Compact Crop Cutter and Thresher

Akshay D Barbade, Sagar D Girase, Manoj A Deore, Kaustubh D. Patil

ABSTRACT- Rice harvesting and threshing is done manually in Punjab whereas in Sindh, harvesting is done manually and threshing by tractors as well as bullocks treading. The reconditioned wheat combines are also used for rice harvesting in Punjab. These are insufficient in number and hardly cover 40 percent rice area in Punjab. These are not properly adjusted for rice harvesting and are operated by poorly trained operators. This results in sizable field loss and internal damage to harvested rice grains and hence affects its milling quality. Agricultural mechanization refers to interjection of improved tools, implements and machines between farm workers and materials handled by them. Independent India ushered in a process of agricultural mechanization and revival of rural agroprocessing which got acceleration during post-Green Revolution period. Irrigation pump sets, power threshers, tractors, power tillers and matching implements, including for 65Million draft animals have became popular. Seed and seed-cumfertilizer drills, planters, mechanical rice transplanters, vertical conveyor reapers, and combines soon followed. In the recent past, Zero-till Drill and Raise Bed Planters have found good acceptance from the farmers. Currently mechanization is in increasing demand. Farmers and policy makers and developmental agencies now realise that for increasing production and productivity at reduced unit cost of production, free of arduous labour, agricultural mechanization is essential. It is brought in centre stage with globalization of world markets. Introduction of electromechanical power units supplementing and substituting traditional animate sources of farm power is going to continue. For achieving desired intensity of cropping average farm power requirement of 2 kW/ha is considered essential, currently it is 1.15kW/ha. Shifts in agriculture leading to crop diversification towards horticulture, animal husbandry fishery, forestry and on-farm agro-processing are going to bring in greater degree of mechanization. India dominated by small and marginal land holdings may not have same trend of mechanization as the developed world but it is going to grow close to it with its own variant as labour wages go up and WTO Competition compels us to keep reducing unit costs of production, processing, packaging, and retail and situations demanding provision of custom servicing, custom agro-processing and acceptable standards of living.

Keyword- Rice, processing, Sindh, Agricultural, WTO, Punjab, policy, Introduction

I. INTRODUCTION

There is scope of mechanisation in every unit operation of production agriculture, post-harvest and agro-processing, and rural living. Mechanisation has varied connotations. While in the developed world it tends to be synonymous to automation but in developing countries, like India, mechanisation means any improved tool, implement, machinery or structure that assists in enhancement of workers' output, multiplies the human effort, supplements or substitutes human labour that is enabling and removing, avoids drudgery or stresses that adversely affect human mental faculties leading to errors, imprecision and hazards and eventually loss of efficiency. It also means automation and controls that assure quality, hygiene. Agricultural mechanisation in a limited sense relates to production agriculture. Rice is an important crop for local consumption and export. Generally it is grown on an area of 2.3 million ha with production of about 4.8 million tons. The country earns about Rs. 30 billions foreign exchange through its export. Harvesting and threshing play a significant role in realizing the full benefit of raised crop by reducing post- harvest losses as well as improving quality of milled rice. In Pakistan, the harvesting and threshing is done manually except in Punjab where 40 percent area is harvested by combines. There is a sizeable grain loss and damage during harvesting and threshing with traditional manual practices and by use of old and reconditioned wheat combines by poorly trained operators. With the migration of rural labor to the cities for better employment opportunities, there is acute shortage of labor during peak rice harvesting and threshing period. This causes delay in rice harvesting and threshing and thus increases both quantitative and qualitative post- harvest losses. Because of insufficient number of combines and difficulty in manual threshing of Super Basmati rice which is occupying 70 percent Basmati area in Punjab, the paddy growers of Super Basmati prefer to get their crop combined on their availability in their areas even if it is not fully matured and thus suffer loss due to lower price of their produce. In this paper, the effect of harvesting method and harvesting time, grain moisture content, threshing method and time on yield losses and grain quality has been discussed.

II. IMPORTANT LAND MARKS

Colonial India had witnessed many droughts and famines and some of them very devastating. Founding fathers of modern India took upon themselves a responsibility to avoid famines. To this effect they accorded high priority to agriculture and allied activities. Agricultural education, research and development infrastructure were strengthened. State Agricultural Universities on the pattern of American Land Grand Colleges with integrated teaching, research and frontline extension were established starting 1960 providing trained human resource, location specific technologies and their frontline demonstrations. Indian Council of Agricultural Research (ICAR) reorganised itself (1965). The commodity institutes with the Deptt. of Agriculture and Cooperation and Central Commodity Committees were transferred to ICAR leaving tea, coffee, silk etc. Central and State Governments invested in infrastructure development to provide irrigation water, seed, fertilizer, pesticides and credits, minimum support price (MSP) and buffer stocking to prevent wild fluctuation in market prices besides food security. However,

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food security eluded India for two decades, food imports at times being the largest import bill of the country. India witnessed Green Revolution in 1967-68 and subsequently White Revolution, Blue Revolution and Yellow Revolution, achieving quantum jumps in production and productivity in foodgrains, milk, fishery, and oilseeds, respectively. It is experiencing horticultural revolution, revolution in poultry production. Peers and policy makers are looking towards Evergreen Revolution.

III. RICE HARVESTING

Harvesting of rice generally refers to all operations carried out in the field till the crop is transported to the threshing plate form except for combining and strip harvesting. These include cutting the rice stalk or reaping the panic les, either laying out the paddy-on-stalk or stacking it to dry, bundling and transport. The rice is harvested manually and by using mechanical means. The manual harvesting has been mainly practiced in developing countries and least developed countries. Whereas mechanical harvesting using reaper-windrower, reaper-binder, combine harvester and stripper harvester is employed in developed countries. A. Manual Harvesting Methods a. Panicle reaping. This is accomplished by using a hand-held cutting tool or knife (called *yatab* in the Philippines and *ani-ani* in Indonesia and *kae* in Thailand). A quarter-circle blade fixed cross-wise on a wooden, grip-sized handle is passed between the index and the middle fingers which grab the panicle stems and execute the cutting action by pressing the panicle stems against the blade. The method is still used in areas where the traditional varieties are grown which are resistant to shattering, an important feature when handling and transporting. The bundles of panicles from the field to the house. The labor required for panicle reaping (240 labor-hour/hectare) is at least four times more than hand sickle harvesting. It is advantageous over the stalk cutting by sickle when fields are flooded or terraced, as in the hilly areas that are inaccessible by wheeled vehicle. The carrying capacity of transport labor is more than that when the straw is cut long by sickle. In addition, it is an income source for the landless rural folks. Long-stalk cutting by sickle. The stalk is cut by sickle about 10-15 cm above the ground. There are many variations in sickle design, depending on the socio-cultural acceptance of the harvesting labor. After cutting, the stalks are laid in small bundles on the stubble to dry their ears for two or three days. In some places in Thailand the bundles are sized such that each one will give about 10 kg of paddy and laid up on the field for a few days to dry up. The reaping efficiency depends upon the plant density and variety, degree 0 f lodging, the soil condition and the skill of the harvester. Lodged paddy and saturated soils may reduce the cutting rate by 50 %. This method is efficient than panicle reaping as it requires 60-80 labor hours to harvest one hectare of rice crop. Additional 100-200 labor-hours are required for manual gathering and binding of one hectare harvested crop.

IV. GROWTH IN AGRICULTURAL MECHANIZATION

With the introduction and growth of tractors in India in production of matching equipment for scraping and land levelling, seedbed preparation, seeding and planting, seed-cum-fertilizer drilling, spraying and dusting, harvesting and power threshing, 2-wheel and 4-wheel tractor trolleys got in to indigenous manufacture and these got reserved for Small Scale Industries (SSI) sector. It became a very competitive farm equipment industrial activity in Punjab and in pockets all over the country. However, to enhance quality of farm equipment many items have been dereserved, now. By early 1980s vertical conveyor reapers (VCR) were introduced to mechanise sickle harvesting, initially walking type, then a larger tractor version and subsequently riding type self propelled units. During 1982-84 production of tractor mounted VCRs increased ten fold each subsequent year reaching to 3000 in third year but got reduced to 2000 annual production in the fourth year, the year insurgency in Punjab touched its peak. At this point of time Punjab farmers found combining of rice and wheat cheaper and less risky. Several manufacturers (29) in Small Scale Sector took to general purpose standard grain harvesting combines by manufacturing tractor mounted, self propelled and tractor driven versions. Combining, however, created problem of rice and wheat straw gathering, transforming and handling as Bhusa. Straw disposal through incineration was found creating serious environment pollution whereas straw incorporation in to the soil was leading to nitrogen stealing. Invention and introduction of straw combines did provide a solution to reclaiming wheat Bhusa but still about 50-60% of the rice and wheat straw is being disposed by burning. It may not be entirely due to combines, demand for wheat bhusa has also declined. Its transport to feed deficit areas in loose farm is expensive and uneconomical. Complete feed block buffer stocking to fight feed famines is a possibility.

These amendments in agriculture were accompanied with due inputs of mechanisation in natural resource development, agricultural field operations and on-farm primary processing. After intensive testing and evaluation in late 1950s, manufacturing of irrigation pumping sets commenced. Initially two-thirds were engine operated and one-third electric operated. As rural electrification advanced, proportions have changed in favour of electrical power. Animal drawn improved equipment such as seed drills, seed-cum-fertilizer drills, 5 hp power threshers primovers like diesel engines, electric motors got into manufacture and use. Central Tractor Organisation (CTO) established soon after independence to reclaim marshy lands in Tarai of UP and scrub forests elsewhere to settle displaced people who came from across the border set the pace of tractorisation in India. CTO used crawler tractors, their operation, upkeep and later on indigenous fabrication of certain fast wearing components, after OE stocks exhausted, were locally developed. For tractorisation of agricultural field operations around mid-1960s small 4-wheel general purpose tractors were brought in CKD (completely knocked down) condition and assembled, marketed, operated, and serviced by training Indian technicians. Confidence thus gained resulted in progressive indigenous manufacture. Swaraj 35 hp from M/s Punjab Tractor was the first totally indigenous tractor. A little later two-wheeled tractors popularly known as power tillers were introduced and at one stage more than a dozen firms had manufacturing licenses.

However farming system in vogue, wet cultivation during kharif and upland farming during rabi, and lack of proper after-sales-services support adversely affected their growth. All but two Mitsubishi and Kubota by M/s VST Tillers, Bangalore and M/s Kerala Agro- Industries Corporation survived. Today India is the largest producer of tractors in world with about 2,75,000 tractors per year and about 15,000 power tillers. Chinais able to market its power tillers in India at cheaper prices, nevertheless there are after sales service problems in many cases

V. MECHANICAL HARVESTING METHODS

Unless labor in harvesting has become scarce in a locality due to industrialization or migration to employment from rice areas, rice harvesting will continue to be done with the sickle method in most developing countries. In the Philippines, the income or share in kind (usually 1/6 of the harvested paddy) gained by a manual harvester is high compared with other field operations. In times of calamity as in a typhoon where the rice crop is lodged and soaked, a farmer-owner is sometimes constrained to share up to 1/2 of the harvest to the harvesters rather than lose the crop altogether. The following mechanized harvesting methods are used depending upon the custom and the suitability of the machine to the soil conditions and the crop being harvested, the local custom, affordability of the machine, and other socio-economic factors.

(a) Wind-rower. This cuts and unloads paddy only laterally. These machines have theoretical work capacity varying from 4 to 8 hlha but need big labor force (100 to 200 h/ha) for manual gathering and binding of the paddy.

(b) Reaper-bindero.- This had once been popular in Japan but is being replaced by the combine. The machine cuts and bundles the stems together and lays them in the field in one operation. Equipped with a cutting bar and a gathering and binding device, these machines do good work even in harvesting lodged paddy (20°-30° angle to the ground). Depending on their construction features (adjustability of height, width of cutter), the work capacity of these machines vary from 5 to 20 h/ha with grain losses lower than 2 percent. In addition to the above methods, combines and strippers are also used to simultaneously harvest and thresh paddy and have been described under paddy threshing section.

VI. HANDLING OF HARVESTED CROP

The gathering and bundling of the harvested crop (by manual labor with sickle and reaper windrower) needs 100-200 labor hours. Each additional handling step causes losses (Naphire, 1997) which varied from 1-2 % (Samson and Duff, 1973), and 2-7 % (Toquero and Duff, 1974). In-field transport which includes bundling of the cut stalks causes 0.11 to 0.35 % losses. Field stacking of the harvested crop can incur losses ranging from 0.11 to 0.76 %. The longer the stack is left in the field, particularly where the grain moisture content is high, the greater is the degree of loss. Heating of the harvested crop stack causes yellowing of the rice grains due to attack of micro-organisms and fermentation.

VII. FACTORS AFFECTING GRAIN LOSSES

Harvesting Time

Table1. Effect of Harvesting Time on Grain Losses

Harvesting Time	Grain Losses (%)
One week earlier than maturity	0.8
At maturity	3.4
One week after maturity	5.6
Two week after maturity	8.6
Three week after maturity	40.7
Four week after maturity	60.5

Source: Almera 1997 (Taken from IRRI Table 3.1.1 authored by Ray Latin and edited by AGSI/F AO) web site www.fao./inpho/compend/text/ch

Table 2. Harvesting losses related to condition of ripeness of rice

Harvesting system	3 days before normal stage %	Normal stage for traditional %	3 days after normal stage %	5 days after normal stage %
Traditional hand Cut	6.00	8.70	10.50	12.00
Reaperbinder	1.00	3.10	1.20	5.80
Combine harvester	2.00	3.10	1.20	5.80

Source: Hilangalantileke (Taken from IRRI Table 3.1.4 authored by Ray Lantin and edited by AGSI/FAO) web site www.fao./inpho/compend/text/ch

Proper time is important in harvesting the crop as losses increased with delay in harvesting. Recommended harvesting time of rice is one week before the maturity date. Harvesting systems and time of harvesting profoundly affect the extent of losses. I n case of traditional system of harvesting, the harvesting losses are minimal at 3 days before normal stage (ripeness) and increase linearly as the harvesting is delayed. In case of reaper binder, the losses are least at 3 days before normal stage and then increase but their pattern is inconsistent. But in case of combine harvester, the minimum loss is at 3 days after normal stage (Tables 1 and 2). Premature cutting of the rice keeps the grain from reaching maturity, and can cause serious losses in the quality of the product. Furthermore immature grains due to too early harvest result in high percentage of broken and low milling recovery. Maximum head rice recovery was obtained when the rice crop harvested at 35 days after 50 % flowering at moisture content ranging from 20-30 %. The recovery reduced with delay in harvesting beyond this time. Harvesting 33-39 days after 50 % flowering gave significantly higher head rice recovery than 27 30 days or 42 days after flowering (Table 3) (Ali et al1993 and Salim and Sagar, 2003). Delayed harvesting also exposes the crop to insects, rodents and birds, in addition to increased risks of lodging and grain shattering. The ideal is to be within the window of optimum harvest period.

Table 3. Effect of Harvesting Intervals after 50 % flowering of Basmati in Pakistan

Harvesting interval (days)	Moisture (%)	Total milled rice (%)	Head rice (%)
27	27.8	68.2	C 49.6
30	25.3	69.1	B 52.8 bc
33	22.9	70.2	A 54.5 a
36	20.3	70.4	A 54.6 a
39	17.9	70.4	A 53.8 ab
42	15.5	70.3	A 81.9 c

In a column, means followed by a common letter are not significantly different at 5 % level by DMRT Source: M. Salim. and MA. Sagar 2003) The indicators of optimum harvest of grains are as follow:

a) The variety has reached the particular date of maturity or number of days after heading, i.e. 28 to 34 days

b) Eighty percent (80 percent) of the grains or the upper portion of the panicle has changed from green to straw color;

c) At least 20 percent of the grains at the base are already in hard dough stage;

d) The hulled grain is clear and hard

VIII. RICE THRESHING

Paddy threshing involves the detachment of paddy kernels or grains from the panicles through rubbing action, impact; and stripping. The rubbing action occurs when paddy is threshed by trampling b y humans, animals 0 r tractors. The impact method is the most popular method 0 f threshing paddy. Most mechanical threshers primarily utilize the impact principle for threshing, although some stripping action is also involved. The third type, stripping has also been used in paddy threshing. Some impulsive stripping occurs ordinarily with impact threshing in conventional threshing cylinders. Paddy threshers may either be hold-on or throw-in type on the basis of paddy feeding method. In the hold-on type, paddy straws are held stationary while threshing is done by the impact on the particle from cylinder bars, spikes or wire loops. In the throw-in type, whole paddy stalks are fed into the machine and a major portion of the grain is threshed by the initial impact of the bars or spikes on the cylinder. The initial impact also accelerates the straw and further threshing is accomplished as the moving particles hit the bar and the concave. In the throw-in type of thresher, large amounts of straw pass through the machine. Some designs utilize straw walkers to initially separate the loose grain from the bulk of straw and chaff.

Manual-Threshing. In this method, threshing is accomplished by either treading, beating the panicles

on tub, threshing board or rack, or beating the panicles with stick or flail device. The pedal-operated thresher (Fig 2) consists of a rotating drum with wire loops, which strip the grains from the panicles when fed by hand. It can also be operated by women and can be used in hilly or terraced areas because of its portability. Machines driven by a manual device or a pedal are often used to improve yields and working conditions during threshing. By means of the handle or pedal, a big drum fitted with metal rings or teeth is made to rotate. The rice is threshed b y hand-holding the sheaves and pressing the panicles against the rotating drum. The speed of the threshing-drum must be kept at about 300 revolutions per minute (rpm). The hand-held sheaves must all be of the same length with the panicles all laid in the same direction, and the grains must be very ripe and dry. The machine must be continuously and regularly fed, but without introducing excessive quantities of product. If the paddy obtained contains too many un-threshed panicles and plant residues, a second threshing must be followed by an effective cleaning of the product. Use of these threshing machines may require two or three workers. Depending on the type of machine, the skill of the workers and organization of the work, yields can be estimated at a maximum of 100 kg/in.

Power Threshing. Treading of the harvested crop under tractor tires (Fig 3) is a method used in some Asian countries. The popularity of this method can be attributed to its convenience and the lack of suitable tractor PTO-driven threshers. The grain is separated from the straw by hand and then cleaned by winnowing. Most, if not all powered paddy threshers are equipped with one of the following types of cylinder and concave arrangement: (a) rasp bar with concave (b) spike tooth and concave (c) wire loop with concave (d) wire loop without concave. Testing carried out at International Rice Research Institute (IRRI), Philippines indicated that the spike-tooth cylinders performed well both with the hold-on and the throw-in methods of feeding and its threshing quality is less affected bychanges in cylinder speed. In the axial-flow thresher, the harvested crop is fed at one end of the cylinder/concave and conveyed by rotary action on the spiral ribs to the other end while being threshed and separated at the concave. Paddles at the exit end throw out the straw and the grain is collected at the bottom of the concave after passing through a screen cleaner. Several versions of the original IRRI design of the axial-flow thresher have been developed in most countries to suit the local requirements of capacity and crop conditions. Thus, there are small-sized portable ones and tractor PTO-powered and engine-powered ones. Many custom operators in Asia use the axial flow threshers to satisfy the threshing and grain cleaning requirements of rice farmers. There is a need to dry the harvested rice in the field for better performance of the threshers. However, in order to maintain the high quality of the harvested grains, it should be threshed immediately after harvesting. Avoid field drying and stacking for several days as it affects grain quality due to over drying. Stacked grains of high moisture content results in discoloration or yellowing.

Combine: The small combine has become popular in Japan since the 1960s. The Republic of Korea has also manufactured it commercially since the early 1980s. It is gradually being introduced in other Asian countries but primary hurdle to adoption is the high initial cost and adaptability to local conditions. The selfpropelled machines have cutting widths of 50 to 150 cm and have capacities of about 0.5 ha/h 1997). Thailand has local versions of large combines popular in developed countries and is being adopted because of the increased costs and scarcity of labor. As a rice-exporting country, Thailand attempts to mechanize rice production and processing operations. Vietnam may also adopt mechanized methods because of economies of scale. Although Malaysia is a net importer of rice, it depends on modified large combines imported second-hand mainly from Europe to harvest its rice crop.

Large combines are being used in commercial rice production in countries like Brazil and Uruguay in Latin America and in Europe and the USA. Their introduction and field use in some African countries through aid programs is under much criticism as to their appropriateness in situations where ready and efficient repair and maintenance facilities and services are not available. In California rice is harvested by large, self-propelled grain combines which cuts the entire plant and separates straw from grain internally (Fig. 4). The following situations hinder the adoption of combine harvesters.

(a) Low income, inability to raise capital, reluctance to change traditional methods, poor Mechanical aptitude and the desire to save straw for uses other than farm.

(b) Small 1 and holding, very small plot size with high bunds, poor water control, inadequate ground support and poor traffic ability for powered harvesting equipment, and lack of access of roads to the fields. In case of combine-harvesters, these should be equipped with tracks, rather than wheels, so that harvesting can be done even on very wet ground. (c) Excessive moisture content at harvest time, uneven ripening, severe lodging and entangling of paddy (specially the traditional long-stalked varieties), and high-shattering and low grain straw ratio varieties. (d) The rice husks contain silica, which gives them a highly abrasive quality that provokes rapid wear on the moving parts of the machines.

Stripper Harvester. This is an innovation Item the International Rice Research Institute (IRRI), Philippines which adapted the rotary stripping comb principle developed by the Silsoe Research Institute in Silsoe, U. K. The rice stripper ideally works with a variety which is non-lodging, of medium stature with erect panicles, and have low to medium shattering. A high grain: straw ratio is advantageous in achieving high harvesting productivity. The IRRI-designed pedestrian stripper-gatherer has undergone several field trials in more than 20 rice-producing countries since 1994 and the reactions to the machines were mostly favourable, except when the machine has to be used in wet or soft fields where traction is a problem. Efforts however, are needed atom the national institutions in the various countries to extend the machine to farmers or to harvesting custom operators and to modify the machines to suit local soil and crop conditions. The local manufacturers must first be trained in its fabrication and in the provision of efficient and reliable after-sales services. The attempt to make a small and ride-on combine version of the machine has been beset by traction and floatation problems in wet and soft soils. The design and development activities on it have been discontinued or suspended by IRRl. There is still a lack of functionally and economically suitable equipment for tropical conditions due to inadequate research, development and thorough field-testing activities in the developing countries in mechanical harvesting. The high cost of imported equipment and the requirement of good machinery management must compete with relatively low-cost labour. In Pakistan, both IRRI designed axial-flow and Korean hold-on paddy threshers were evaluated, adapted and got locally developed by the Farm Machinery Institute (FMI) of the Pakistan Agricultural Research Council (PARC), Islamabad. But these were not accepted because of their low output. Recently a larger capacity (1.5 ton/hour) version of tractor operated paddy thresher built on IRRI axial flow concept was imported from Thailand by the FMI. It was evaluated on IRRI paddy variety and demonstrated extensively in Sindh. On its acceptability among large IRRl paddy growers in Sindh, it has been got locally developed. Large and self propelled combines imported from the West were also introduced in the country for wheat harvesting in early Eighties. With increase in prices of these combines, reconditioned combines are being brought in the country and are available at approximate price of Rs 1.2 million. These are also being used for paddy harvesting since mid Ninety. The Japanese head feeding combines brought under KR-2 Grant in late Ninety are also used for paddy harvesting. Presently 30-40 percent of paddy area in Punjab (Pakistan) is harvested by combines particularly Super Basmati (difficult to thresh by manual labour). The harvesting charges are Rs. 2500 and 6200//ha for reconditioned and Japanese head feeding combines, respectively.

The higher charges for Japanese head feeding combines are due to little grain breakage and saving of paddy straw by their use. The manual harvesting and threshing of paddy charges varies from Rs. 3500 to 4500 per hectare. Like reaping of rice, there are not much studies conducted in the country on threshing of nee. The results of loss assessment study conducted by JICA in Pakistan on mechanized reaping and threshing of paddy (Anonymous, 1986) indicated: a) The average reaping loss with reaper was 0.3 %t. b) The average reaping loss with auto combine and combine were 1.1 and less than 0.3 %, respectively c) 4.0 and less than 1.3 %, respectively. d) The quality loss including non-husked and increased ratio of cracked kernels with auto combine and combine were 4.1 and 3.0 %, respectively. In another study conducted by PHMP in collaboration of Rice Program and FMI, NARC; Rice Institute, Kala Shah Kaku (Ahmad, T. et al, 2004) on "Effect of paddy harvesting method on rice quality and head rice recovery" have indicated: a) There is statistical significant effect of harvesting methods on milling yield in tons of head rice recovery (%) and broken rice (%) at 5 % level b) The mean value of head rice recovery (49.5%) of manual harvesting and threshing method was higher than conventional and head feeding combines harvesting.

The mean value of head rice recovery was higher in head feeding combine harvesting (46~5%) than conventional combine harvesting (44.9%). c) A positive correlation of 0.74 was found between harvesting stage and moisture contents of harvested paddy grains. d) There was not any statistically significant difference found of harvesting stages on head rice recovery (%) and broken rice (%) at 5 % level. The head rice recovery increased with harvesting stage up to 2 green grains and after that the effect of harvesting stage is inconsistent. Similar trend was observed in case of broken rice.

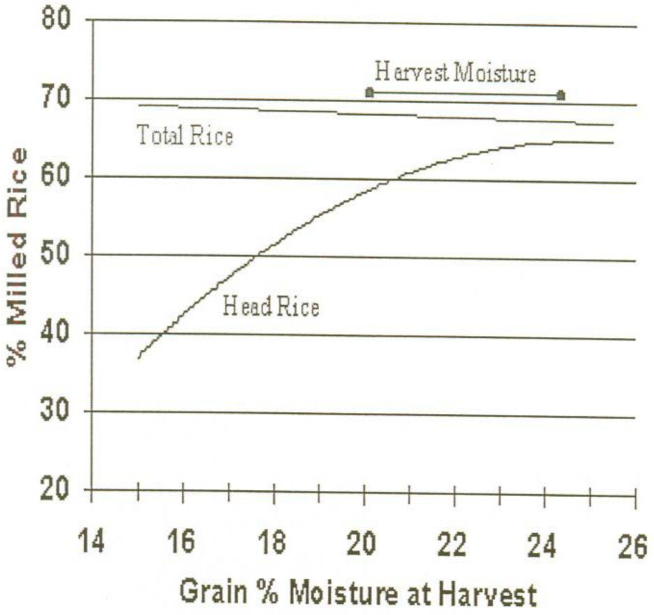

Figure 1. Effect of Grain Moisture Content at Harvest on Milling and Head Rice Recovery

Figure 2. Small Pedal Operated Rice Thresher

Figure 3. Rice Threshing by Tractor

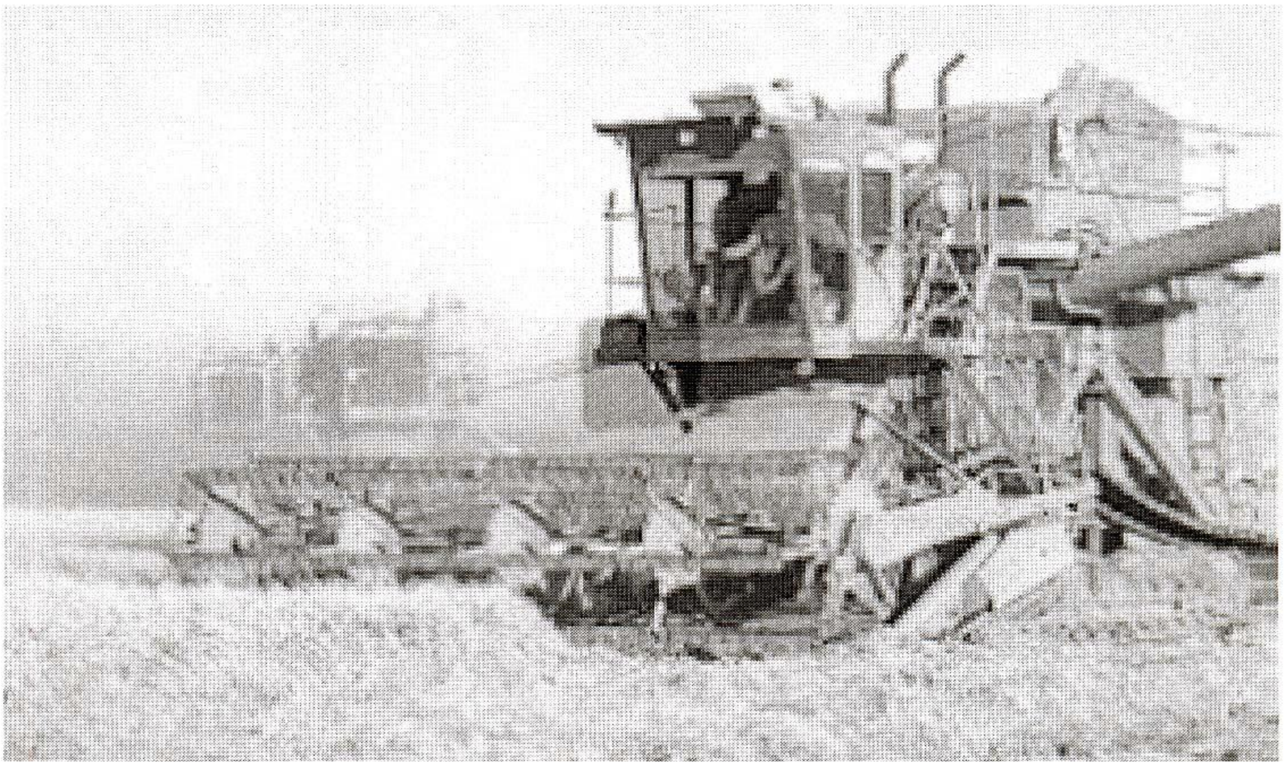

Figure 4. Typical self-propelled rice combine harvester.

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Farm Power Units

1. Animate energy, both human and draft animals (DAP) will continue to be important sources of farm power specially on small and marginal farms, hill agriculture, horticultural crop cultivation, animal husbandry and fishery. However, use of DAP is likely to decline slowly and may stabilize around 20-25 M pair of bullock equivalent. Due [to lack of opportunities in other sectors of Indian economy, use of human as farm workers is likely to grow but at a slow rate with elements of under employment.
2. There is going to be increasing demand for riding type farm equipment. Animaldrawn tool carriers under different brand names are going to get in use. Likewise riding type power tiller farm operations will be in demand. Some power, no doubt is lost in transport of the operator and the tool carrier, but the loss is more than made up through gain in net operational time due to favourable work-rest cycle in a riding type manmachine System. Drudgery to the operator is minimized.
3. R&D in yokes and harnesses, draftability studies are going to create more dynamic DAP use systems, use of unequal animals, DAP of two different species are likely to come up.
4. Small engines (1-3 hp) for handheld and knapsack power operated equipment for pruning/coppicing, hedge trimming, cutting of bushes, tree felling, tea harvesting, spraying, and dusting etc are likely to become popular.
5. Due to global competition agricultural enginesdiesel, petrol, kerosene, biofuel are going to be better through superior metallurgy and manufacturing processes. Advances in combustion chamber designs, fuel injection etc shall make them more fuel efficient. Noise and vibration problems are going to receive greater attention.
6. Paucity of petroleum reserves is going to bring biofuels - alcohol from sugarcane, molasses, corn cob etc and non-edible vegetable oils certified for use as biodiesel.
7. For stationary operations for shaft power, electrical power generation, and process heat for agro-processing alternate energy sources such as producer gas from crop residues, farm and roadside grown energy plantations, processing wastes like rice husk, groundnut shell etc are going to find greater acceptance. Solar Thermal System and Thermal Power Units run on crop and processing residues are likely to gain popularity as standalone power units.
8. Light weight and modular PT for hill agriculture/ terraced farming are going to appear using diesel and bio fuels.
9. Average farm power availability is going to go up from current 1.15 KW/ha to 2 KW/ha for desired intensity of cropping and to assure timeliness.

IX. RURAL LIVING

1. In a village eco-system, 80% of the total energy spent goes to domestic sector and of that 80% goes for cooking. Fetching of drinking water, collection of fuel wood are ordeal to rural women and children. Rural kitchens are full of smoke, illilluminated, cause of many health hazards. Quality of fuel decides quality of life to a housewife, rural or urban alike. In that scenario biogas stoves, pyrolysed briquetted fuel and sigdi, biogas lantern, biogas run ovens; solar cookers - individual and community type, solar water heaters are under promotion and are likely to increase in number supplementing and substituting conventional cooking and water heating.
2. With the rural electrification in India, refrigerators are reaching rural homes which provide capacity to store perishables safely and prevent wastage. 3. Pressure cookers which are energy efficient are also reaching rural homes.
4. Other kitchen appliances like mixer grinders, electric iron, electric fans and lights are being used in electrified villages.
5. Butane supply to rural areas is gradually spreading which is going to conserve fuel wood and other biomass for organic recycling.
6. Smokeless cooking stoves that are energy efficient therefore, under promotion in a big way.
7. Hapur Kothis, metallic air tight storage bins have found acceptance that keep the food grains safe protected from rodents, and enable fumigation in the event of infestation.
8. Ata chakkis are doing custom milling likewise motorised wet grinders have become popular reducing drudgery in rural home. Single phase electric motor run cleaning grading and size reduction equipment also open avenues of custom servicing to other.
9. Rural water supply and sanitation and rural roads and public transport are gradually growing. Dry and wet type bore hole latrines provide cheap sanitation to rural homes
10. Biogas plants, composting, vermi-composting allow rural people to convert organic wastes in to wealth extracting energy, and plant nutrients in litter free, fly free, incineration free manner.
11. Rural agro-processing centres and other home level agro-processing and craft activities using mini-burr mill, solar dryers etc are enabling additional income and employment in spare time.

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