REVIEW OF LITERATURE
II. REVIEW OF LITERATURE

In an effort to know in detail the post harvesting losses of rice, an attempt has been made to review the earlier works done on conventional harvesting and rice combine harvester as this study on developing a mathematical model to assess post harvest grain losses in rice combine harvester.

2.1 Losses in conventional post harvest system

Harvest is a crucial time for rice farmers everywhere. They are anxious to reap the rewards for the season’s effort. Harvest is more of a bottleneck in the humid tropics for paddy growers facing complex of weather and labour issues. Rice is a highly vulnerable crop once it reaches maturity. Delay in harvesting results in serious losses in quantity and quality.

Manual harvesting of paddy using sickle is widely prevalent. The sickle varies in curvature, size, thickness and weight depending upon the locally available blades. The blade serration is inclined towards the wooden handle. After cutting, the paddy stalks are left on the ground, tied with same stalks to form a bundle the size of which depends upon the choice of the harvester, paddy cultivation and
threshing methods. Harvested stalks are transported from the field to the threshing yard mainly by head carry, shoulder carry and by animal pulled carts.

Paddy is a difficult grain to thresh because it is hard to strip from the panicle. A spike-tooth threshing type cylinder is usually used because of it demands aggressive threshing action. Paddy should be threshed as soon as it ripens to avoid crackage by the sun.

The sequence of manual harvesting, field drying, bundling and stacking in traditional systems can incur losses from 2 to 7 percent. In field transport, which includes bundling of the cut stalks, transporting is done either manually or by animal pulled carts, where losses range from 0.11 to 0.35 percent. Field stacking of the harvested stalks incurs losses ranging from 0.11 to 0.76 percent. The longer the stack is left in the field, particularly where the grain moisture content is high, the greater is the degree of loss (Samson and Duff, 1973).

Duff and Toquero (1975) reported that, depending upon the number of times the harvested stalks are handled from the field to the threshing yard, shattering loss increases at 7 per cent at every stage.

The manual harvesting losses for the first crop of rice (July to Nov) in the farmers’ field at Kampaengsan District, Nakhon Pratom
province, the total harvesting and binding losses were 4.9 percent and 5.9 percent at 21.6 percent (wb) and 15.9 percent (wb) of grain moisture content, respectively, while at a grain moisture content of 15.8 to 21.6 percent (wb), the total losses were about 5.5 percent, including harvesting losses of 3.9 percent and binding losses of 1.6 percent (Khunchom Na Ayutaya, 1985).

Ilangoantilalce et al., (1987) reported that the increased demand for food resulted in an increase in food and agricultural products in Asian countries. Along with high yields there has been an increase in grain losses in post harvest operations, mainly in the handling of grain harvesting.

The post harvest rice loss assessment comprises of harvesting, field stacking, field transport, threshing, cleaning and drying. During these operations the losses ranges from 7.3 to 9.9 percent. More than 80 percent of farmers are sure that loss exists in the post harvest operations (Haque et al, 1988). They attribute the main causes of loss to the carelessness of hired labour, varietal characteristics, shortage of labour and time.

The time of harvesting of paddy is an important variable, which governs the field yield, threshability, seed germination and head yield.
of rice and cutting energy required for harvesting. The Ratna variety should be harvested after 32 to 42 days after flowering (panicle moisture content 18 to 23 %) to get maximum field yield of paddy (Varshney et al., 1988).

Harvesting of crop is the most labour consuming field operation in paddy cultivation. Efficient harvesting is a main factor that reduces grain losses. Due to rapid urbanization and migration of farm labour to cities a big vacuum lias been created in the supply of Farm labour. The paucity of labour force has been forcing the farmers to opt for mechanization.

Harvesting and its handling operations are significant factors in the post production sequence as grain losses are incurred at every stage. Each additional handling step results in the loss of 1 to 2 percent, for highly shattering varieties (Shreuddin Bukhari et at 1991).

The harvesting of crops in India is mostly done manually using sickles. The mechanized harvesting of crops is at a low level in India. The socio-economic condition of farmers, non-availability of efficient power source compatible harvesting mechanism of some of the existing harvesters and combines are the main cause for the same (Yadav and Yadav, 1992).
Azhar Saeed et al., (1995) reported that the conventional paddy threshing methods are not only time consuming and labourious, but also results in more grain losses. Grain losses up to 7.93 per cent have been observed in Punjab, whereas these losses are even higher with deterioration in quality of paddy in Sind.

The post harvest activities in Bangladesh are traditional and labour intensive. The main activities are harvesting, threshing, animal or mechanical treading, sun drying, traditional parboiling and milling in huller mills. The post harvest losses in paddy are estimated at about 13 percent of which the processing losses are very high. The post harvest losses are due to delayed harvesting, improper handling and incomplete threshing (Akhter Ahmed et al, 1996).

The situation of grain demand supply has been serious, but grain loss during post production has long been ignored. In fact, great grain losses during post production activities have occurred in vast rural areas. People always pay great attention to pre-production and production system. Post production system is neglected by farmers as well as by the Government. Since the reformation of the agricultural economy, the structure of agricultural production has greatly changed. Rural enterprises, commercial business and services have been
developed. As a result, farm labour transfer has been promoted. In economically developed areas, agricultural land units were merged and consolidated into the hands of skillful farmers and a number of specialised farm households. Therefore, lands became larger units labour shortage has became inevitable in farming, especially in grain post production operations (Fie Yong, 1997).

Khan et al., (1997) reported that in experiments at Bhubaneswar, Orissa the percentage of yield loss of rice through harvesting, bundling, transportation and threshing was 0.68, 1.21, 1.06 and 3.79 percent respectively, in cv., CR - 1009 and 0.97, 1.52, 1.56 and 4.06 percent, respectively in cv., Lalat.

2.2 Development of post harvest machinery and its effects

Paddy harvesting was traditionally done manually by sickles and the threshing by using animals or tractor treading. With the advent of industrialization, there was migration of labour from agricultural to other sectors away from the farmers’ economy such as industries, construction, tourism, etc. Due to this, the agriculture sector had been left with limited workers with limited time to engage in labour intensive farming activities like weeding, harvesting, etc. Hence, mechanization of these operations is necessary and rice combine
The cost ratio of manual harvesting and mechanized harvesting is 2:1. At the peak harvest season, scarcity and unavailability of labour increases the labour costs with the result, farmers now pay an exorbitant amount of Rs. 1200/- per hour for harvest. On the other hand, due to change in climatic condition, delayed harvesting of rice results in considerable damage to the standing crops in the field.

There are two types of combine harvesters. They are either wheel or track mounted. The main wheels of paddy combine are equipped with large, deep, mud lugs to give better traction in muddy, poorly drained field. So, the engine of greater horse power is chosen to travel over the paddy field (Smith and Wilkes, 1976).

Krishnaseni (1980) studied the harvesting loss of Thailand rice variety RD-7, harvested by the Mametora reaper. At a grain moisture content of 20 to 25 percent (wb), the harvesting losses ranged from 0.3 to 1.1 percent and increased to 10 percent, when the grain moisture contents were lower than 18.5 percent (wb).

Nadeem (1982) conducted a study at AIT, Bangkok, on the harvesting loss of Thailand rice, variety RD-7, which was harvested by
using Chinese reaper. The harvesting loss at maturity, for a normal density transplanted crop, was around 4 percent (gear combination II) and 4.7 percent (gear combination III).

Khunchom Na Ayutaya (1985) studied the threshing loss of Thailand rice variety RD-11 in locally made axial flow thresher. The average threshing loss was 0.2 to 5 percent at a grain moisture content of 22.2 percent (wb) and 10.6 percent (wb) respectively and average around 0.4 percent for grain with a moisture content ranges from 18.8 to 22.9 percent (wb).

The power thresher was gradually replacing the traditional practice of threshing, using hand beating and foot trampling. The adoption of the thresher was preferred to minimize field losses during harvesting and threshing. It was reported that the harvesting losses amounted to 23 percent because of deterioration during stacking of paddy in the field. By adoption of thresher the losses decreased to about 3 percent (RNAM, 1987).

Anwarul Haque et al., (1989) observed the post harvest practices in Bangladesh during threshing and sun drying. The practices studied were threshing by hand beating, ox-treading, use of pedal threshers hand beating followed by ox-treading, cleaning of threshed paddy. The
total loss estimates from threshing through sun drying varied between 3.1 to 4.0 percent.

Fouad et al, (1990) reported that the two different self-propelled combine harvesters were tested in Egypt. They were conventional combine harvester and rice combine harvester. The tests were conducted for different percentages of straw, grain moisture content and harvesting speeds in both the harvesters. Grain losses field efficiency and harvesting costs were analyzed. Grain losses, increased with increase in combine speed losses in the conventional combine were higher than the rice combine, losses were affected by time of harvest, field efficiency decreased with increase in combine speed and field capacity. The total cost of harvest for the conventional combine was less than the rice combine.

Vanishchang (1990) tested the field performance of a Japanese rice combine harvester (head feed) at Sriracha district, Chonburi province. The effective field capacity was 0.23 hectare per hour at a grain moisture content of 22.4 percent (wb). The total grain losses at this moisture were 4.3 percent. The total cost of operation was US $ 69 per hectare assuming 400 working hourly and US $ 47 per hectare at 800 hours of annual use.
Vechasit (1993) reported that the harvesting loss of a locally made reaper was around 2.8 percent at grain moisture content of 11.7 percent (wb).

Threshing is the detachment of paddy kernels from the panicle of the rice plant. The separation of grains from the panicle occurs due to the rubbing action, impact and stripping. The rubbing action takes place when paddy is threshed by trampling by man, animal or tractors. Impact action takes place during drum beating but both impact and stripping action was used for pedal thresher and power thresher (Md. Abdual Kadclur Miah et al., 1994).

Most of the cereal crops are generally harvested by sickle, which is quite tedious and labour intensive job. During the peak season of harvesting, farmers have to face the difficulty for timely reaping. Mechanical harvesting could well be the answer to overcome the above problem. About 75 per cent of the farming operation is done on small and marginal holding size farmers (Singh and Bachchan Singh, 1995).

2.3 Field evaluation on rice combine harvester

Harvesting by combine harvesters accounts for the bulk of the paddy crop produced in developing countries. Even though many of the paddy fields are still cut by hand sickle, threshers help alleviate the
harvest time bottleneck. Rising labour costs and manpower scarcities for harvesting have hastened the development of a wide range of harvesters across the world in the last 40 years. Indian Rice Research International’s axial flow thresher programme came at a propitious time and was influential on machine adoption in a number of countries. Rice combine harvester does all the operations from harvesting to winnowing simultaneously.

Field efficiency varies with pattern of field operation, crop yield, moisture and crop conditions. Turning and idle travel, materials handling, cleaning clogged equipment, accounts for majority of time in the field.

The rate of work of a combine depends on the size, rate of travel and yield of grain. The capacity of a small grain and soyabean combine of 4.2 m cutter bar is 15 to 20 hectare per day. For the soft soil, it reduces to 10 hectare per day, for the same combine where per day working hours is 8 hour (Smith and Wilkes, 1976).

Hassan and Larson (1978) reported the combine capacities performance from data gathered in time studies of sorghum harvesting. They recorded the activities using time study board and stop watches on: harvesting, turning, grain elevating, travel to and from trailer,
cleaning, minor maintenance and adjustment of machine and operator personnel time. These data were used to compute effective field capacities and field effectives. The time studies revealed that the average effective field capacity and field efficiency is 1.42 hectare per hour and 72 per cent, respectively. The average forward speed and machine width were 4.04 kilometer per hour and 5.09 m, respectively.

The field efficiency is the ratio between the productivity of machine under field conditions and theoretical maximum productivity (ASAE, 1983).

Field efficiency, are accounted with the failure to utilize the theoretical operating width of the machine, time lost due to operator capability and habits and operating policy and field characteristics. Field efficiency is not constant for particular machine varies with the size and shape of the field (Fouad, 1984).

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

Fouad et al, (1990) studied the performance of a self-propelled German harvester on rice harvesting in Egypt. The specifications of rice harvesting Deutz-Fahr (M 980) combine harvester with 54 kW diesel engine were 3 m of cutting width, 1030 mm wide and 560 mm diameter of peg type drum and operated at 800 rpm. Drum concave clearance was adjusted to 15 mm in front and 7 mm in rear according to the instructions. They found the grain loss was 178 to 380 kilogram per hectare for Ryhe variety rice where grain losses increased with the increased forward speed (0.8 to 2.9 km/h). The field efficiency was increased from 54 to 82 per cent with a reduced forward speed from 2.9 to 0.8 kilometer per hour, where time losses were counted for turning, grain unloading and removal of straw clogging for the same variety of rice in the field soil moisture content of 30 to 32.7 per cent during the harvesting.

In Thailand, four locally made rice combine harvesters (with 80 to 100 horse power prime movers) were tested in four fields each. The tests were conducted to determine actual field capacity and field
efficiency, which varied from 0.32 to 0.96 hectare per hour, with a field efficiency of 29 to 91 percent (Krishnaseni and Nakkua, 1991).

Mongkholtanatat (1993) reported that combine harvesters were developed in Australia, Europe, and America more than 100 years ago. They were mostly used for wheat harvesting. These combines were introduced to Thai farmers through the National Agricultural Exhibition organized by the Thai government 80 years ago.

Nakwattananukul (1993) assessed the impact of using the rice combine harvester. Based on the results of the study it was classified the impacts into following categories: they were first is labour shortage. Use of rice combine harvester was able to solve the problem of labour shortage, pursued with high wages of harvesting labour, during harvesting season. The capacity of the machine ranged from 3.2 to 6.4 hectare per day, while a labour could only harvest 0.04 to 0.12 hectare per day. Second is economics: The farmer’s investment cost for harvesting is reduced by using the machine against the manual harvesting. It is also possible for a machine contractor to get higher returns in less than a year.

Vechasit (1993) reported that the effective field capacity of a locally made reaper was 0.17 hectare per hour.
Field performance estimates of many machines utilized in United State farms are summarized in the ASAE Agricultural Engineers Yearbook (ASAE, 1997).

A new Holland (Clayson 1545) European self-propelled conventional all crop combine harvester was used in a commercial farm where MR-211 rice variety was cultivated. The average field capacity of the machine was 1.05 hectare per hour with an average field efficiency of 72 percent, and the machine loss over grain was 1.68 percent of the total grain yield, which was reasonable. This machine will overcome the shortage of labour during peak harvesting season with saving time (Swapanakumar Roy, 2001).

23.1 **Sources** of grain **losses** in rice combine harvester

The header losses are affected by the reel peripheral speed (Goss *et al.*, 1958) in relation to forward speed, reel height (Griffen, 1973) and height of cutting. Cleaning losses were affected by adjustments of the size of openings and slope of sieve and a velocity and crop condition (Johanson, 1959). The cylinder grain losses were affected by feeding pattern (Arnold, 1964), Straw walker losses were generally affected by walker design grain / non-grain ratio, feed rate (Reed *et al.*, 1970) and kind and condition of crop. The cylinder and
concave design (Neal and Cooper, 1970) and operating conditions (Delfoss and Pivot, 1983).

The sources of total grain losses while using the combine harvester are preharvest losses, header losses, threshing losses, straw walker losses and shoe losses (Smith and Wilkes, 1976; Culpin, 1986).

To reduce the grain losses, the operator must know the source of losses and how to measure losses. If the grain losses are not acceptable, the operator must reduce them by adjusting the components, which are causing the losses. The losses from improperly adjusted combines can be quite significant. It was reported that in 1985, wheat farmers in Oklahoma lost $37 million in grain due to combine clearance losses, a large portion of which could have been prevented by proper adjustments (Downs et al., 1985).

Researchers at Oklahoma State visited and checked the grain losses from different machines (Downs et al., 1985). They found that the average for machine related losses was 5 per cent of total yield. Most experts agree that if correctly adjusted and operated, the loss should be between 1 to 3 per cent of the total yield (FMO, 1987).
2.4 Development of Mathematical models

A model is an efficient tool to forecast the demand for a given situation provided the model incorporates all parameters in the system. The parameters such as crop, moisture and machine affect the requirements of harvesting and threshing operations by combine harvester.

The available models for the estimation of losses during harvesting and threshing operations are extremely simple, therefore, have limited application.

Clark and Zaidi (1976) used a traditional regression model to compare the effects of five threshability parameters on machine variable. The five parameters included two cylinder speeds and three concave clearances. Tests were conducted on an instrumented threshing cylinder.

Saijpaul et al., (1976) conducted an experimental study on an integral separator and cleaner unit for a combine. He used a central composite rotatable design and fitted a third order polynomial model into the experimental data and draw contour plots of the response surface.

Huynt et al., (1977) developed a mathematical model, based on the stochastic concept, to quantify the threshing and separation process.
of cereal crops in a conventional thresher. The estimated model predicted threshing performance and explained the influence of various threshing design parameters and operating conditions.

Huynt and Powell (1978) developed a statistical model, which gave a quantitative description of the separation process of wheat in a cleaning shoe. The model predicted shoe losses for a given shoe design and evaluated the effects of different cleaning process parameters.

Baer (1983) states that, model provides for the effect on grain losses of the design parameters of the threshing apparatus, straw walker and cleaning mechanism.

Klenin et al., (1985) estimated energy requirements of harvesting machines using multiple linear model of only two system parameters i.e. weight of the machine and crop throughput.

Hetmanski (1989) presented a mathematical model of the threshing mass movement of the straw walker. The most important constructional and kinematic parameters of the straw walker are taken into account. The model was verified using computer simulation.

The probability of reliable operation of combine harvester was analyzed, and a mathematical formula for calculation of financial loss due to breakdown. It considered the cost of one hour of operating time,
the recuperation period of the initial investment and the length of idle time (Ignatenko et al., 1989).

Mikucki (1993) analyzed and evaluated the grain losses during harvesting and presented a mathematical model of losses with a combine harvester. The problems associated with the application of electronic control systems in agricultural machines were also discussed.

Jozwiak (1994) studied the choice of probabilistic models for farm machinery simulation. The correlation of empirical data with theoretical models was verified, for an example of combine harvester operation, for exponentional, weibulls, normal and log-normal distributions. The results are applied to a simulation experiment.

The threshing process in a combine harvester was assessed by random variables, such as the moisture content of grain, grain damage and under threshing losses. An attempt was made to describe the process using a stochastic model and to simulate it with the application of the Mounte Carlo method. Empirical data necessary to develop the model were collected during harvesting. The total grain losses were affected by under threshing and damage percentage of harvested grain (Zlobecki et al., 2000).
Baruah and Panesar (2002) reported that a model has been developed for combine harvester for the mechanistic energy requirements. Component models for all the machine components of the combine harvester viz., reel, cutter bar, platform conveyor, feeder conveyor, threshing cylinder, straw walker, sieves, blower, grain conveyors, tailing conveyors and traction device, were developed based upon the physical, mathematical and engineering principles.