTO to counter shaft

Two sixteen teeth sprockets were fitted on the PTO shaft of the tractor and sixteen teeth sprockets on counter shaft and power was transmitted by chain so transmitting ratio was 1.

Transmission Ratio of Counter Shaft to Gear Box

Power was transmitted from counter shaft to gear box by universal shafts so again transmitting ratio was 1.

Transmitting ratio of gear box to bevel gear

Transmitting ratio ofgear boxwas distributed as $I_1 = 1.8$

Then the gear box output shaft speed, N_2 was calculated by the formula

$N_2 = N_1 / I_1$

$= 540 / 1.8$

$= 300$

Transmission Ratio of Bevel Gears to Sprocket of Triple Pitch Roller Chain

Bevel gear transmission system is provided to transmit power from gearbox output shaft to the conveying chain sprockets. Two pinion gears were fitted on gear box output shaft which gave drive to the two ring gears fitted on the same shaft of the sprocket of triple pitch roller chain

The transmission ratio of bevel gears was calculated as

$I_2 = I / I_1$

$= 3.6/1.8$

$= 2$

10 teeth on pinion and 20 teeth on ring of bevel gears were considered

When the speed of active pinion gears was N_2 = 300 rpm, the ring gear speed N was calculated as

$N = N_2 / I_2$

$= 300 / 2$

$= 150$ rpm

Thus,rotational speed of sprockets of triple pitch roller chain equal to 150 rpm

The details of power transmission system are included in **Table 1**.

Power Transmission to the De-Topping Unit

The sprockets of the de-topping unit took drive from the triple pitch roller chains (**Fig. 6**). So, the linear velocity of sprocket of the de-topping unit was equal to the triple pitch roller chain linear velocity v_1 = 0.75 m s^{-1}.

Taking diameter of circular disc's sprockets db = 0.08 m (on availability)

The rotational speed (Nb) of circular discs is calculated by the formula

$v_1 = (\pi d_b N_b) / 60$

$0.75 = (3.14 \times 0.08 \times N_b) / 60$

Therefore, rotational speed of cutting discs = 180 rpm

Linear Speed of Cutting Discs

Linear speed of the cutting discs was calculated as

$= \pi\ d_d N_b / 60$

$= (3.14 \times 0.135 \times 180) / 60 = 1.3$ m s^{-1}

Prototype and Field Trial

The tractor operated carrot digger was manufactured in "Vishavkarma Engineering Works" Bhuna Road, Tohana, District Fatehabad (Haryana), India (**Fig. 9**) and field trial was taken at farmer's field. The soil character was sandy loam with 13.86% moisture content on dry basis. Field was sowed by broadcasting method after which ridges were formed of size 56 cm at bottom and 25 cm at top with center to center distance of 66 cm. The number of carrots on one meter row length was 48 with depth of 22 to 26 cm. The results showed that the machine operated smoothly and could dig 100% carrots. The de-topping efficiency was 100% though the picking efficiency was low (61.56%)of the conveying unit, this was due to the reason that the carrots were sowed by broadcasting method and were not in rows.The machine can be operated with 35 hp tractor.

Conclusions

A tractor operated carrot digger was developed, which can dig, separate, de-top and collect carrots in crates simultaneously. The different components of the digger weredigging unit, conveying unit, de-topping unit, collecting unit, main frame and power transmission system.Digging efficiency, picking efficiency and cutting efficiency of de-topping unit were 100%, 61.56% and 100%, respectively.Effective field capacity of the digger was 0.11 ha h^{-1} with field efficiency of 61.70%. The time and cost of operation saving was found to be 94% and 63.36% with developed carrot digger in comparison to manual method of harvesting.

The field test shows that the carrot harvester runs smoothly, but needs improvement in picking unit. It will be success if carrots are sown in single row on ridges rather than the broadcasting method, wherein seeds are broadcasted and ridges are made.

Fig. 9 Physical map of designed tractor operated carrot digger

REFERENCES

Srivastava, A. P., D. V. K. Samuel, I. Mani. 2009. Mechanization of vegetable production and post harvest management, First edition. New Delhi: Westville Publishing House.

Srivastava, N. S. L. 2000. Role of mechanization of horticultural crops with emphasis on automation. Agricultural Engineering Today; 24(5): 13-28.

Shirwal, S., I. Mani. 2014. Study on Design Parameters Effecting Mechanical Carrot Harvester. International Journal of Engineering Sciences & Research Technology; 1664-1670.

Hagen, K. B., H. Jostein, K. H. Ringdahl. 1993. Physiological and subjective responses to maximal repetitive lifting employing stoop and squat technique. European Journal of Applied Physiology and Occupational Physiology;67(4): 291-297.

Agbetoye, L. A. S., J. Kilgour, J. Dyson. 1998. Performance evaluation of three pre-lift soil loosening devices for cassava root harvesting. Soil & Tillage Research;48: 297-302.

Horia, M., E. A. Sahhar, M. M. Mustafa, F. A. Elhady. 2008. A developed machine to harvest carrot crop. Misr J. Ag. Eng; 25 (4): 1163-1173.

Yulan, L., S. Youpan, L. Shihao, C. Danping, W. Gaoping. 2012. Development and prototype trial of digging-pulling style cassava harvester. Transactions of the Chinese Society of Agricultural Engineering; Vol. 28: 29-35.

Khura, T. K., I. Mani, A. P. Srivastava. 2011. Design and development of tractor drawn onion (Allium cepa) harvestor. Indian Journal of Agricultural Science; 29 (6): 44-48.

Sharma, D. N., S. Mukesh. 2013 Fram Machinery Design, Principles and Problems, 3rd Edition. New Delhi: Jain Brothers.

Narender. 2012. Performance evaluation of root crop digger. Unpublished M.Tech. Thesis, Department of farm machinery and power engineering, COAE&T, Chaudhary Charan Singh Haryana Agricultural University, Hisar.

Klenin, N. I., I. F. Popov, V. A. Sakun. 1985. Agricultural Machines. Theory of operation, computation of controlling parameters and the conditions of operation. New York: Amerind Publishing Company Private Limited.

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(Continued from page 31)

Johnny, M., J. Karimu and P. Richards. 1981. Upland and swamp rice farming systems in Sierra Leone: the social context of technological change. Africa. Vol.51 Issue 02, pp 596-620.

FAOSTAT. 2015. http://faostat3.fao.org/home/E [Accessed: 02.02.2015]

The World Bank Group, 2015 http://www.worldbank.org/ [Accessed: 02.02.2015]

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Test Results In-Vessel Composting System at the Cattle Farm Located in the Central Part of Russia

by
Yuri Ivanov
Professor
Director at All-Russian Research Institute of Mechanization of livestock, Moscow
RUSSIA
vniimzh@mail.ru

Vladimir Mironov
Professor
Chief researcher at Research Center of Biotechnology RAS, Moscow
RUSSIA
7390530@gmail.com

Abstract

In Russia, the main way to process manure into organic fertilizer is to compost it with peat or straw. The most widespread is the compost production technology using installations of tunnel type. Research was carried out at the dairy cattle farm. It was found that the period of manure biofermentation with cereal straw was 21-28 days, with the energy density of 12.9 kWh/t. Assessment of the work of tunnel type installation showed that in comparison with the Mobile Container Technology energy intensity increased more than in 4 times from 1.5 -3 to 12.9 kWh/t, and in comparison with Rotating drums Compost Technology energy intensity decreased by 4.3 times from 55.0 to 12.9 kWh/t. Labor used per unit of output was 0.97 m-h/t that is 28-49% higher than in the process of compost production from manure and peat. Content of N-P-K (nitrogen, phosphorus, kalium) in the compost was 2.5-1-1% for a.d.s (absolutely dry substance/ on dry weight). Total mass loss made 13% due to the decomposition of organic substance. Thus, in order to reduce the cost of manure processing in conditions of cattle farms located in the central part of Russia, it is advisable to use the tunnel installations for cattle manure and straw compost mixture disinfection for 7 days and further compost formation in storage pits in open areas for up to 35 days.

Introduction

Composting is the main way of manure processing into organic fertilizer in countries with temperate and cold climates, including Russia. Composting (solid phase microbial fermentation) is the exothermic process of biological oxidation, in which organic substrate undergoes the biodegradation of mixed population of microorganisms under conditions of high temperature and humidity (Forster, Wade, 1990). In the process of composting participates many known species of bacteria (more than 2,000) and at least 50 species of fungi (Yemtsev and Mishustin, 2005) [1].

At the moment in Russia as most common in-vessel composting systems is used the compost production technology in installations of tunnel

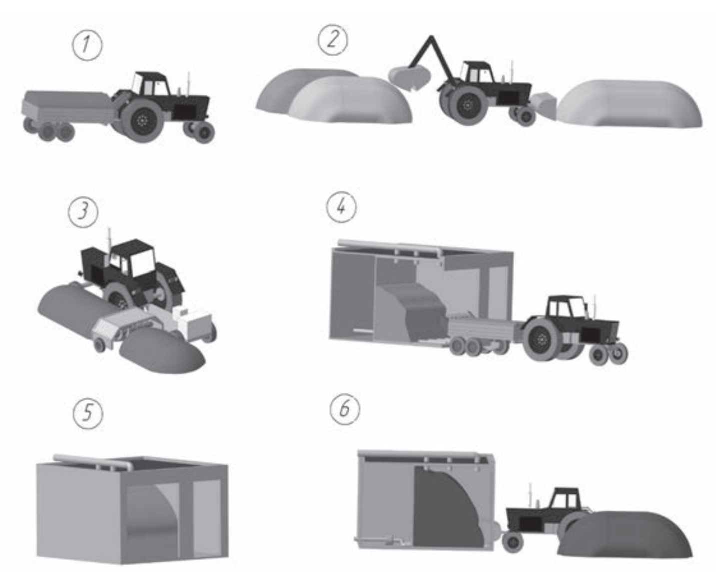


Fig. 1 Technological scheme of compost production in tunnel type installations (in the text)

type, **Fig. 1** [2]. In comparison with the Mobile Container Technology [3] and Rotating drums Compost Technology [4] the main advantage of the technology is simple design of tunnel technical systems and the ability to use the widespread agricultural machines. Despite the obvious benefits of this technology, it also has drawbacks:

- tunnel installation-work cyclicity causes microbial breakdown energy losses into the environment in the process of processed compost unloading;
- installation-energy intensity increase and performance decrease when composting the not easily decomposable components of composting mixtures (sawdust, straw, etc.);
- high operational costs of installation loading and unloading.

In an attempt to gain the practical experience in the use of tunnel installations on cattle farms located in the central part of Russia, as well as to explore the installation operation features, possible drawbacks and solutions, investigative studies and operational experiments were conducted, the main objectives of which were:

- determination of technological operation best sequence, preparation time frame, straw and manure mixture composting features;
- research of thermal processes during composting;
- determination of regularities of basic physical parameters change during composting;
- determination of change of compost agrochemical properties.

Materials and Methods

Research was carried out at the dairy cattle farm. Livestock is kept on a leash with manure cleaning by means of scraper conveyors and further manure storage on a concrete pad. As bedding is used conifer sawdust in quantity of 1 to 3 kg per head per day.

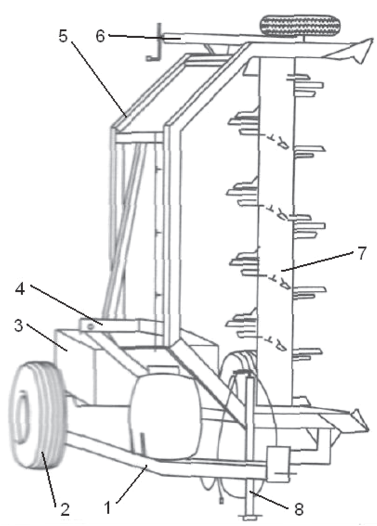
Experiments were conducted from May to September; average air temperature was 22°C.

Raw material for compost production made the following components:

- cattle manure with humidity of 78-81%;
- wheat straw with humidity of 17 to 20%, with particle size of 10 to 15 mm.

Mixing components was carried out by means of turning windrow machine, which represents a truck on two supporting wheels with a concrete balance weight mounted on it, **Fig. 2**. To the frame of the truck is mounted a rotating mechanism of U-shaped frame fitted with a hydraulic cylinder, a supporting wheel with height adjustment mechanism and rotor with installed the blades on it. A tractor using the cardan shaft and gearbox drives rotor drive shaft. Before starting work, U-shaped frame using a hydraulic cylinder is brought in a horizontal position. For rotation to the next windrow and transportation U-shaped frame is brought in the vertical position. The balance weight prevents lateral displacement of the machine. Turning windrow machine performance makes up to 300 t/h. The machine is unitized with wheel-type tractor Belarus MTZ-82 with power of 75 horsepower hours, nominal tractive effort 12.5-18.0 kN and average weight of 2.9 tones.

Therefore, further studies is ac-



1-frame; 2-support wheels; 3-balance weight; 4-articulated mechanism; 5-rotor frame; 6-frame height setting mechanism; 7-mixing rotor; 8-driveshaft

Fig. 2 Turning windrow machine

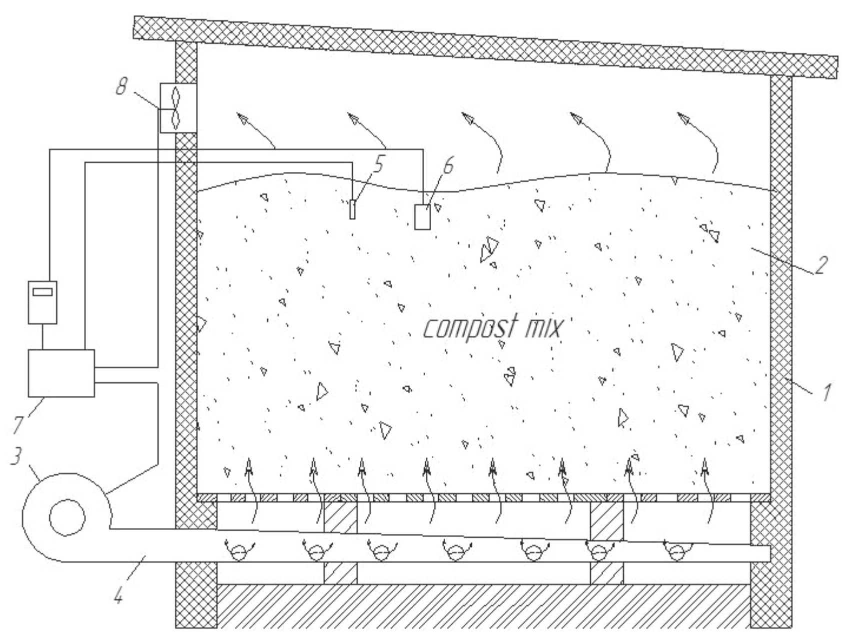


Fig. 3 Scheme of the experimental tunnel (in the text)

cepted compost mixture of manure and straw of the following composition and properties:

- maximum particle size not exceeding 150 mm;
- humidity around 60%;
- content of organic substance (OS) in a.d.s. not less than 66%, including carbon not less than 33%;
- C/N ratio = 37.

For experiments, the tunnel measuring: 6 m width, 6 m length, 4 m height was built. Wall material —brick. Slab—reinforced concrete plate.

The tunnel is an air-intake section 1 for faster composting compost mix 2, with a gate at the one end and a communicated air intake system 3 with forced-feed fan, consisting of metal tubes 4 positioned at a certain distance from each other and embedded in the concrete floor and of perforated top part 10 and 11, **Fig. 3**.

Around the section perimeter, there are openings that allow placing the thermocouple 5 and oxygen sensors 6 communicated with air management system 7 and 8.

The experiment was conducted according to the following technological scheme.

The straw was delivered to a concrete pad and was placed in layers up to 1.0 m using clam-type loader. Then dung and semi liquid manure was delivered and was unloaded on the straw. In 27 hours, the components were mixed using turning windrow machine and the mixture was placed in V-type windrows. The operation was repeated 2-3 times to achieve optimum mixing grinding of the components. Daily temperature control was conducted in the middle of the windrow at a height of 0.5 and 1.0 m from the base every 3 linear meters using remote-reading thermometer.

Initial temperature of raw material t_{prim} = 12°C. When the temperature in a mass reached more than 45°C at least in 7 points out of 10, the mass using the clam-type loader was loaded in the manure spreader trailer, **Fig. 4**. This was trailed using wheel-type tractor into the tunnel and stopped so that the distance from the back header of the trailer to the rear wall of the tunnel was 1.5 to 2.0 m.

In the section of the tunnel at the same time, there were about 35 tons of compost mixture. The initial average height of compost mixture in tunnels was 1.8 m.

After the section was packed, the gate was closed and forced-feed fan was powered on. The air pressure from the forced-feed fan was pumped throughout the perforated pipes in the floor area into the composting material.

Tunnel composting time was 33 days. Aeration was conducted cyclically every 24 minutes for one minute in volume $0.54*10^{-3}$ m^3 per 1 kg of compost mixture. Aeration regime was set based on the results of earlier studies [5]. The fan control was carried out using the timer switch.

In order to activate the microbiological processes at each load of the tunnel in the compost mixture, 3.5 tones (10% of compost mixture weight) of "hot" finished compost was added, prepared earlier with an average temperature of 53°C.

Temperature measurement in mass was carried out using remote-reading thermometer with an accuracy of ±0.1°C, according to the scheme in 36 equidistant points. In each of these points two temperature values were measured - at a depth of 0.5 m and at a depth of 1.0 m. Then the average temperature values in each point were determined.

Upon expiration of the 27 days of composting, the mixture was unloaded using front-end loader to a concrete pad and was formed in stacks 1.7 to 2.0 m high.

When conducting industrial experiment, the determination of density values, relative humidity, exchangeable acidity and agrochemical quality of compost mixture and the finished compost were carried out using known methods [6].

An interval of 7 days was selected to sample composting material at 25 points to verify its quality.

Selected point samples with a weight of no less than 0.5 kg were combined in a joint sample and after careful mixing; the average sample with a weight of 1 kg underwent the agrochemical composition analysis.

To determine the number of repeated experiments, the confidence coefficient of 0.9 and permissible error of ±3σ was selected where σ is the average standard deviation according to the number of repeated experiments. The ±3σ is considered sufficient under normal research into technology to find dependencies of influence of various factors.

Fig. 4 Manure spreader trailer loading and compost mixture windrow (operation of compost mixture windrow formation)

Results and Discussion

On completion of studies the graphs of the average temperatures change depending on composting time were drawn, **Fig. 5**.

On the second day after the mixture laying mixture, because of the microbiological activity in the mass, the temperature reached a critical level of more than or equal to the 53°C.

The average temperature in 5-6 days reached a maximum value of 75-77°C, the temperature at specific points of the mixture reached the 86°C. Then there was observed a smooth temperature decrease.

Time history of temperature is well approximated by a polynomial of the fourth order, with a determination coefficient of $R^2 = 0.8799$:

$$t_{cp} = -0.0004\tau^4 + 0.0311\tau^3 - 0.8663\tau^2 + 8.6823\tau + 46.488 \quad (1)$$

where t_{cp} = the average temperature in the compost mixture, °C; τ = the time of composting in days.

Table 1 shows the composting mixtures density and relative humidity values in the process of composting in tunnel at intervals of five days.

The results of agrochemical composition analysis are shown in **Table 2**.

As a result of investigative study and production experiments, the following data on the qualitative, quantitative and energy processing indicators were found:

- in the process of preliminary preparation of the masses in the stacks, it was observed that the humidity reduction was from 67.6 to 63.8% and density reduction was from 792.3 to 686.1 kg/m^3 due to mass aeration in windrow conditioning and windrow loading;
- the mass in a windrow heated up for 5 to 7 days up to temperatures of 40 to 45°C, where the temperature increase was affected by ambient air temperature, mixture quality and conditioning number;
- the process of composting in tunnel proceeded at a temperature of composting mixture of more than or equal to 53°C for 25 days at a depth of 1 m, and more than 32 days at a depth of 0.5 m, while the maximum average temperature values in a mixture of 77°C reached on 6-7 day;
- at some point the temperature values reached 86°C;
- relative humidity of composting mixture *W* varied in the range between 63.8% to 64.9%;
- on 7th day, it was observed a sudden filling of the aeration pipes by the excess fluid to the extent 2.0 m^3 and continued with uniform descent to 0.3 m^3 per day until mass unloading that occurred due to the phenomenon of self-sealing and expressing under the action of gravity;
- acidity *pH* of composted mixture varied upward to the alkalinity value of 7.9 and to a value of 8.1;
- composted mixture density ρ during processing varied from 686.1 kg/m^3 to 939 kg/m^3, while on the 15 composting day the value of this parameter has a minimum value ρ_{min} = 541 kg/m^3, the resulting increase in density can be attributed by the significant decomposition of organic substance and its mineralization, as well as the by phenomenon of self-sealing under the action of gravity;
- contents of organic substance in a mixture reduced from 38.9 to 28.39%;
- concentration of plants nutrients increased by 66% for nitrogen, 42% for phosphorus , 14%, for kalium that is due to the mineralization of organic substance during composting;
- weight of finished compost was 30.4 tons;
- specific energy consumption was 12.9 kWh per ton of finished compost;
- specific diesel fuel consumption was 4.84 liters per tonne of compost;
- specific time cost for handling operations was 0.97 persons per hour per tonne (m-h/t) of compost.

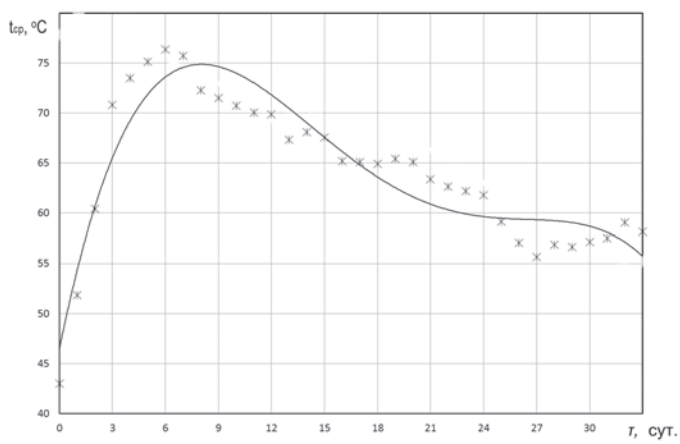


Fig. 5 Time history of composting mixtures average temperature values

Table 1 Time history of density ρ (kg/m^3), relative humidity *W* (%) and acidity *pH* of composting mixture

Indicator	Unit of measurement	Start experiment	5 d.	10 d.	15 d.	20 d.	25 d.	30 d.
Relative humidity, *W*	%	63.8	66	59	64	66	58	64.9
Density, ρ	kg/m^3	686.1	632.3	658.3	541	701.7	766	939
Acidity, *pH*	unit	7.9	7.7	7.6	7.4	7.6	7.8	8.1

Conclusions

Analyzing the obtained results, it can be concluded higher energy intensity activity of the manure-straw mixtures in the tunnel. Thus, in comparison with the basic technology of production of compost from cattle manure and peat the processing term of raw materials has increased from 4-8 to 21-28 days, due to a significant decomposition period of cereal straw fiber. In turn, the energy intensity of the process increased more than in 60 times - from 0.15 up to 12.9 kWh/t, which is also due to increased aerated air volume and processing periods. In comparison with the Mobile Container Technology, energy intensity has increased by more than 4 times from 1.5-3.0 to 12.9 kWh/t, which may also explain by the increase of processing terms using manure-straw raw materials. In comparison with Rotating drums Compost Technology intensity is reduced by 4.3 times from 55.0 to 12.9 kWh/t.

Labor content per unit of output made 0.97 m-h/t that is 28 to 49% higher than in the basic technology of compost production from manure and peat - 0.5 to 0.7 m-h/t. This is a result of the significant difference of physical and mechanical properties of straw and manure, and of the consequent increase in the number of mixing at the stage of preparing the compost mixture.

The quality of the obtained fertilizers depends primarily on the composition and quality of raw material, but not lower than the indicators for existing technologies N-P-K (nitrogen, phosphorus, kalium) which make 2.5% -1 -1 per a.d.s. Total mass loss made 13% due to the decomposition of organic substance.

Compost mixture humidity remained virtually unchanged with 63.8% to 64.9% that is explained on the one hand by the loss of moisture due to evaporation and the simultaneous formation of water because of microbial degradation of fiber.

Use a straw as raw material for production of compost significantly increases term of composting, which reduces the volume of processing per unit of time. At the same time, the use of relatively simple and widely used agricultural machines leads to high reliability and availability of the present system of manure processing.

The use of specialized technological lines - Rotating drums Compost Technology and Mobile Container Technology leads to significant capital costs to create them as well as the additional financial costs of training and technical services.

In this respect, the most effective process for cattle farms, located in the central part of Russia, is to use the camera rigs for short-term disinfection units (up to 7 days) of compost mixture of cattle manure with straw and further compost preparation in windrows in open areas in up to 35 days.

Acknowledgements

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REFERENCES

1. Yemtsev, V. T. Microbiology/V. T. Yemtsev, E. N. Mishustin. -M.: Drofa, 2005. - 445 p.
2. Kovalev, N. G. Organic fertilizers in the twenty-first century (Bioconversion of organic raw materials): Monography/2003. N.G. Kovalev, I. N. Baranovsky. -Tver: Chu Do 2006. - 304 p.
3. The Containerized Compost System. Mixed organics composting facility. Green Mountain Technologies, Inc US [electronic resource]. -Electron. Dat. -2008. -Access mode: http://www.gmt-organic.com
4. BioCycle. Journal of composting and organics recycling. US-Vol. 37, no. 8, August, 1996.
5. Mironov, V.V. Influence of preparation modes on agrochemical composition of compost/V.V. Mironov//Herald of the Voronezh State University. -Voronezh: VSU publishing house, 2005, Nr. 2. -P.146-148
6. Methods for analysis of organic fertilizers/compilers: L.I. Yeskova, S.I. Tarasov under gen. rev. of A.I. Yeskov. -M.: Russian Agricultural Academy - GNU VNIPTIOU, 2003. -552 p.

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Table 2 Time history of agrochemical properties of composting material in composting

Indicator	Unit of measurement	Start experiment	7 d.	14 d.	21 d.	28 d.
the content of total nitrogen	% a.d.s.	1.531	1.444	1.575	1.487	2.537
P_2O_5 total	% a.d.s.	0.68	0.7	0.72	0.8	0.97
K_2O total	% a.d.s.	0.99	1.00	1.00	1.12	1.13
organic matter content	% a.d.s.	38.9	37.82	37.51	45.9	28.39

Comprehensive Cost Analysis of Operating A Medium Size Rice Processing Machine in Bhutan

by
Kinga Norbu
Programme Director
Agriculture Machinery Centre
Ministry of Agriculture and Forest
Royal Government of Bhutan
P.O.Box:112
Bondey, Paro
BHUTAN

Introduction

The government is promoting medium size rice processing machines in rice growing Dzongkhags in the country under the Accelerating Bhutan Socio Economic Development programme. The objective behind the initiative is to have good processed packaged rice for sale in the domestic market. The government is also equally implementing programmes such as increasing irrigation network and farm mechanization programme which will lead to more area under cultivation and thus increasing the paddy production in the country. With high yielding varieties introduced, the scope of increased production is ensured which are all meant to reduce the import of rice in the country.

The rice processing machine however needs investment which includes both infrastructure and the installation of the plant. It also required the paddy storage, the drying area and the milled rice storage. The storage houses also require controlled temperature to protect it from insect infestation and reduce mold formation etc. which however it not included in the government initiative at present. The government had invested in the construction of the infrastructure and purchase, installation of the rice mill. The proposal is to hand over the operation to Food Corporation of Bhutan initially and then hand over to the private. Hence this study will ascertain the cost analysis of operating this size rice mill.

Materials and Methods

The cost of construction and purchase and installation of the rice milling machine was Nu 1.9 m and cost of rice mill was 2.04 m (DoA tender document). The fixed cost and variable cost have been calculated (Kinga, 2013). The fixed cost includes depreciation cost, interest on investment, insurance cost. The variable cost includes electricity cost, labour wages and repair and maintenance cost.

Depreciation cost

According to Kepner *et al.* (2005), the annual depreciation was calculated as

$D = (P-S) / L$

Where D = Yearly depreciation; P = Purchase price of the machine (Nu), S= is the salvage value or the selling price of the machine after its useful use (Nu) and assumed as 10% of the machine price; L = useful life of the rice mill between buying and selling (10 years for farm machinery).

Interest on investment

In Bhutan, the maximum interest generated through fixed deposit is 4%.

According to the Kepner *et al.* (2005) and Khairo *et al.* (2009) the annual interest on the investment was calculated as follows:

$I = \{(P+S) / 2\} \times (i / 100)$

where, I = Rate of interest in %, i = Annual interest rate for buying a rice mil

Insurance and taxes

It is amount spent on insurance every year as this rice mill.

$In = (1.1P / 2) \times (in / 100)$

Where, In = Rate of insurance and taxes, %; in = Annual insurance and taxes rate (2% per annum for agricultural use).

Calculation of Variable Cost of the Rice Mill

Electricity cost

It is calculated as the total KW × number of operating days × the rate (BPC).

Repair and maintenance cost

According to Kepner *et al.* (2005) it was taken 2.5% of the purchase price. However for Bhutanese terrain, it was proposed 8% as the repair needed is frequent.

RM = 8% × purchase price of farm machinery (Nu)

Operator and labour wages

Labour cost = Nu 7,000/head/month × 12 months × 4 person

Mathematical Analysis

Cost of operation is the cost involved in the operation of the rice mill

CoO = {Total Annual Cost (Nu / year)} / {Capacity of the machine (acre / year)}

where total annual cost includes both fixed cost and variable cost. The capacity of the machines is its performed capacity in acre/year

The cost of milling has been calculated based on three categories

- The initial investment as zero as the both the construction and purchase are done by the government
- The initial investment calculated on rental basis at 10%, 20% and 30% respectively
- The initial investment included as if it is operated by private without any government support.

The rice milling recovery was considered at 67% from the paddy as 20-22% includes the husk and remaining included in the polishing. The cost of the paddy purchased is assumed at Nu 30/kg and the selling of the rice in the market is assumed at Nu 70/kg as surveyed from the farmers. The moisture content of the paddy at purchase time is assumed at 22% m.c w.b.

The change in weight because of the variation in the moisture content is calculated through this equation (Kinga, 2012)

$Water\ (X) = W - W \times \{(100 - MC_i) / (100 - MC_f)\}$

Where W is the weight of the rough rice in gram, MC_i is the initial moisture content in decimal, X is the amount of water to be added to removed in gram, and MC_f is the final moisture content in decimal.

Results and Discussion

The discussion has be segregated into:

Paddy Weight Variation With Change in Moisture Content

The weight of the paddy is directly influenced by the moisture content of the paddy. The moisture content during the purchase is assumed to be at 20% from the harvesting which is presumed at 22-24% m.c w.b. At the milling time, it is important that the moisture content is in the range of 11-13% m.c.w.b to ensure less breakage during the milling process. This change in moisture content from 22% or 18% to 13% m.c.w.b also reduces the over-all weight of the paddy which is a loss as shown in **Fig. 1**.

Even at 22% m.c.w.b when the paddy is purchased from the farmers' fields, the loss incurred in paddy weight after drying to 13% m.c.w.b which is the ideal m.c for milling was 1.2 t when quantity of paddy purchased is around 1,400 tonnes. The loss amount incurred was Nu 36,000 for this quantity which may be negligible. Hence more concern on the moisture content during purchase of paddy should not be a prominent issue.

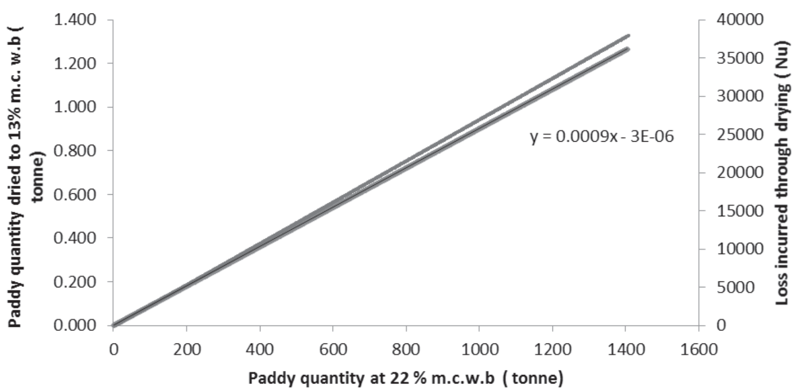

Fig. 1 Paddy weight variation through drying and cost incurred

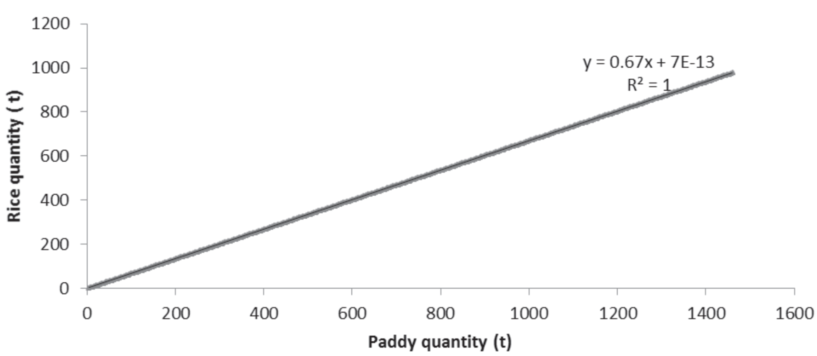

Fig 2 Rice and paddy quantity relationship

Rice Milling Recovery

During the milling process, the paddy has to be converted into rice. The rice milling recovery is assumed to be 67%. The remaining loss consists of the husk and the bran removed. The **Fig. 2** clearly showed the trend of the rice amount during milling from the paddy available.

However this trend is assumed under the condition that the moisture content of the paddy is around 13% m.c w.b required for milling. It gives a very clear picture and indication of how much rice quantity can be collected once the milling operation is completed. The quantity of rice collected is always lower than the initial paddy quantity as the remaining loss consists of husk, bran, brokens etc. The rice collected was 630 tonnes for every 1,000 tonnes of paddy milled.

Cost Analysis Between Paddy Purchase and Rice Sold

Fig. 3 shows the difference with increasing rice processed and sold. More the rice processed wider will the difference between the two lines in the graph which is better for the firm.

The difference is the amount that includes loss/profit, the milling cost, transportations, packaging and selling of rice. When 500 tonnes of paddy is purchased, it will cost Nu 15.00 m and same when processed and sold will fetch 23.45 m. When 1,000 tonnes of paddy is purchased it will cost Nu 30.00 m and same when processed and sold will fetch Nu 46.9 m. This is at the prevailing rates being practised by farmers. This clearly shows that when the paddy quantity is increased, the difference or the revenue made will widen as per the equations in the **Fig. 3** above.

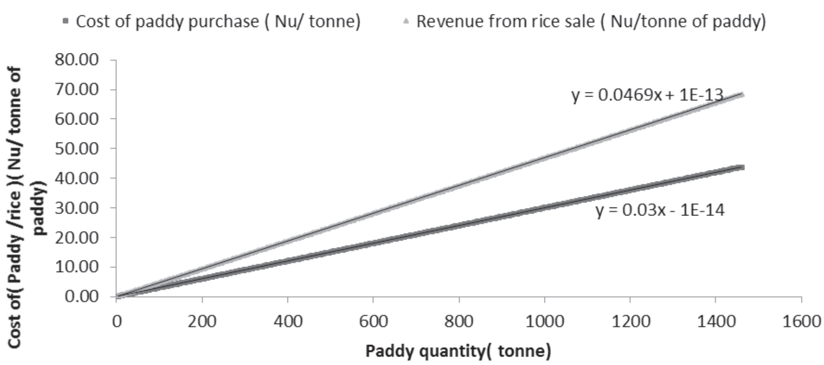

Fig. 3 The prevailing paddy cost and rice price (Nu/ tonne)

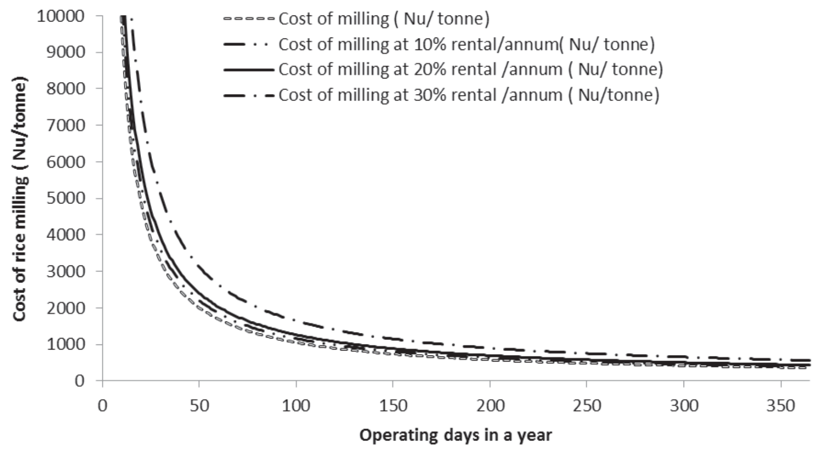

Fig. 4 The cost of milling (Nu/ tonne) with operating days

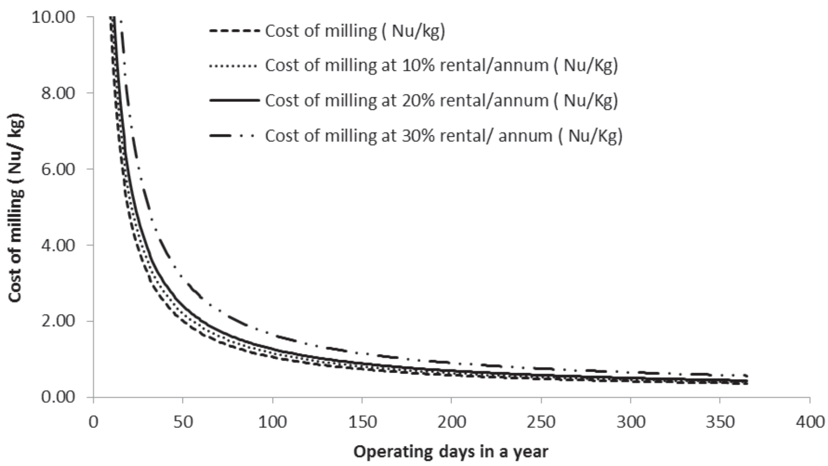

Fig. 5 The cost of milling (Nu/kg) with operating days

Cost of Milling

The cost of milling of the paddy into rice is the major operation with other operations also equally important to deliver the milled rice to the consumers. The cost of milling/ tonne with this investment on plant and infrastructure is shown in **Fig. 4**. It also includes if rental is charged at 10-30% to the mill users when investment is from the government.

It is clearly shown that if milling cost/tonne is to be brought to Nu 1,000/tonne then, the operating days should be 105 days with investment, 118 days with 10% rental per annum, 130 days with 20% rental per annum and 176 days with 30% rental per annum for using the mill and the infrastructure.

However if cost of milling is to be brought to and less than Nu 2/ kg, then the operating days should be 50 days, 55 days, 61 days and 80 days respectively with respect to the rental charge percentages. It can be clearly seen that with increasing operating days, the cost of milling can be reduced further down which is good for the business as shown in **Fig. 5**.

In case the government decide to let the FCB or any firm operate it without any rental charge or investment on the plant and the infrastructure as subsidy, the cost of milling which will be again lower is shown in **Fig. 6**.

It can be seen that the cost of milling is further lowered. Only Nu

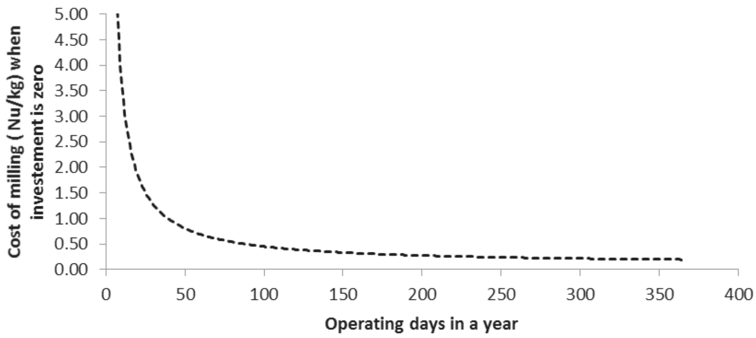

Fig. 6 The cost of milling with subsidy with both rice mill and infrastructure

0.50/kg will be the milling cost if the mill is operated in full capacity for 88 days which is less than 3 months.

Revenue Generation

An empirical formula can be used to forecast the revenue generated derived from all the figures and assumptions stated above

Revenue generated (M) = (0.07 × 0.67X - {[0.03 × X] + [0.002 × X]})

Where *X* is the paddy quantity (tonne)

Conclusion and Recommendation

Interesting observations through this study and analysis of the data are as follows

- The moisture content of the paddy during purchase may not greatly influence the profit margin as the loss amount is not so significant when the paddy quantity is so huge. However the drying process may prolong and add up to unnecessary expenditure.
- The rice milling recovery at 67% indicates that the remaining 33% which consists of husk, bran and the broken as loss. Hence it is important to ascertain alternative use of these by products which also could fetch money.
- If the quantity of paddy purchased is higher, the revenue made is also higher when processed in rice and sold. Hence it will always be profitable if the paddy quantity is increased when other factors like spoilage and optimum storage conditions are addressed.
- There is a great difference between the cost of milling with subsidy from the government in free rice mill and infrastructure, or investment in rice mill and infrastructure and finally also with rental charge on these facilities. Still it is a good business to own and run a rice mill.

Acknowledgments

The author would like to thank the Farm mechanization specialist for providing the cost of the rice mill and the infrastructure and also discussion and suggesting on the economics of the rice mill. The author also would like to thank the ABSD meeting presentation which led to research on this investment.

REFERENCES

Kepner, R. A., R. Bainer, and E. L. Barger. 2005. Principles of Farm Machinery. CBS publishers & Distributers, Darya Ganj, New Delhi. 32-35.

Kinga, N. 2012. Efficacy of hot air drying of rough rice against rice quality and grain weevil. Masters thesis (unpublished), Kyushu University, Japan.

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ABSTRACTS

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

1375

Study on the Nozzles Wear in Agricultural Hydraulic Sprayer: E. M. Sehsah, Associate Prof. of Dept. Agric. Eng. Dept Fac, of Agriculture, Kafr El-Sheikh Univ. 33516, EGYPT, sehsah_2000@yahoo.de; **M. M. El Baily**, Researcher Dr., Agric. Eng. Institute, A.R.C., EGYPT

The aim of the current study was to investigate some factors affected on the sprayer flow rate and nozzle wears includes spraying pressure, duration of test, type of nozzles. The current research conducted in the laboratory of Agricultural Engineering Department, Faculty of Agricultural Kafr El Sheikh University, Egypt. Five different types of nozzles were used under three different operating pressure 150 kPa, 220 kPa and 370 kPa. The time operating tests curried out at 0 h, 48 h, 120 h, 180 h and 240 h. The nozzle wear value for the Tip ceramic AD120-04 nozzle was 10.2% at maximum operating pressure 370 kPa and after 240 h duration operation time. The increasing of duration operation time test of the different nozzles tips tends to increase the nozzle wears. The ceramic AD120-04 nozzle gave the low values of nozzle wear compared to LU90-03, LU90-05, ST110-04 and ES90-04 nozzles at all operation time and three operating pressures. The nozzle wears value after 48 h was 3.8% for ES90-04 at 370 kPa operating pressure. The nozzle wears value after 240 h were 15.45%, 15.8%, 10.2%, 14.8% and 16.05% for LU90-03, LU90-05, AD12-04, ST110-04 and ES90-04 at 370 kPa operating pressure respectively. Brass ES 90-04 nozzle gave the maximum nozzle wears after 240 h duration time. The nozzle wear for ES 90-04 brass nozzle were. 12.7%, 13.95% and 16.05% at 150 kPa, 240 kPa and 370 kPa operating pressure respectively

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Traditional Harvest and Post-Harvest Practices of Kendu Leaves (Diospyros melanoxylon) in the State of Odisha, India: S. Mishra, College of Agricultural Engineering and Technology, Orissa University of Agriculture and Technology, Bhubaneswar-751003, INDIA; **K. Rayaguru**, same; **M. K. Mohanty**, same

Kendu Leaves (*Diospyros melanoxylon*) is an important Non-Timber Forest product species in India. It is also called as silver leaf for its great economic values which is used for *bidi* (poor man's cigarette) rolling. *Kendu* leaves collection provides about 90 days employment to 7.5 million people; a further 3 million people are employed in secondary processing industry. The species found in degraded deciduous forest of peninsular India. In Odisha, it is found as shrub (because of annual cutting) in waste land of Odisha. The typical leaves undergo harvesting and post-harvest operations like coppicing or bush cutting, plucking, *keri* formation (bundling of leaves), drying, bundling of *keri*, packaging, transportation. This paper brings out the traditional unit operations which are extremely unhygienic, time consuming and tedious. The present paper also identifies the areas for process development to minimize the losses. So suggestions have been made to use the modern technology or mechanisation by replacing the traditional technique, by which leaves of improved quality may be obtained.

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1386

Comparative Grinding Behavior and Powder Characteristics of Basmati Rice Brokens: Y. Singh, Research Scholar, Dept. of Food Engineering and Technology, S. L. Institute of Engineering and Technology, Longowal -148106, Punjab, INDIA, yogender784@yahoo.co.in; **K. Prasad,** Associate Professor, same, dr_k_prasad@rediffmail.com

Dry grinding behavior and powder characteristics of raw and parboiled Pusa 1121 basmati rice brokens were assessed. Grinding duration was found to be having the role in deciding the ultimate size of ground particles with the particle size distribution and confirmed its direct influence on the characteristics of pretreated parboiled rice. Grinding laws namely Kick's, Rittinger's and Bond's law were applied. The grinding constants (K_K, K_R, W_I) for different laws reflected the dependency on grinding duration. Dry grinding of raw rice brokens produced higher fractionations on smaller sieve size in comparison with parboiled rice brokens in the identical grinder and grinding process. Dry grinding of raw and parboiled broken rice resulted in significant difference in powder characteristics. Consequently, the grinding time and powder characteristics of raw rice brokens are more viable in producing fine particulates than parboiled one.

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1427

Status of Draught Animal Power Availability in Selected Villages of East and South Districts in Sikkim State of India: **R. K. Tiwari,** Research Engineer, AICRP on UAE, The College of Agricultural Engineering and Post Harvest Technology (CAEPHT), Ranipool-Sikkim, INDIA, rk96tiwari@gmail.com; **D. Chaudhuri**, Project Coordinator, AICRP on UAE, Central Institute of Agricultural Engineering (CIAE), Bhopal-MP, INDIA

The agriculture in Sikkim is mixed type and at the subsistence level. Animal husbandry is an integral part of household economy in Sikkim. Most of the field operations are done manually and by use of animals. The present use of draught animals is limited only to cultivation operations (100-120 h per year) in Sikkim. Increased utilization (300-500 h per year) may be taken up by rotary mode applications for post harvest operations and electricity generation at village level and pack load transport in hilly terrain to make the work animals energy efficient and cost-effective. Bullocks are the major source of farm power (57,218 number: Livestock census: 2007) mostly used for cultivation operations in valleys and terraces. Village survey information included population of draught animals, traditional/improved equipment, major crops and rotations, total area, irrigated area, cultivable area, operational land holdings, electro-mechanical power sources, electricity status and labour available. In the farmer's survey, ten framers or actually available were surveyed in each village for bullocks breed, annual use, price, body dimensions, type of feed and schedule animal shed, labour engaged, crops grown and crop rotations, custom hiring equipment used and rate for hiring required. Present coverage is 2.22 ha/bullock pair in south and east Sikkim. 50% farmers prefer custom hiring of bullocks for field preparation. The command area per ha by use of traditional equipment is 1 ha (50-70 terraces).The expected command area by use of improved equipment is 1.5 ha (80-100 terrace). Farmers willingly prefer to opt improved equipment subject to the availability of equipment and skill. Maximum farmers depend on animal power for cultivation.

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1428

Comparative Performance Evaluation of Different Animal Drawn Improved Seeding Equipment for Black Gram Under Terrace Condition of Sikkim: **R. K. Tiwari**, P. I and Research Engineer, AICRP on UAE, CAEPHT, College of Agricultural Engineering and Post Harvest Technology, Ranipool, Sikkim, INDIA, rk96tiwari@gmail.com; **S. K Chauhan**, Assistant Agril. Engineer, same

The black gram in Sikkim is sown in 5,960 ha with average yield of 880 kg/ha. The maximum area (2,410 ha) of black gram is in west Sikkim district. The black gram sowing (manual broadcasting practice) is mostly done in July-August in terraces of Sikkim. The two row animal drawn improved zero till seed drill (weight: 23.7 kg, unit price : Rs. 2700, overall dimension: 730 × 940 × 735 mm) was tested for sowing black gram (seed rate: 15 kg/ha) at 275 mm row spacing after three weeks of normal sowing. The effective field capacity and field efficiency were 650 sq.m/h and 65% respectively. The cost of operation was Rs. 580/ha. The use of zero-till seed drill saved 16% seeds over traditional sowing practice and yield was also higher (5.8%) due to line sowing of seeds.In east Sikkim, animal drawn light weight CAEPHT multipurpose tool frame with seeding attachment (overall dimensions: 730 × 700 × 960 mm, weight: 19.8 kg, unit price : Rs. 8000/-, command area: 1.5 ha) was tested in terraces for sowing black gram at normal sowing period (July). It showed higher work rate (1250 sq.m/h) due to increased working width of 720 mm. The residual moisture content (dry basis) was 20.6%. The average depth of operation was 34 mm and cost of operations was Rs. 400/ha. The black gram seeds sown using tool frame seeding attachment provided 4% more yield as compared to two row zero till seed drill and the crop yield was 9.8% more over manual sowing by traditional broad casting method.

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EVENT CALENDAR

2018

◆ **Asia Agri-tech Expo & Forum**
July 26-28, Taipei, TAIWAN
http://www.agritechtaiwan.com/en-us/

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

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

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

◆ **Agro & Poultry—International Trade Exhibition—**
September 7-9, Dar Es Salaam, TANZANIA
http://www.mxmtradefairs.info/agrotz_txt/agtz.php

◆ **South African Institue of Agricultural Engineers (SAIAE) Symposium and Biennial Continuous Professional Development Event**
September 17-20, Salt Rock, SOUTH AFRICA
http://saiae.co.za/

◆ **PAS 2018—5th China International Precision Agriculture and High-efficiency Utilization Summit**
September 19-20, Shanghai, CHINA
http://www.passummit.com/en/

◆ **Global Water Security for Agriculture and Natural Resources**
October 3-6, Hyderabad, INDIA
http://asabewater.org/

◆ **Agrosalon**
October 9-12, Moscow, RUSSIA
http://www.agrosalon.com/Visitor/VisitorsInfo/

◆ **Golden Autumn—Russian Agricultural Exhibition—**
October 10-13, Moscow, RUSSIA
http://goldenautumn.moscow/en/

◆ **World Agri-tech Innovation Summit**
October 16-17, London, UK
https://worldagritechinnovation.com/

◆ **Scientific-technical Progress in Agricultural Production**
October 17-18, Minsk, BELARUS
http://belagromech.by/en/conference/c6f623f5c6e562a8.html

◆ **The 12th CIGR Section VI Technical Symposium**
October 22-25, Ibadan, NIGERIA
http://www.cigrvinigeria2018.org/

◆ **AFITA/WCCA 2018—Research Frontiers in Precision Agriculture—**
October 24-26, Bombay, INDIA
http://www.afita2018.org/afita_wcca2018/index.html

◆ **KIEMSTA 2018**
October 31-November 3, Cheonan, KOREA
http://kamico.or.kr:8001/KIEMSTA/e-main.html

◆ **GlobalG.A.P. Summit 2018**
November 5-7, Lima, PERU
http://www.summit2018.org/

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

◆ **EuroTier**
November 13-16, Hanover, GERMANY
https://www.eurotier.com/

◆ **Nebraska Power Farming Show**
December 4-6, Nebraska, USA
https://nebraskapowershow.com/

◆ **FIRA—International Forum of Agricultural Robotics—**
December 11-12, Toulouse, FRANCE
https://www.fira-agtech.com/

2019

◆ **3rd Rendez-Vous Techniques AXEMA**
February 23, Paris, FRANCE
https://cloud.agoraevent.fr/Site/144103/4647/Event

◆ **SIMA**
February 24-28, Paris, FRANCE
https://en.simaonline.com/

◆ **World Agri-tech Innovation Summit**
March 19-20, San Francisco, USA
https://worldagritechusa.com/

◆ **HortEx Vietnam 2019**
March 13-15, Ho Chi Minh City, VIETNAM
https://www.hortex-vietnam.com/

◆ **Agritechnica**
November 10-16, Hanover, GERMANY
https://www.agritechnica.com/en/

◆ **XXXVII CIOSTA & CIGR Section V International Conference**
June 24-26, Rhodes, GREECE
http://ciosta2019.com/

◆ **2019 EFITA International Conference**
June 27-29, Rhodes, GREECE
http://efita2019.com/

■■

Congratulations! Winners of ASABE Award

The 2018 Annual International Meeting of the American Society of Agricultural and Biological Engineers was held in Detroit, Michigan from July 29th to August 1st. And all major awards were presented during the ASABE Award lunchon on August 1st. We'd like to express congratulations to all the recipients and make a special mention of some of them as below:

Award	Winner
Kishida International Award	John K. Schueller
Netafim Award for Advancements in Microirrigation	Megh R. Goyal
Henry Giese Structures and Environment Award	Irenilza A. Nääs
International Food Engineering Award	Vijaya Raghavan
John Deere Gold Medal Award	Thomas Marek
Massey-Ferguson Educational Gold Medal Award	Fedro S. Zazueta
Cyrus Hall McCormick Jerome Increase Case Gold Medal Award	Hongwei Xin

Maury V. Salz took over the presidency of ASABE from Stephen Searcy at ASABE Business Meeting. Salz is President of CLAAS Omaha, Inc. Sue E. Nokes was selected as President-Elect. She is Professor of University of Kentucky.

■■

Megh R. Goyal, Our Cooperating Editor in Puerto Rico, Received Netafim Award for Advancements in Microirrigation

Megh R. Goyal, PE, is the 2018 recipient of the Netafim Award for Advancements in Microirrigation for his work introducing microirrigation technology in the Caribbean, North and South America, and India through publications, research, and extension activities for scientific and farming fraternity. Award was presented at the International Meeting of American Society of Agricultural & Biological Engineers during July 29-August 1 of 2018 in Detroit, Michigan.

Goyal is the senior editor-in-chief at Apple Academic Press in Oakville, Ontario. He is also a retired professor in agricultural and biological engineering from the University of Puerto Rico at Mayagüez. He was the first agricultural engineer to receive a professional license in agricultural engineering in the Colegio de Ingenieros y Agrimensores de Puerto Rico. He was declared the father of irrigation engineering in Puerto Rico of 20th century by the ASABE Puerto Rico section, for his pioneering work on microirrigation, evapotranspiration, agroclimatology, and soil and water engineering.

Goyal has distinguished himself through many accomplishments in microirrigation and irrigation research, extension, and teaching and through his intense promotion of agricultural and biological engineering. Many irrigation systems in Latin America and Caribbean regions are designed, developed, and managed based on Goyal's pioneering work.

Beyond his immense impact on irrigation in agriculture throughout Central and Latin America, Goyal's pioneering work in irrigation has also been applied to research and education in the medical field. He was editor on Biomechanics of Artificial Organs and Prostheses, and Biofluid Dynamics of Human Body Systems based on research and teaching materials developed by Goyal in courses on fluid mechanics, engineering mechanics, and mechanics of materials at the University of Puerto Rico at Mayagüez.

Mr. Megh R. Goyal with Mr. Yoshisuke Kishida at the ASABE Annual International Meeting 2018

Goyal is a 41-year member of ASABE. He also maintains membership with the International Soil Science Society, US committee on Irrigation and Drainage, and Indian Society of Agricultural Engineers.

Goyal has authored or coauthored more than 200 peer reviewed articles and other publications. He has edited 58 books, most notably Elements of Agroclimatology, Scientific and Technical Terms in Bioengineering and Biotechnology, and Evapotranspiration: Principles and Applications for Water Management. Recently, Goyal has been working on the publication of a multi-volume series of books on all aspects of microirrigation and agricultural engineering entitled: Research Advances in Sustainable Micro Irrigation, Innovations and Challenges in Micro Irrigation, and Innovations in Agricultural and Biological Engineering. He has received numerous awards including the Agricultural Engineer of the Year award from the ASABE Puerto Rico section, several ASABE Educational Aids Blue Ribbons and ASAE paper awards, ASAE Membership Grand Prize and the Nolan Mitchell Young Extension Worker award.

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Co-operating Editors


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M F Fonteh


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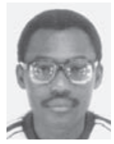
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A I Khatibu


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


M A L Roudergue


R Aguirre


O Ulloa-Torres


Y M Mesa


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S G C Magaña


H Ortiz-Laurel


A I Luna Maldonado


G C Bora


M R Goyal


A K Mahapatra


S M Farouk


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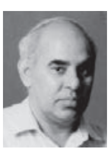
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Retirement Co-editors' Name List

Co-editor's name	Nationality	Inaugural year	Retired year	Co-editor's name	Nationality	Inaugural year	Retired year
Adrian Moens	Netherlands	1972	1989	Julien G. Van Lancker	Brundi	1981	1989
Bala Krishna Shrestha	Nepal	1972	1991	Suppiah Kathirkamathamby	Sri Lanka	1981	1991
Chul Choo Lee	Korea	1972	2014	Armed Hossain Mirdha	Mexico	1982	1991
Chau Van Khe	Vietnam	1972	1980	A. A. Valenzuela	Chile	1982	2013
Manbahadur Gurung	Bhutan	1972	2006	David Boakye Ampratwum	Ghana	1982	2011
Merle L. Esmay	U. S. A.	1972	1990	Kshirode Chandra Roy	Bangladesh	1982	1985
Giuseppe Pellizzi	Italy	1973	2012	M. H. Abdel Aziz	Saudi Arabia	1982	1991
Mohamed A. Bedri	Sudan	1973	1987	Krishna Prakash Srivastava	Ethiopia	1983	1989
Shahansha-Uddin Choudhury	Bangladesh	1973	1991	Muhammad Siddique Chaudhry	U. S. A.	1983	1991
T. B. Muckle	U. K.	1973	1978	Wimala Tissa Weerakoon	Zambia	1983	1985
Chang Joo Chung	Korea	1975	2014	Harry D. Henderson	Lebanon	1984	1985
T. Touggaard Pedersen	Denmark	1975	1990	Mohammad Afzal	Pakistan	1984	1994
Bilash Kanti Bala	Bangladesh	1976	1982	A. P. Kaloyanov	Bulgaria	1985	2013
George B. Hanna	Egypt	1976	1988	Soedjatmiko	Indonesia	1986	2014
Jun Sakai	Japan	1976	2015	Aalbert Anne Wanders	Netherlands	1988	2007
Siswadhi Soepardjo	Indonesia	1976	1985	Ali Mahmoud El Hossary	Egypt	1988	2010
Tieng-Song Peng Taiwan	Taiwan	1976	2015	Chanchai Rojanasaroj	Thailand	1988	2011
Mohammad Ilyas	Pakistan	1977	1981	Edward A. Baryeh	Zimbabwe	1988	2014
Amala Prasad Sharma	Fiji	1978	1981	T. P. Ojha	India	1988	2015
Arumugam Kandiah	Ethiopia	1978	1989	Eltag S. Eldin Mahmoud	Sudan	1990	2011
Bherulal T. Devrajani	Pakistan	1978	2004	Henrik Have	Denmark	1990	2009
John Kilgour	U.K.	1978	2014	Graeme Ross Quick	Australia	1995	2015
Satish Chandra	Fiji	1979	1990	Rafiq ur Rehman	Pakistan	1995	2015
Jitendra P. Mittal	Nigeria	1980	1993	Abdulsamad Abdulmalik Hazza'a	Yemen	1999	2014
Naresh Chandra Saxena	India	1980	1988	Yunus Pinar	Turkey	1983	2016
Paris Andereou	Lebanon	1980	1984	William J. Chancellor	U.S.A	1972	2017
Wang Wanjun	China	1981	2012	Kunihiro Tokida	Japan	2016	2017
Allah Ditta Chaudhry	Pakistan	1981	2015	Shujun Li	China	2012	2018
Allan L. Phillips	U. S. A.	1981	2004				

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Vol.48, No.3, Summer 2017

INSTRUCTIONS TO AMA CONTRIBUTORS

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

Criteria for Article Selection

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

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

Rejected/Accepted Articles

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

Procedure

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

Format/Style Guidance

a. Article must be sent by E-mail with Word File and PDF File attached.
b. The data for graphs and photographs must be saved into piecemeal data and enclosed (attached) with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
(i) brief and appropriate title;
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d. Tables, graphs and diagrams must be numbered. Table numbers must precede table titles, e.g., "Table 1 Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Fig. 1 View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies **in US dollars** and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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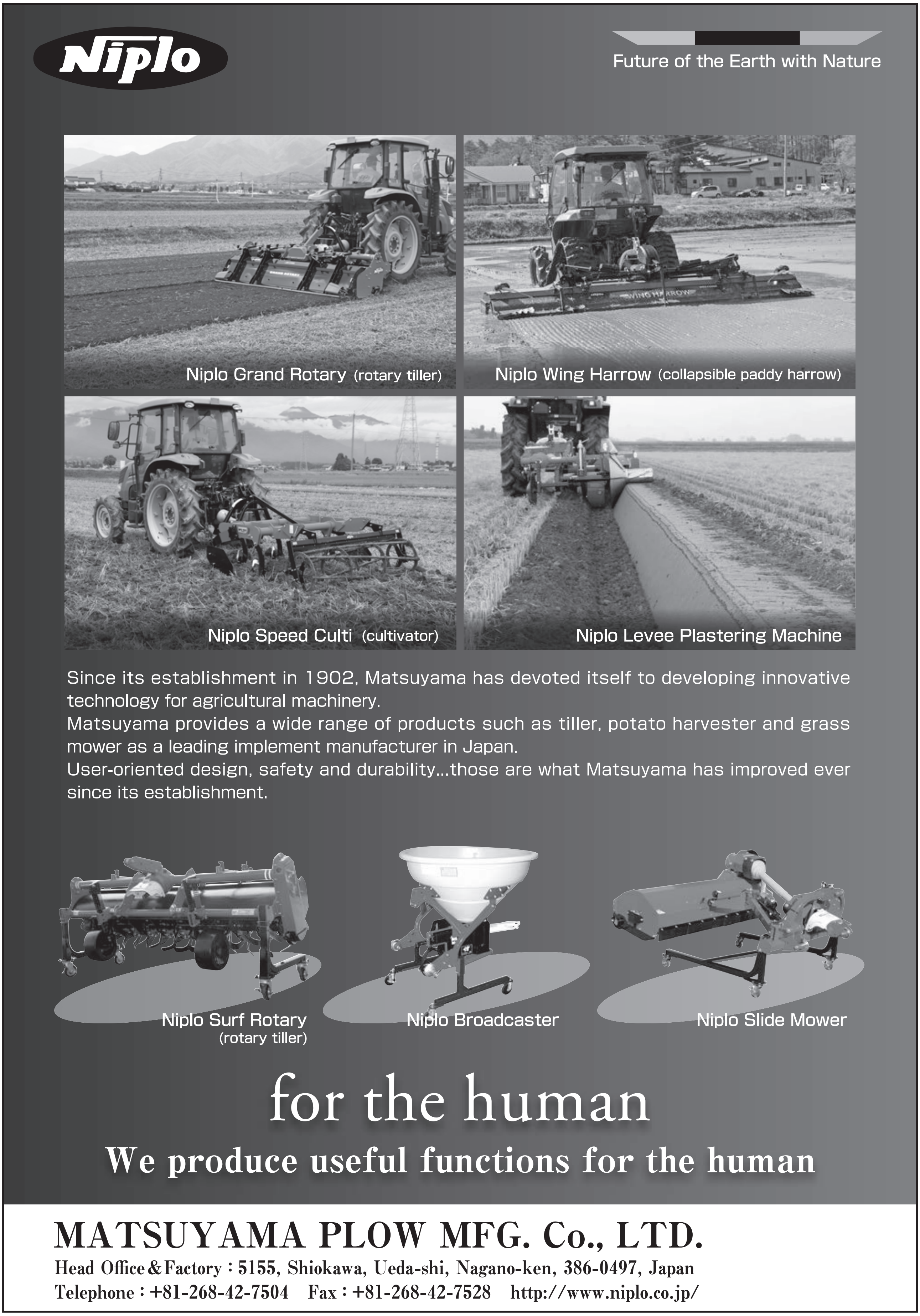
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