ANALYSIS OF HARVESTING AND THRESHING SYSTEMS OF WHEAT

By

VIJAY KUMAR MITTAL

A Thesis

submitted to the Faculty of the Post-Graduate School,
Indian Agricultural Research Institute, New Delhi,
in partial fulfilment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

in

AGRICULTURAL ENGINEERING

Division of Agricultural Engineering
Indian Agricultural Research Institute
NEW DELHI

1976

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C E R T I F I C A T E

This is to certify that the thesis entitled, "Analysis of harvesting and threshing systems of wheat" submitted in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY IN AGRICULTURAL ENGINEERING of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, is a record of bonafide research carried out by Shri Vijay Kumar Mittal under my guidance and supervision and no part of the thesis has been submitted for any other degree or diploma. The assistance and help received by Shri Vijay Kumar Mittal during the course of the investigations have been duly acknowledged by him.

A.M. Michael 17/6

(A.M. Michael)
Research Guide and Chairman
Advisory Committee

New Delhi
Dated the June 17, 1976

D E D I C A T E D

to

My parents

Shri Girwar Singh and Smt. Shanta Devi

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During moments of solitude and introspection in the course of this study, I have gathered the feeling of an appreciation and admiration to many kind people with whose encouragement, inspiration and help, the present study was made possible. It is to them that I want to pay my homage today.

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Finally, I wish to place on record that I would cherish more than any other, the encouragement, support and love of my wife Veena which enabled me to face out the problems and vicissitudes during the period of this study.

New Delhi
June 15, 1976

(VIJAY KUMAR MITTAL)

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ABBREVIATIONS

ampere	A
average	avg
centimetre	cm
degree	deg
diameter	dia
gram	g
hectare	ha
horse power	hp
kilogram	kg
kilowatt	kw
kilowatt-hour	kwh
litre	l
metre	m
minute	min
Paise	p
power take off	pto
quintal	q
revolutions per minute	rpm
Rupees	Rs
square centimetre	cm^2
square metre	m^2
volt	v

CHAPTER I

INTRODUCTION

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INTRODUCTION

Wheat is one of the major crops of India. It occupies the second position in respect of area under cultivation and total production and is second only to rice. From the global point of view, India ranks third among the major wheat growing countries, with a production figure of 26.5 million tonnes and an area of 19.2 million hectares in 1971-72. Table 1.1 gives the production figures of wheat in India for the period of 1964-65 to 1974-75.

Table 1.1 reveals the impact of the green revolution. In 1965-66, the total production of wheat was about 10.4 million tonnes from an area of about 12.6 million hectares of land. The production figures rose to 26.4 million tonnes in 1971-72 from an area of about 19 million hectares, although subsequently, there was a decline mainly on account of adverse weather conditions, increase in price of fertilizers and energy crisis. The declining tendency was overcome subsequently and the production figures continued to increase from 1974-75 onwards. The breakthrough in wheat production

Table 1.1. Area and production of wheat in India

Sl. No.	Agril. year*	Area ('000 ha)	Production ('000 tonnes)
1.	1964-65	13,422	12,257
2.	1965-66	12,572	10,394
3.	1966-67	12,838	11,393
4.	1967-68	14,998	16,540
5.	1968-69	15,958	18,651
6.	1969-70	16,626	20,093
7.	1970-71	18,241	23,832
8.	1971-72	19,139	26,410
9.	1972-73	19,463	24,735
10.	1973-74	19,057	22,073
11.	1974-75	18,108**	24,235**

* Agricultural year is from July to June. Directorate of Economics and Statistics, 1975.

** Estimated. The estimated production of wheat during 1975-76 is 27 million tonnes (Times of India, June 5, 1976).

was made possible by the incorporation of modern agricultural technology in wheat-farming. The increase in production over the past several years has brought in its wake new problems. The increasing trend is however expected to continue, in view of the increasing emphasis on improved technology in agriculture to raise production.

One of the main problems related to the production of wheat crop concerns with the harvesting and threshing operations. These operations may be either traditional, modern or having a combination of both, with varying degrees of mechanization. The harvesting and threshing of wheat involve many problems because of the short harvesting season for multiple and intensive cropping, uncertainty and vagaries of weather, shortage of labour during the peak season and the importance of the timeliness factor due to the technological changes, especially from the point of view of obtaining a better price. In addition to these problems the farmers, in general, try to complete the harvesting and threshing of the crop as quickly as possible in order to avoid heavy field losses resulting from the delay in harvesting and threshing and save themselves from the drudgery in the hottest period of the year.

Several systems of harvesting and threshing of wheat exist. The farmer is faced with the dilemma of deciding which system suits his requirement. A systems approach which deals with the innumerable problems of harvesting and threshing is desirable in determining the most suitable harvesting and threshing system under the conditions generally prevailing in India. The suitability of such a system will be governed by its performance, both in terms of efficiency and economy.

The mechanization of harvesting and threshing operations involved in a particular system (as envisaged in this work) appears to be occurring in response to changes in the demand for farm energy relative to the supply of labour. Tractors and improved agricultural implements seem to contribute to increased farm production. The long-term effect of farm mechanization in the context of farm employment is important and has to be given due consideration. However, at the same time, careful consideration is also to be given to the productivity concepts to be incorporated in agricultural operations. 'Rules of thumb' which presume that machines displace labour or create additional employment, offer neither advantages nor any guidance in formulating a suitable policy. The main consideration in this respect is to be given to the economic stimuli generated in order to make the machine profitable to the individual operator. Suitable policy decision can then be formulated, based on this information and having due regard for the social benefits and the costs to be incurred by the individual farmer. The returns are to be assessed in relation to a particular system involving a single machine or a groups of machines in the harvesting and threshing of wheat.

1.2 Importance of the project

The problems associated with the harvesting and threshing of wheat crop, are to be examined with special reference to the conditions prevailing in the major wheat growing regions of India. The solutions based on the economic and statistical models as evolved and developed in the western countries are rarely applicable to India in their entirety. They are to be analysed in relation to the specific conditions existing in India.

The major area in India under wheat lies to the north of the Vindhya mountain range. A glance over the distribution of holdings (Table 1.2) makes it amply clear that the same type of system of harvesting and

Table 1.2. Farm holdings in India - estimated number and area operated by size, 1961-62*.

Sl. No.	Area of holdings (hectares)	Operational holdings			
		Number of holdings ('000)	Percent of total holdings	Area operated ('000)	Percent of total area
1.	Upto 0.20	4,838	9.71	464	0.35
2.	0.20- 0.40	4,255	8.54	1,245	0.94
3.	0.40- 1.01	10,772	21.62	7,284	5.50
4.	1.01- 2.02	11,181	22.44	16,224	12.25
5.	2.02- 3.04	6,158	12.36	14,979	11.31
6.	3.04- 4.05	3,478	6.98	11,947	9.02
7.	4.05- 6.07	3,881	7.79	18,569	14.02
8.	6.07- 8.09	1,843	3.70	12,582	9.50
9.	8.09-10.12	1,111	2.23	9,688	7.30
10.	10.12-12.14	663	1.33	7,165	5.41
11.	12.14-20.23	1,121	2.25	16,569	12.51
12.	20.23 and above	523	1.05	15,748	11.89
	All sizes	49,824	100.00	132,444	100.00

* Source : Indian agriculture in brief. Fourteenth Edition (April, 1975), issued by the Directorate of Econ. and Stat. Min. of Agr. and Irr. Govt. of India, New Delhi. pp.1-269.

threshing is neither desirable nor possible to be adopted in every type of holding considering wide variation in area of holdings.

At the same time, incorporation of productivity concepts in agricultural production systems is imperative. In the history of mankind, increases in the demand for food are derived from the growth in population. Since the time of Malthus, the food problem has been viewed as a food cum population problem (Brown and Eckholm, 1975). Therefore, to fight the Malthusian spectre, productivity of each farm-unit must be increased through the transformation of traditional agriculture into modernized agriculture. This is possible only through the maximum utilization of modern technology in crop production. The modern multiple cropping technology makes it possible to have four food crops in a year (Fig. 1.1). Growing four food crops from the same unit of land poses many problems associated with harvesting and threshing. Timeliness of operations is one of the major constraints which calls for the adoption of suitable machinery.

Several alternatives exist for the farmer to adopt any one of the combination of operations (policy) of harvesting and threshing of wheat. The major questions

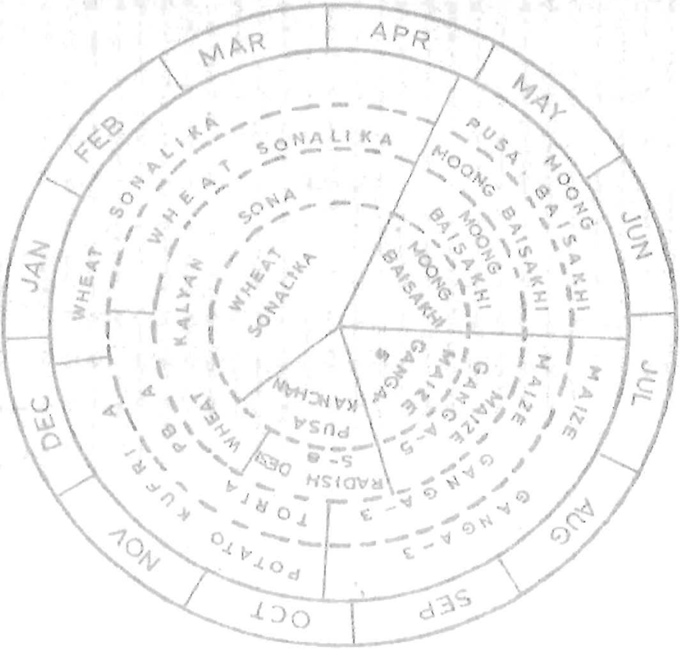

Fig 1.1 Concept of multiple cropping: sequence of four food crops

Source : Recent research on multiple croppings I.A.R.I. Bull. (New Series) No. 8, New Delhi, 1972 before farmers in a specific crop situation are - which combination is to be selected, on what basis and on what cost.

The above considerations indicate need to develop information and data in relation to the different systems of harvesting and threshing either in vogue or likely to be adopted.

With the underlying thoughts and concepts enumerated above, efforts have been made to develop suitable information pertinent to the possible policies of harvesting and threshing of wheat, in this study.

1.3 Specific objectives

The following are the basic objectives of the study reported in this thesis :

A. To evaluate the following operation-combinations for harvesting and threshing (policies) :

(a) Tractor operated combine harvester cum thresher.

(b) Reaper harvesting and manual bundling + stacking + thresher (not bhusa making) + bagging.

(c) Reaper harvesting and manual bundling + stacking + thresher (bhusa producing) + winnowing and cleaning + bagging.

(d) Reaper harvesting + manual bundling + stacking + drummy thresher + winnowing, cleaning and bagging.

(e) Sickle harvesting + manual bundling + stacking + thresher (bhusa producing) + bagging.

(f) Sickle harvesting + manual bundling + stacking + drummy thresher + winnowing, cleaning + bagging.

(g) Sickle harvesting + manual bundling + stacking + animal threshing with olpod thresher + winnowing, cleaning and bagging.

These policies are to be evaluated with respect to (a) field losses (b) machine losses (c) labour requirement (d) operational time involved and (e) cost.

B. To ascertain optimal systems for harvesting and threshing of wheat crop in northern India on the basis of the criteria i.e. (a) timeliness (b) cost efficiency and (c) performance efficiency.

CHAPTER II

DEFINITIONS OF TERMS AND CONCEPT USED

CHAPTER II

DEFINITIONS OF TERMS AND CONCEPT USED

2.1 Terms used primarily for systems analysis

I Field efficiency

Field efficiency is the ratio of effective field capacity to the theoretical field capacity usually expressed in percentage.

II Effective field capacity

Actual rate of performance of land or crop actually processed in a given time, based upon total field time is termed as effective field capacity.

III Theoretical field capacity

Theoretical field capacity is the rate of performance obtained if a machine performs its function 100 percent of the time at the rated operating speed, using 100 percent of its rated width.

IV Field time

Field time is the time, a machine spends in the field measured from the start of functional activity to the time, the functional activity for the field is completed.

V Field speed

Field speed of a machine is average rate of travel in the field during an uninterrupted period of functional activity.

VI Economic life of machine

The useful service life of a machine before it becomes unprofitable for its original purpose due to obsolescence and/or wear, is taken as economic life of machine.

VII Machine system

Machine system is an arrangement of two or more mechanisms to achieve a desired output.

VIII Timeliness

Timeliness of an operation or machine is its ability to perform an activity at such a time that quality and quantity of product are optimized.

2.2 Terms associated with economics

I Operating costs

Operating costs are those costs which depend directly on the amount of use.

II Fixed costs

Fixed costs are those costs which are independent of the machine-use and include costs such as depreciation, interest on investment, taxes, insurance and storage. Fixed costs must be charged regardless of machine productivity.

III Total cost

Total cost is the sum of fixed and operating costs.

IV Depreciation

Depreciation is the reduction in value of a machine due to obsolescence, wear and tear.

2.3 Terms associated with systems approach

I System

A system is an assemblage of interrelated parts of a whole with a conceptual boundary providing a structural autonomy to it from the environment. The entities excluded by the boundary form the environment of the system.

II Systems concepts

Systems concepts include general theory and principles. The emphasis is on the philosophy and the view point is conceptual.

III Systems management

Systems management involves application of theory to man-machine systems. Alternative names for this are management science or operational research. It is a way to organize resources and the view point is pragmatic.

IV Systems analysis

System analysis formulates models for analysis and plans out methods to solve problems. The view point is planning and control.

V Systems approach

This includes systems concepts, systems management and systems analysis. The boundaries assigned to these divisions of the systems approach are blurred and a situation may incorporate all three features in varying proportions.

VI Performance of a system

The performance of a physical system depends upon that of all its components, but transcends that of any one portion. The essence of this concept is that system-performance cannot be determined from the performance of its individual components alone. A system's characteristics are more than the sum of the characteristics of its components and are derived from the nature of the interconnection of the individual elements.

2.4 Concept used in the present study

Basically, the wheat harvesting-threshing systems are :

I Non-mechanized system of harvesting and threshing

II Partially mechanized system of harvesting and threshing

III Fully mechanized system of harvesting and threshing.

In the present study, the first system is characterized by sickle-harvesting and threshing by bullock treading coupled with the use of olped thresher.

Partially mechanized system of harvesting and threshing consist of several combination of operations such as sickle-harvesting or reaper-harvesting coupled with one of the threshing methods such as threshing with spike tooth thresher or hammer mill type thresher with sieving and bagging arrangement or hammer mill type thresher without sieving and bagging arrangement.

Fully mechanized system has been envisaged to complete all jobs of harvesting and threshing simultaneously. Such a machine-system consists of combine harvester-thresher.

The concept has been presented in Fig. 5.1 in which a combination of machines or tool selected to perform the tasks of harvesting and threshing has been envisaged or termed as a <u>policy</u>. To obtain desired product (the grain) from the standing crop.

Thus, the policies constituting any one of the alternate combinations or arrangement of harvesting and threshing machines have been envisaged as follows.

Symbol	Policy
S - 1	tractor operated combine harvester cum thresher.
S - 2	reaper-harvesting and manual bundling + stacking + thresher (not *bhusa* making) + winnowing and cleaning + bagging.
S - 3	reaper-harvesting and manual bundling + stacking + thresher (*bhusa* producing) with sieving and bagging arrangements.
S - 4	reaper-harvesting + manual bundling + stacking + thresher (*bhusa* producing) without sieving and bagging arrangement + winnowing cleaning and bagging.
S - 5	Sickle-harvesting + manual bundling + stacking + thresher (*bhusa* producing) with

sieving and bagging arrangement.

S - 6 sickle-harvesting + manual bundling + stacking + thresher (_bhusa_ producing) without sieving and bagging arrangement.

S - 7 sickle-harvesting + manual bundling + stacking + bullock treading with olpod thresher + winnowing, cleaning and bagging.

In actual practice too, some of these policies are being followed by Indian farmers growing wheat for harvesting and threshing operations.

CHAPTER III

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

Harvesting may be defined as the mass detachment of the crop plants, usually by cutting, with the help of blades and their removal from the field to isolate and concentrate the desired plant part, usually the grain. Threshing, on the other hand, consists of a group of operations that are designed to detach the desired product from the mass of the harvested crop material and to separate it from the mixed mass. The threshing operations usually mean the detachment of grains from the plants by beating or rubbing and the separation of grains from the mass of straw by means of screens or blowing the straw away.

Harvesting and threshing systems employed in wheat cultivation depend upon the devices used to harvest and thresh and the sources of power used. A particular system of harvesting and threshing to be adopted by a farmer depends upon the factors like size of farm, capital investment capacity, technical awareness, labour availability and importance attached to timeliness. There have been attempts by earlier workers to investigate the variables influencing the feasibility and efficiency of harvesting and threshing systems. The work most pertinent to the present study is reviewed in this chapter.

B Historical developments

3.2 Hand tools

The earliest mention of the sickle in Indian Vedic Literature is found in Shatapada Brahman (circa 2500 BC-500 BC) in which a reference has been made not only about the sickle (datra srani), but also about the threshing floor (khela), sieve (titau) and winnowing fan (surpa).

In ancient times, the Egyptians used to harvest both wild and cultivated wheat with a primitive form of sickle. The Romans used a one-handed instrument with the blade set out at right angles to the handle. This was the earliest form of scythe. A curved iron sickle, almost similar to the modern one, was widely used during the Middle Ages. In the nineteenth century, the cradle scythe was being widely used for the purpose of cutting wheat. 'Hainault scythe' and mowing scythe were in use in Europe during the Middle Ages (Partridge, 1973). Fig. 3.1 shows some of hand tools used for harvesting wheat.

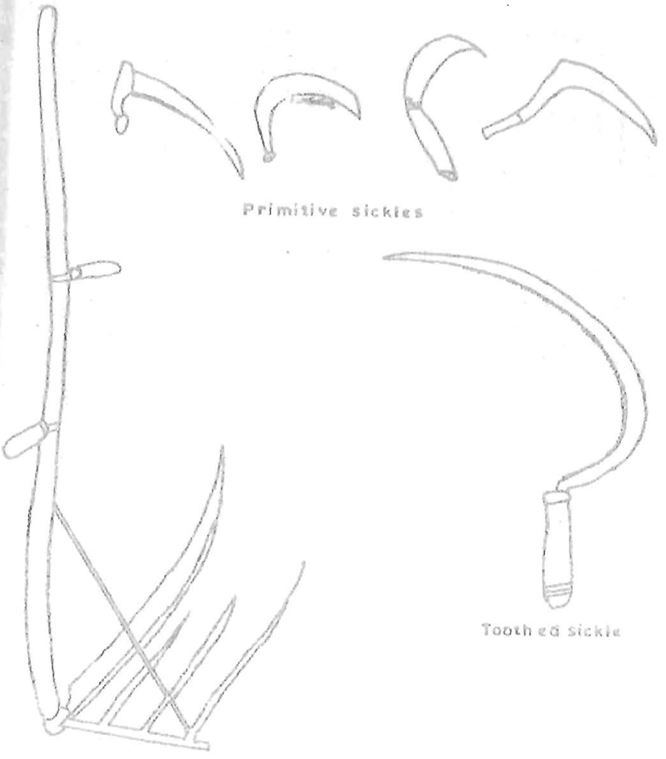

Fig 3.1 Hand tools for manual harvesting

In India, majority of farmers use sickles for harvesting cereal crops. These sickles are either plane blade type or serrated blade type.

3.3 Reaping machinery

Amongst the outstanding developments of the nineteenth century was the gradual perfection of a wheat reaping machine and its subsequent development into the reaping and binding machine. Joseph Boyle of London (Partridge, 1973) secured the first patent for a reaping machine in 1800 incorporating a circular iron plate being rotated through gearing from the travelling wheels. An important contribution was made by Henry Ogle (Patridge, 1973) who invented a reaping machine capable of laying the wheat crop in parcel or sheaves. However, two American models made by McCormick and Hussey (Patridge, 1973) caused a sensation at the Great Exhibition of 1851 in Britain (Figs. 3.2 and 3.3). The credit for developing the first practically successful reaper goes to McCormick (Patridge, 1973) who marketed his first reaper in 1840. By 1880, reapers with sheaf binding mechanism were introduced in U.S.A. Figure 3.4 shows McCormick's hand binding harvester. The mechanical sheaf binder was the final stage in reaper development. An American, Walter A.

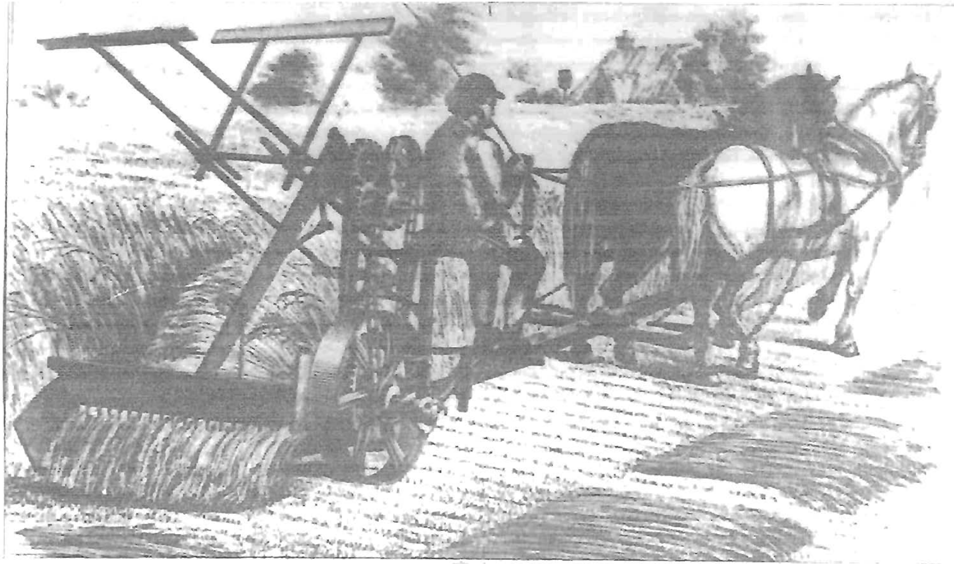

Fig. 3.2 McCormick's original reaper, 1851 A.D.

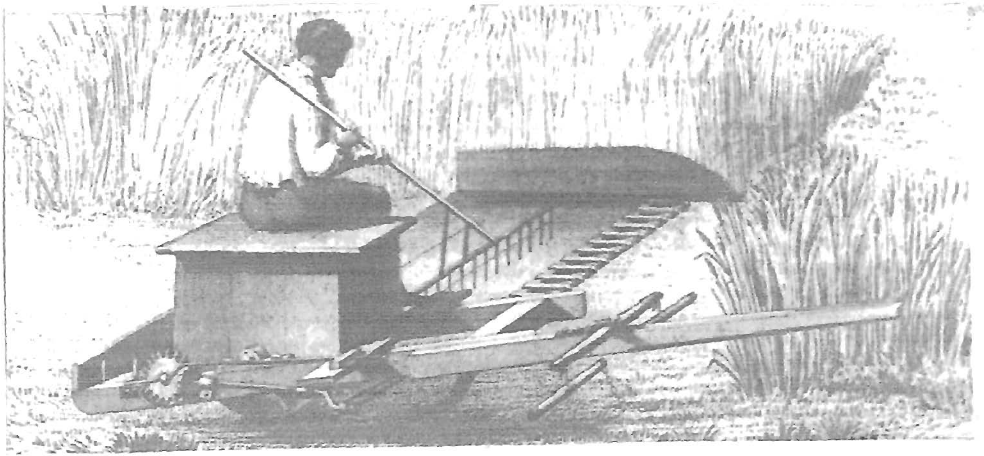

Fig. 3.3   Hussey's American reaper, 1851 A.D.

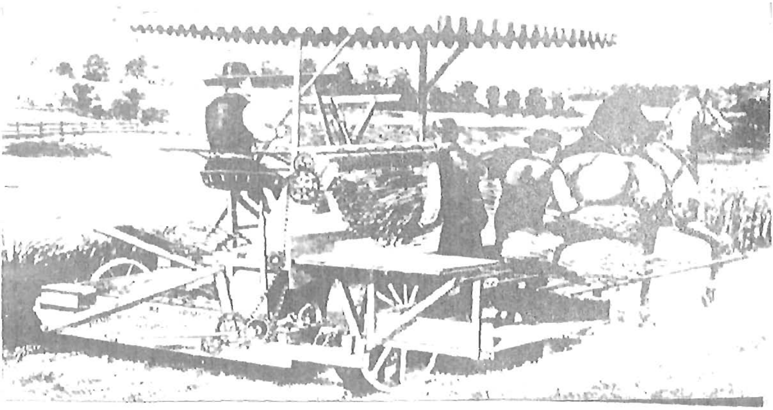

Fig. 3.4 McCormick's hand binding harvester, 1880 A.D.

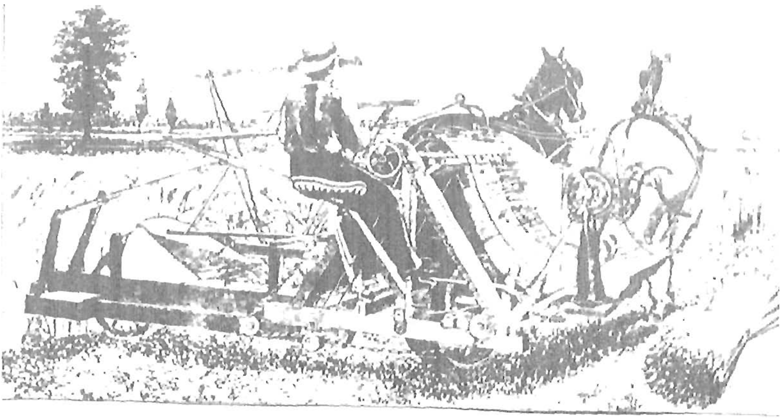

Fig. 3.5 Walter A. Wood's harvester with self binding mechanism, 1876 A.D.

Wood (Patridge, 1973) patented a wire sheaf binder in 1871 which was exhibited in England some five years later (Fig. 3.5).

3.4 Threshing and winnowing

The earliest known method of threshing was to beat the grain from the ears of wheat with a stick. The Egyptians and Indians (in the Vedic times) used to spread out loosened sheaves on a wide area of firm ground and then used to separate out the grain by driving oxen to tread over the spread heap of harvested material. The Romans used their 'tribulum' (a heavy wooden platform mounted upon rollers) for threshing (Patridge, 1973). It was dragged by oxen. The 'flail' was being used during Middle Ages in Europe and continued to be in use until the late nineteenth century.

Threshing floor was an important feature in any village, commune or farm in Europe upto the end of 19th century and is very much common even now in the developing and under-developed countries.

Michael Menzies (Fussel, 1952) invented the first mechanical thresher in about 1732 incorporating a number of flails attached to a horizontal beam turned by a gigantic water wheel. Ilderton of Alnwick, Northumberland

(Fussel, 1952) was the first to construct a thresher using the idea of rubbing the grain free by passing the sheaves between two rollers. Andrew Meikle of East Lathian (1786) constructed successfully a threshing machine on an entirely new principle (Fussel, 1952; Patridge, 1973). The grain in this machine, was separated from the straw by means of a revolving cylinder subsequently called a threshing drum, which was furnished on the outside with four longitudinal beater bars of wood faced with iron. The drum was operated by a water wheel. He received an English Patent for this machine in 1788. Subsequently horse-powered machines were developed which were being used on individual farms and also being used for custom-hiring in mid-nineteenth century (Patridge, 1973).

In the United States, Hiram and John Pitt (1837) of Winthrop, Maine were the first to produce a combined threshing and winnowing machine. With the advent of first steam engine and then the internal combustion engine, modified versions of threshers came into use. Figure 3.6 depicts a typical nineteenth-centure threshing scene in Great Britain. The use of the threshing machine remained confined mainly to the European countries and

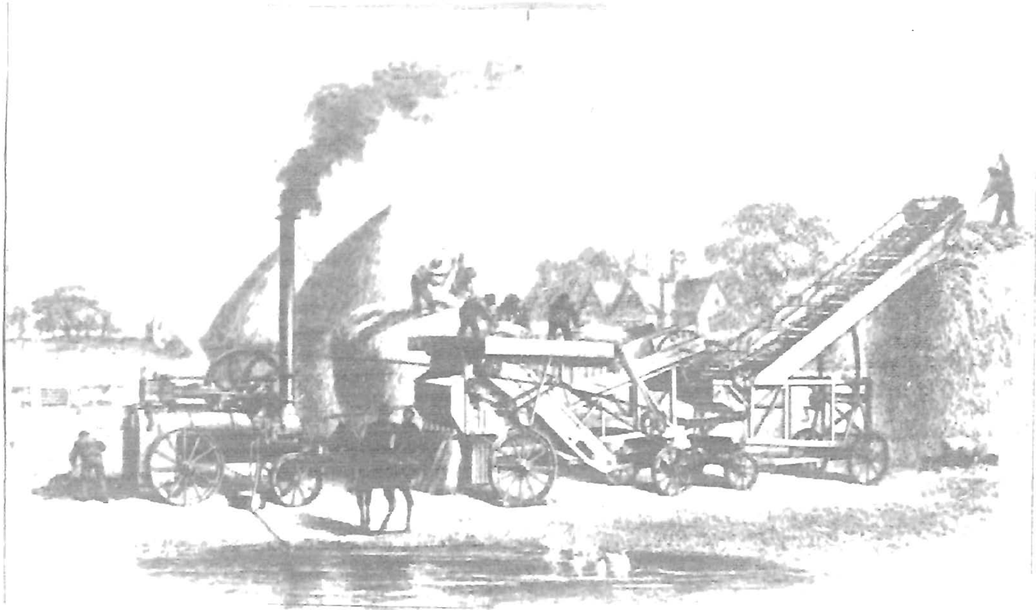

Fig. 3.6 Nineteenth century threshing scene in Britain

the United States until about the year 1940. The idea of winnowing by mechanical means was introduced in Holland during the eighteenth century by James Meikle (Patridge, 1973).

James Sharp (1770) constructed a more compact version of winnower. By 1795 winnowers coupled with threshers came into use.

3.5 Combined-harvester-thresher

A combined-harvester-thresher or 'combine' (as is known today) is the machine which does the simultaneous job of field-harvesting, threshing, cleaning and collection of grain. The development of the combined harvester-thresher commenced with the U.S. Patent of Samuel Lane in 1828 (Patridge, 1973). Messers H. Moore and J. Hascall (Patridge, 1973) of Michigan, U.S.A. developed the first practical combine in 1836. Figure 3.7 shows schematically the early model of a machine for harvesting, threshing, winnowing and bagging. By 1860, it was further modified and perfected. The early combines were drawn by horses. Steam tractors and internal combustion engine tractors were used later. The self-propelled combine was introduced in England in 1928 (Patridge, 1973).

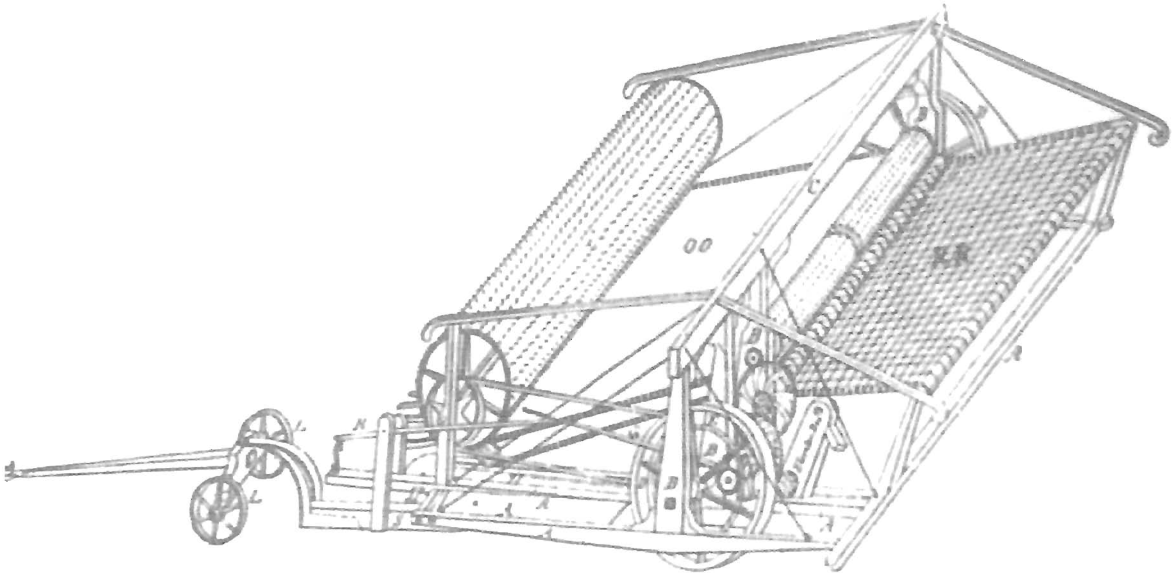

Fig. 3.7 Machine for harvesting, threshing, winnowing and bagging grain, U.S. Patent, 1836

(Source : Patridge, M., 1973)

By 1940, combines were being used for barley, oats and pulses. The total number of combines in the world was about 30 lakhs by 1960 and their use was extended to harvesting of all grains, beans, pulses and maize (Feiffer and Feiffer, 1969).

In India the use of combines until 1965 was limited only on some big private and government farms. With the advent of the green revolution, these were introduced to a limited extent to handle the large production volume of wheat of high yielding varieties. Various models of self-propelled and pull type combines were imported from U.S.A., U.K., West Germany, Italy, U.S.S.R. and East European countries (Patil, 1976). Messers Vicon Limited Bangalore started the manufacture and marketing of Vicon pull type combine around 1970 (Rao, 1972).

C Mechanization in relation to harvesting and threshing

3.6 The threshing and threshing systems for wheat can be viewed as conventional, partially mechanized or completely mechanized systems in the overall context of mechanization.

Mechanization per se has been both favoured and disfavoured by various authorities. But, considering the incorporation of productivity concepts in the process of food production, mechanization seems not only to be necessary but also imperative.

The world's principal unrealized potential for expanding food production is now concentrated in the developing countries, including India (Brown, 1975). India's area of crop land is roughly comparable to that of the United States. Yet, it harvests only about 100 million tonnes of grain while the United States harvests about 250 million tonnes. Low productivity due to halting technological progress is the main cause of this unrealized potential. Lack of mechanization is one of the main deterrents.

Mechanizing the harvesting and threshing operations of wheat - partially or completely influences the productivity of labour, energy consumption per unit of land, labour employment, timeliness of field operations and grain losses. In this regard, the comments, observations and findings of various research workers are worth noting.

Mellor (1967) observed that one of the ultimate objectives in a developing country is the increased productivity of labour. Labour productivity reflects the quantity of goods and services available to man for consumption. Johnston, Page and Warr (1972) argued about the possibility and desirability of implementing agricultural strategies having multiple objectives, one of which is the increased farm output at low cost. Billings and Singh (1969) stated that a demand by a farmer for energy was a function of (1) the crop raised, (2) the type of soil, (3) the level of rainfall, (4) intensity of cropping, (5) the crop rotation followed and (6) the technology used. The timeliness and intensity of operation were thought to be associated with energy-availability, the lack of which resulted in losses to both the farmers and the society.

According to Cottrel (1955), there was correlation between wage rates and horse-power per hectare in most of the countries and mechanization in this respect, played a vital role to increase farm productivity.

Giles (1967, 1975) examined the relationship between the yields of various crops and power used in different countries. He observed that the average aggregate yields of major crops per hectare was a function of the number of horse power available per hectare of cultivated land. It appears that 0.50 to 1.00

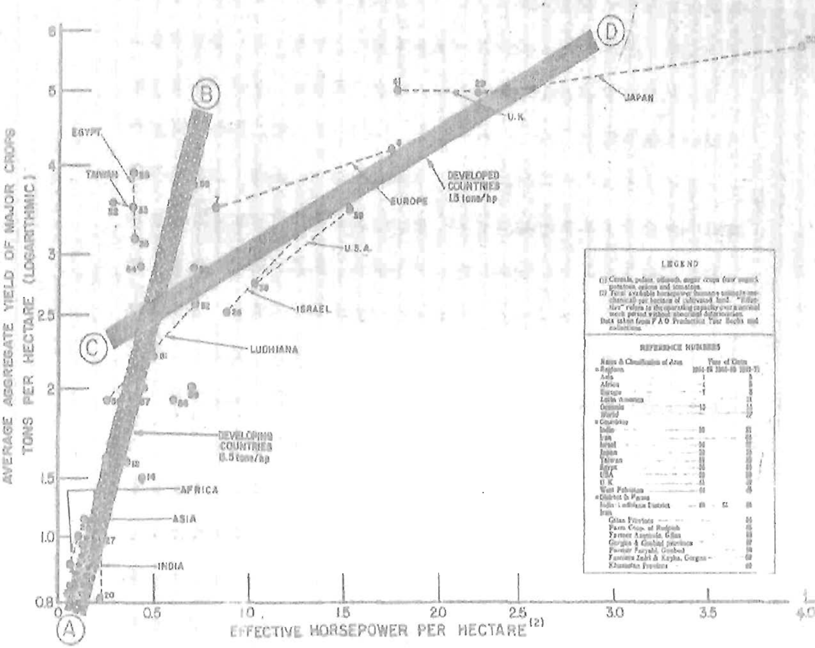

Fig. 3.8 Relationship between average aggregate yields of major crops and power input

(Source : Giles, 1975)

horse power per hectare was required to obtain 2.00 to 3.00 tonnes yield per hectare. Figure 3.8 shows the relationship between average aggregate yields of major crops in kilograms per hectare for major food crops in selected countries/continents of the world in 1964-71 and power input.

Billings and Singh (1970) projected mechanization and rural employment in Punjab through 1983-84. They expected Farm Machinery to become a common feature in Punjab when 100 per cent of wheat would be mechanically threshed. They anticipated high yielding varieties alongwith multiple cropping to require more labour than would be available, using the present level of mechanization. Increased mechanization could offset the increased labour demand to the extent that the amount and duration of seasonal deficit would remain the same.

Johl (1970) reported that due to the use of tractor power and pump sets, the intensity of cropping in Punjab increased from 126.70 per cent in 1966-67 to 144.26 per cent in 1969-70. During the same period, the cropped area and cultivated area in the state increased by 26 per cent and 11 per cent, respectively. There was an accompanied increase in labour-employment by 58 per cent. The bullock-power, of course, was substituted with tractor power.

Singh (1973) concluded that the use of inanimate energy resources was linked with higher crop yields because of the possibility of application of large amounts of energy in a short period of time so that cultural practices could be carried out at a nearly optimum time than might be case when all energy must be provided from animate sources.

Rao (1975) on the basis of studies on the costs of harvesting and threshing wheat in Punjab during 1970-72, made the following conclusions:

(1) use of combined-harvester-thresher turned out to be the costliest from the special point of view because of its labour displacing potential as the labour-input accounts for over 70 per cent of the cost under traditional method,

(2) from the point of view of the individual farmer, the use of a combined-harvester-thresher was cheaper than the traditional method of harvesting and threshing and

(3) manual harvesting, combined with mechanical threshing was the cheapest for the individual farmer as well as the social point of view.

In reaching the aforementioned conclusions, it must be pointed out that the cost-calculations did not take into accounts the uncertainties of hired-labour-availability, weather-hazards and the value of timeliness.

In a survey of the impact of agricultural mechanization on employment in District Muzaffarnagar in Uttar Pradesh, Bhatty *et al.* (1973) observed that with the acquisition of a thresher in addition to the tractor and the tubewell, there was additional labour input per hectare in crop culture in both small and medium size farms, compared to those farms having only tubewell and tractor. When all farm and non farm activities were considered there was larger increase in labour-input in small farms but in medium farms there was a slight decline.

Agarwal and Misra (1973) reported the favourable response of farmers to combined-harvesters. The farmers, as per their study, reported the advantages saying that

(1) the combines alleviated the acute labour-scarcity during rabi harvesting,

(2) the combines reduced the risk of damage by inclement weather by shortening the harvesting process,

(3) the farmers and their family-members were

saved from the druggery and tension associated with harvesting,

(4) operation with the combine harvester-thresher was the cheapest and

(5) extra time was available to the extent of 6 to 8 weeks for growing additional crop.

Agrawal and Misra (1973) suggested that simultaneous steps to have agro-based industries like dairying, poultry, piggery and agro-service centres could be made to absorb the released labour as a result of introducing mechanization in harvesting and threshing. At the same time, agriculture could be made more intensive to have increased productivity per unit of land and labour.

A study carried out in Punjab and Haryana by National Council of Applied Economic Research, New Delhi (1974) indicated in case of farmers not using combines the cropping intensity was high with the reduction in farm size and as the farm-size increased, cropping intensity decreased because of constraints due to labour, timeliness and other technological factors. Figure 3.9 highlights this point.

Barger (1948) reported that the cost of combining with the self-propelled type machine was higher for the

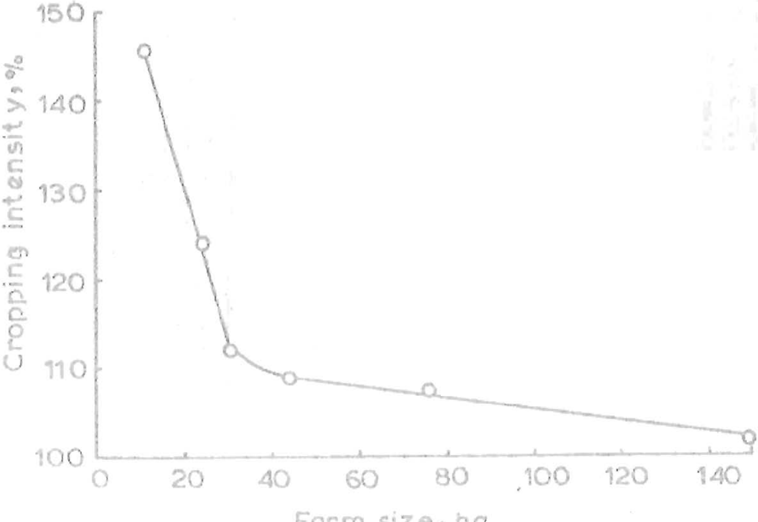

Fig 3.9 Relationship between cropping intensity and farm size (farms not using combines)

Source : Survey by National Council of Applied Econ. Resh., New Delhi

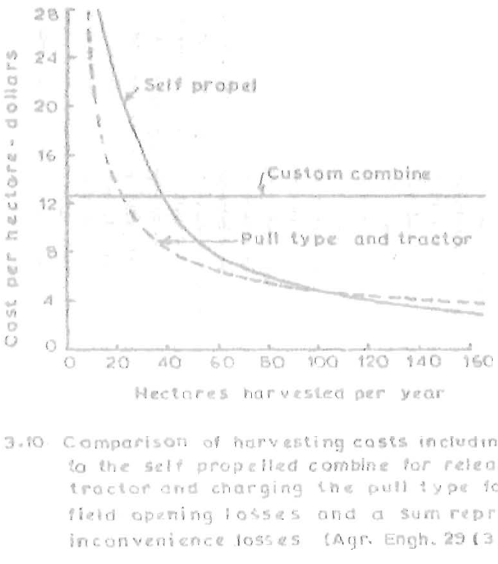

Fig 3.10 Comparison of harvesting costs including credit to the self propelled combine for releasing a tractor and charging the pull type for both field opening losses and a sum representing inconvenience losses (Agr. Engh. 29 (3)-107, 1942 .

smaller areas of land but became lower than the pull type when 100 hectares or more were harvested (Fig. 3.10).

Zachariah (1974) has shown that saving in grain on account of mechanized harvesting (due to combines) alone would be 0.561 million tonne of wheat and 0.360 million tonne of paddy per year. He further pointed out that in monetary terms, it would result in a saving of wheat worth 67.71 crores (@ Rs. 110/- per quintal) and Rs. 28.84 crores for paddy (@ Rs. 80/- per quintal) annually. His estimate on the requirement of combined-harvesters for a minimum level of mechanization in the states of Uttar Pradesh, Punjab, Haryana and Rajasthan was 4050 self-propelled and 3860 pull type combines. However, probably the author is not clear about the size of land holdings while making his projections.

D Design and development of harvesting and threshing machinery in India

3.7 In India, the design and development work of threshers has preceded that of the harvesting machinery, the main cause for this, perhaps, were the delay, drudgery and risks and uncertainties involved in bullock-treading method of threshing.

As an improvement over the bullock treading method of threshing, the olpad thresher, first designed in Gujarat was introduced and popularised among small farmers having 1 to 2 hectares of crop (Khardekar, 1972). The olpad thresher, it has been reported, does the job of 4 to 5 pairs of bullocks.

In Punjab, S.K. Paul, an agricultural engineer in collaboration with Sunder Singh, a manufacturer of agricultural implements in Ludhiana (India) designed and developed around 1960 a wheat thresher on the principle of hammer-mill capable of producing bhusa and separating it from grain by suction and blowing (Pangotra, 1975). Later on, these threshers, known as Ludhiana type threshers, became popular with the farmers in Punjab and Haryana in the wake of green revolution.

Peter (1965) was reported to have developed a wheat thresher with a capacity of 6-7 quintals per hour. The thresher was constructed on the principles of a threshing-fan and centrifugal threshing with aspirator cleaning, utilizing a 5-7 h p prime mover.

During 1969, the research section of the Division of Agricultural Engineering (Indian Agricultural Research Institute, New Delhi) designed and developed three different sizes of threshers (Nirmal and Luthra, 1970;

Sirohi, 1969). These threshers were multi crop threshers of spike toothed cylinder type. Further development and design-modifications are being carried out at Zonal Research Centre, I.A.R.I., New Delhi (Sirohi, 1975).

With the advent of green revolution, efforts were initiated to develop or adopt suitable harvesting machinery to cope with the increased production due to high yielding variety (HYV) programme.

Khanna (1970, 1973) designed and developed a bullock cum engine operated reaper with a cutter bar of 1.5 m and field capacity of about 2 to 2.5 hectares of land per day. He, later on, was awarded a prize by Invention Promotion Board of India (Sirohi, 1970).

Verma and Garg (1971) reported the development and design of tractor rear mounted, p.t.o. operated self raking reaper and the tractor front mounted reaper-windrower and their satisfactory performance for wheat harvesting at the Punjab Agricultural University, Ludhiana in 1971-72. These reapers, as reported, were designed with a cutter bar peak velocity of 100 mpm corresponding to tractor p.t.o. speed of 540 rpm.

Chauhan (1973) reported the work of design and development of a self-propelled type of reaper and binder being carried out after necessary adoptive and test trials on an Italian imported reaper binder. A successful modified design might prove very useful to smaller farmers. The reaper binder, as reported, is a self-propelled unit operated with a 9 hp diesel engine with a cutter bar of 1.36 metres having 60° triangular knife sections.

E Studies in relation to energy and cost involved in harvesting and threshing

3.8 The investigations reported by Ojha (1973) about the requirement of energy for harvesting and threshing of wheat and respective cost of operations at Kharagpur, West Bengal are summarized in Table 3.1.

The results of the project about the energy requirement and cost of operations of harvesting and threshing, as reported by Singh, et al. (1973), are summarized in Table 3.2.

Kulshreshtha et al. (1973) studied the energy requirements in intensive agricultural production at Pantnagar, Uttar Pradesh and also conducted a village survey. Their findings in relation to harvesting and threshing are summarized in Table 3.3 and 3.4. It was concluded that:

Table 3.1. Requirement of energy and cost of operation of harvesting and threshing of wheat*

S. No.	Farm operation	Energy supplied by: Human kwh/ha	Animal kwh/ha	Mechanical kwh/ha	Electrical kwh/ha	Total energy kwh/ha	Percentage of total energy required for all operations	Cost of operation Rs./ha	Percentage of total cost of all operations	Remarks
1	2	3	4	5	6	7	8	9	10	11
	A. Treatment E_1R_1:									Rotations:
1	Harvesting	4.14	-	-	-	4.14	0.91	27.75	5.21	R_1: Paddy-Wheat-Maize
2	Threshing	0.98	-	-	1.58	2.56	0.56	11.52	2.16	R_2: Paddy-Potato-Jute
	B. Treatment E_2R_1:									R_3: Paddy-Wheat-Moong
1	Harvesting	5.02	-	-	-	5.02	1.16	33.60	5.85	Energy treatments:
2	Threshing	1.09	-	-	1.76	2.85	0.65	12.87	2.24	E_1: Manual + Bullock
	C. Treatment E_1R_3:									E_2: Manual + Bullock + Improved machinary
1	Harvesting	4.14	-	-	-	4.14	1.15	27.75	4.68	
2	Threshing	0.92	-	-	1.48	2.40	0.66	10.81	1.82	E_3: Power tiller + Related equipment

Table 3.1 .... contd.

Table 3.1 contd.

1	2	3	4	5	6	7	8	9	10	11
	D. Treatment E_2R_3:									E_4: Tractor (35 hp) +
1	Harvesting	4.36	-	-	-	4.36	1.43	29.26	5.87	Suitable machine
2	Threshing	0.98	-	-	1.58	2.56	0.84	11.52	2.31	Note:
	E. Treatment E_3R_3:									(1) Harvesting in all
1	Harvesting	5.56	-	-	-	5.56	1.29	37.26	6.38	cases with sickle
2	Threshing	1.63	-	-	2.64	4.27	0.99	19.14	3.27	(2) Threshing in all
	F. Treatment E_4R_3:									cases with kubota power thresher +
1	Harvesting	5.24	-	-	-	5.24	1.34	35.06	6.05	5 hp elect. motor
2	Threshing	1.57	-	-	2.53	4.10	1.05	18.41	3.17	(3) Wheat yield

* Adopted from : Ojha, T.P. et al. Energy requirement in intensive agricultural production. Deptt. of Agricultural Engg. I.I.T. Kharagpur. May, 1973. p. 35-39.

Table 3.2. Energy requirement and cost of operation of harvesting and threshing wheat*

Sr. No.	Farm operation	Source of energy	Energy consumption kwh/ha	Percentage of total energy consumed for all operations on the farm for wheat	Cost Rs.P.	Percentage of total cost for all operations of wheat	Remarks
A. Experiment 1: Large type of holding							
1	Harvesting	Human	6.80	1.37	30.50	2.59	Harvesting with sickle.
2	Threshing	Elect. motor	22.24	4.29	23.65	1.93	Threshing with 5 bhp elect. motor operated Ludhiana type thresher.
B. Experiment 2: Small type of holding							
1	Harvesting	Human	8.88	1.53	39.94	2.93	
2	Threshing	Elect. motor (5 hp)	32.60	5.43	34.97	2.49	
C. Experiment 3: Small type of holding							Harvesting with sickle.
1	Harvesting	Human	11.26	2.45	50.98	3.68	Power tiller operated Ludhiana type thresher.
2	Threshing	Power tiller (8 hp)	75.50	16.30	80.42	5.66	
D. Experiment 4: Small type of holding							Harvesting with sickle.
1	Harvesting	Human	9.30	4.31	42.51	2.89	Threshing with Ludhiana type thresher operated
2	Threshing	Bullock	39.52	11.44	42.03	2.45	by 5b hp elect. motor.

* Adopted from : Singh, L.P. *et al.* Annual report of coordinated scheme for research on energy requirement in intensive agricultural production. J.N.K.V.V., Jabalpur. 1971-73. p. 34-36.

Table 3.3. Energy requirement and cost of operation of harvesting and threshing of wheat in heavy and light soils*

Sr. No.	Farm operations	Energy kwh/ha	Percentage of total energy for all operations %	Cost of operation Rs./ha	Percentage of total cost for all operations %	Remarks
1	2	3	4	5	6	7
	A. Heavy soils, highly mechanized cultivation, combine harvester-thresher					
1	Harvesting	67.20	4.73	81.36	10.34	
2	Threshing					
	B. Heavy soils, bullock-power with indigenous implements					
1	Harvesting	13.78	1.24	51.67	4.09	Manual harvesting and threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	258.08	23.38	133.24	10.56	
	C. Heavy soils, bullock-power with improved implements					
1	Harvesting	16.31	1.57	61.16	6.05	Manual harvesting and threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	381.62	36.95	197.18	19.52	
	D. Heavy soils, power tiller with its implements and other machines					
1	Harvesting	13.85	1.32	51.94	5.98	Manual harvesting and threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	264.07	25.24	136.32	15.70	

Table 3.3 ... contd.

Table 3.3 contd.

1	2	3	4	5	6	7
	E. Heavy soils, tractor 30-35 hp with its implements and machines					
1	Harvesting	12.96	0.82	48.00	5.60	Manual harvesting and threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	312.97	19.96	161.00	18.78	
	F. Light soils, bullock power with indigenous implements					
1	Harvesting	16.00	0.96	60.00	4.30	Manual harvesting with sickle. Threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	538.22	32.37	280.77	20.14	
	G. Light soils, bullock power with improved implements					
1	Harvesting	19.00	1.26	71.50	6.12	Manual harvesting with sickle. Threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	537.00	35.80	277.50	23.84	
	H. Light soils, tractor (30-35 hp) with its implements and machines					
1	Harvesting	16.00	0.82	60.00	5.47	Manual harvesting with sickle. Threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	539.00	27.94	285.00	25.98	
	J. Light soils, power tiller with its implements and other machines					
1	Harvesting	15.00	0.81	56.25	3.96	Manual harvesting with sickle. Threshing with metal fab. thresher operated by IH-B275 tractor
2	Threshing	535.00	28.94	270.00	19.02	

* Adopted from: Kulshreshtha, S.P. Annual report : Energy requirements in intensive agricultural production. G.B.P.U.A.T. Pantnagar. 1972-73. p. 18, 20 and 40.

Table 3.4. Energy and cost of harvesting and threshing wheat*

Sr. No.	Farm operation	Energy consumed kwh/ha	Percentage of total energy for all operations kwh/ha	Cost Rs	Percentage of total cost for all operations Rs
	A. Small holdings (0 - 3.00 ha)				
1	Harvesting	18.79	2.02	93.96	11.09
2	Threshing	304.68	32.86	155.04	18.31
	B. Medium holdings (3.00 - 6.00 ha)				
1	Harvesting	16.53	1.58	82.64	12.74
2	Threshing	143.06	13.73	192.52	29.72
	C. Large holdings (6.00 - 12.00 ha)				
1	Harvesting	20.91	1.45	104.57	13.11
2	Threshing	461.13	32.03	260.52	32.66

* Adopted from : Kulshreshtha, S.P. Annual report : Energy requirements in intensive agricultural production. G.B.P.U.A.T. Pantnagar. 1972-73. p. 18,20 and 40.

(1) for both the energy and cost per hectare, the use of the combined-harvester-thresher was least energy consuming and had the 'minimum cost'.

(2) in the village survey, the cost of harvesting and threshing wheat on small holdings (0-3.00 ha) was found to be the least while the energy consumed per hectare was minimum in the case of medium holdings (3.00-6.00 ha) as indicated in Table 3.4.

Arya et al. (1975) reported that in large size tractor plots, the requirement of energy for harvesting and threshing was respectively 19.2 and 13.42 per cent of the total energy requirement of 1266.75 hp-hours per hectare for wheat crop. In the case of bullock operated farms the respective figures for harvesting and threshing were found to be 2.62 and 18.38 per cent of the total energy requirement of 518.12 hp-hours.

The results of the study of energy requirements in harvesting and threshing operations for wheat in the Intensive Agricultural Production Programme in Ludhiana (Punjab), conducted by Singh et al. (1975) are summarized in Table 3.5. One of the main observations was that a 35-hp tractor with a small combined-harvester-thresher would be able to harvest and thresh wheat crop from 40 hectares of land in 20 days. It was observed that for harvesting and threshing the crop area with bullock power and tractor with matching implements, it would take approximately 40 and 28 days, respectively, provided at least 40 or more persons are employed daily for these operations.

It was also reported by Singh et al. (1975) that 75 per cent of the money spent in harvesting and threshing (using bullock as well as tractor drawn equipment) could

Table 3.5. Energy and cost per hectare of harvesting and threshing wheat*

Sr. No.	Farming operation	Energy consumed Man kwh/ha	Bullock or tractor kwh/ha	Mech. or elect. kwh/ha	Total energy kwh/ha	Percentage of total energy for all operations required for wheat cultivation	Cost Rs./ha	Percentage of total cost for all operations
1	2	3	4	5	6	7	8	9
	A. Bullocks with improved implements, Groundnut - Wheat rotation							
1	Harvesting	12.93	-	-	12.93	1.37	207.96	10.91
2	Threshing	8.88	-	198.91	207.79	22.12	385.23	20.22
	B. Tractor and matching implements, Groundnut - Wheat rotation							
1	Harvesting	12.93	-	-	12.93	1.35	207.96	10.56
2	Threshing	13.67	311.15	-	324.82	34.12	589.96	29.97
	C. Tractor with implements of future (Vicon combine), Groundnut - Wheat rotation							
1 2	Harvesting Threshing	1.84	88.96	-	90.80	19.53	221.74	19.44
	D. Bullocks with improved implements, Maize-Wheat rotation							
1	Harvesting	17.91	-	-	17.91	3.19	288.12	19.90
2	Threshing	10.65	-	234.86	245.51	43.81	450.88	31.14

Table 3.5 ... contd.

Table 3.5 contd.

1	2	3	4	5	6	7	8	9
	E. Tractor with matching implements							
1	Harvesting	17.91	-	-	17.91	2.45	288.12	18.08
2	Threshing	13.08	298.92	-	312.00	42.71	566.28	35.54
	F. Tractor with implements of future (combine-harvester)							
1	Harvesting							
2	Threshing	1.84	54.82	-	56.66	10.54	212.74	23.26

* Adopted from : Singh, C.P. et al. Annual Report : Energy requirements in IADP. 1974-75. Deptt. of Farm Power and Machinery. Punjab Agril.'Varsity, Ludhiana. 1975. pp. 1-38.

be saved by introducing new machinery (combine).

The results of the investigations reported by Ojha _et al._ (1975) on the energy requirements and cost of harvesting and threshing of wheat are presented in Table 3.6. It may be seen that harvesting and threshing together consumed 11.89 per cent, 8.60 per cent and 19.15 per cent of the total energy in the three energy treatments.

The studies reported above, point out the importance of harvesting and threshing operations requiring substantial amount of human labour, energy and involving high cost. These factors are greatly influenced by the level of mechanization. However, the studies conducted so far do not reveal the losses of grain, operational time involved in various harvesting and threshing systems and the suitability of any particular system for a specific farm situation.

F Losses and adjustments

3.9 The losses and adjustments in harvesting and threshing machinery are interrelated as these affect machine efficiency, power requirement and quality of work.

Sirohi _et al._ (1971) presented a comparative study

Table 3.6. Requirement of energy and cost of operation of harvesting and threshing wheat*

S. No.	Farm operation	Energy supplied by: Human kwh/ha	Bullock kwh/ha	Mech. kwh/ha	Elect. kwh/ha	Total energy kwh/ha	Percentage of total energy for all operations	Cost of operation Rs./ha	Percentage of total cost of all operations	Remarks
	A. Bullocks with improved implements									
1	Harvesting	8.00	-	-	-	8.00	2.29	66.47	7.62	Harvesting with sickle.
2	Threshing	5.58	27.92	-	-	33.50	9.60	141.23	16.21	Threshing with olpod thresher with bullock treading
	B. 8 hp rotary power tiller equipped with suitable implements and machine									
1	Harvesting	6.76	-	-	-	6.76	2.12	56.15	9.36	Harvesting with sickle.
2	Threshing	3.55	-	-	17.09	20.64	6.48	58.26	9.71	Kubota power thresher with 5 hp elect. motor
	C. 35 hp tractor equipped with suitable machines									
1	Harvesting	8.91	-	-	-	8.91	2.00	74.02	9.47	Harvesting with sickle.
2	Threshing	1.94	-	74.33	-	76.27	17.15	117.33	15.02	Ludhiana thresher run by 35 hp tractor

* Adopted from: Ojha, T.P. et al. Annual report : The coordinated research scheme on energy requirements in intensive agricultural production. Deptt. of Agr. Engg. I.I.T. Kharagpur. 1974-75.

of drummy threshers - the first with a winnowing fan with a drum diameter of 90 centimetres and clearance 5 centimetres and the other thresher with a drum diameter of 100 centimetres complete with winnowing fan, set of vibrating screens and auger and having clearance of 5 centimetres. They recommended a speed of 475 rpm of threshing drum for the best performance of both the threshers.

Pathak (1970) reported that in the case of an axial threshing cylinder the fineness of bruising was regulated with the cylinder speed and the depth of the counter teeth. It was observed that cylinder speeds of 288 to 30 metres per second resulted in a better machine performance. The bruising was not fine enough at higher moisture content.

The studies carried out by Singh et al. (1973) in connection with the harvesting and threshing of grain at different moisture contents indicated that:

(1) the total losses increased with the increase in moisture content for the given range of 6 to 11 per cent and

(2) the breakage of grain with the combine was more at higher moisture content.

Pathak *et al.* (1973) reported that the threshing percentage, which was an indirect measure of energy-transfer, was a function of peripheral velocity, moisture content, material and shape of the impact member. There was a non-linear increasing relationship between moisture content and threshing percentage.

Mittal (1972) reported that in Punjab 1,16000 threshers, ranging in their power-requirement from 5 hp to 35 hp, were being used by the farmers in 1970-71. According to the results of the field study, a majority of farmers were not aware of the adjustments and their effect on machine performance. Mittal (1970, 1971) in the course of field studies regarding the use of Vicon and G.D.R. E512 combines, observed grain losses totalling 8.4 and 0.53 per cent, respectively.

Singh (1970) reported that the threshability and damage of wheat grain were influenced by the threshing cylinder type, feed rate, cylinder speed and concave clearance. It was reported that the best peripheral speeds were 1450-1550, 1150-1250 and 850-950 metres per minute, respectively, for hammer type, straight bar and spike tooth type cylinders. The visible damages at these speeds were reported to be 3.8-4.2, 3.0-3.4 and 2.4-3.10

per cent and unthreshed loss in the range of 1.4-1.3, 1.6-1.3 and 0.5-0.37 per cent, respectively. It was observed that the feed rates affected seed losses and visible damages.

The results of the performance tests in harvesting wheat crop using some of the threshers manufactured in India reported by Kaul and Kumar (1975) are presented in Table 3.7. The data presented in table provide useful information on the crop input capacity, energy consumption, grain loss, grain crackage, power consumption and output. However, it does not provide information on the speed of operation which happens to be one of the most important parameters influencing machine - performance.

The ISI standards (IS: 6320-1971 and IS: 6284-1971) prescribe the following criteria for the performance acceptability of threshers:

(1) the capacity of thresher should not be less than 85 kg of wheat crop per kwh energy consumed,

(2) the threshing efficiency should not be less than 99 per cent,

(3) the cleaning efficiency should not be less than 96 per cent, and

(4) the total loss should not exceed 5 per cent, in which crackage shall not be more than 2 per cent.

Table 3.7. Comparative performance of threshers using wheat crop*

S. No.	Thresher type	Crop input capacity		Energy kwh/ qtl.	Grain loss with bhusa percentage of output	Grain crackage percentage of output	Power		Output qtl./ hr	Report No. THR-
		Kg/kwh	Percentage variation over ISI requirement				Average kw	Peak kw		
1	2	3	4	5	6	7	8	9	10	11
1	Drummy	171	+ 100	1.57	-	0.5	4.1	-	2.6	10/72
2	Drummy with toka	249	+ 193	1.25	-	1.1	2.8	-	2.2	9/72
3	Allahabad type (no. bagging)	111	+ 30	-	7.1	0.2	8.5	-	3.3	7/72
		113	+ 33	2.3	0.1	0.2	5.6	-	2.4	12/73
		116	+ 36.5	-	0.7	0.3	3.7	5.6	1.7	1/70
		122	+ 43.5	2.7	6.7	0.2	4.9	-	1.9	6/72
		135	+ 59	-	1.1	0.5	3.7	6.8	1.8	2/70
		150	+ 76.5	2.0	1.7	2.0	4.0	7.5	2.1	8/72
		151	+ 77.5	-	1.8	0.2	2.6	3.8	1.4	3/70
4	Allahabad type with toke	121	+ 43	2.31	0.2	0.1	9.1	16.0	3.9	13/74
		316	+ 217.5	0.9	0.6	4.8	2.0	4.5	2.2	15/74

Table 3.7 ... contd.

Table 3.7 contd.

1	2	3	4	5	6	7	8	9	10	11
5	Ludhiana type	46	- 46	5.14	2.4	1.4	12.1	16.9	1.9	4/71
		57	- 33	5.22	0.4	4.4	11.4	17.0	2.2	Conf.9/72
		81	- 4.7	3.69	3.4	0.3	10.1	14.9	2.6	5/71
6	Bulk feeding type	110	+ 30	2.7	1.4	2.6	6.1	12.0	2.3	14/74
		122	+ 43.5	2.37	4.0	0.3	12.9	17.5	5.4	16/74

*Adopted from : Kaul, R.N. and Ramesh Kumar. Types and usage of wheat threshers in Punjab. Deptt. of Farm Power and Machinery. Punjab Agr. University, Ludhiana. 1975.

A number of studies have been conducted on losses and their relationship with operational parameters in relation to the use of combines. The results of these studies are equally applicable on the performance of reapers and threshers in general, as far as the cutter bar and threshing losses are concerned.

Bilanski (1966) reported that the high moisture grains required more energy to produce crackage but high moisture grains got permanently deformed at a lower load than drier grains.

King and Riddols (1962) reported decrease in visible damage of wheat grains with the increase of moisture content during threshing but only upto 20 per cent moisture content. Beyond this, the damage increased. They reported the increase in invisible damage during threshing with the increase in moisture content. Because of this, it was recommended that the moisture content of the grain at the time of harvesting should not be more than 16 per cent to meet the seed requirement of 85 per cent minimum germination.

Singh _et al._ (1975) reported the decrease in total losses with the increase in moisture content at the time of harvesting with the combine. The maximum total loss

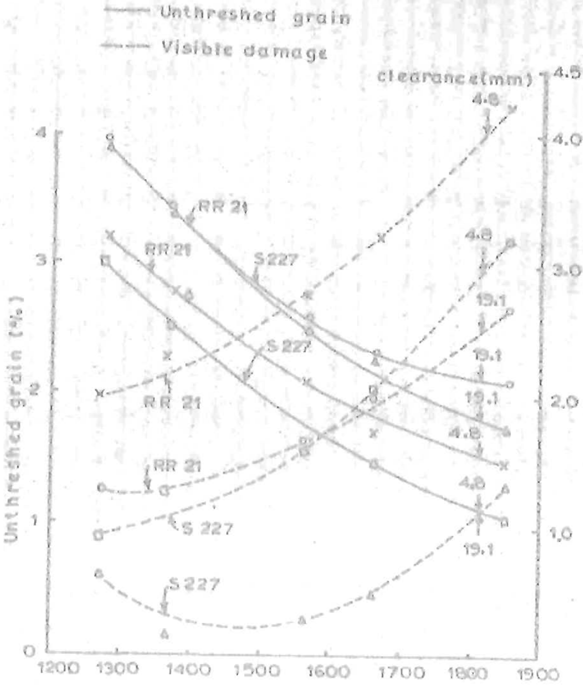

Fig 3.11 Effect of cylinder speed on unthreshed grain and external damage on two varieties of wheat

(Source: Singh, K.N., combine operation for minimum losses) of 4.98 per cent occurred at 7.8 per cent moisture content, while at 11.7 per cent moisture content, the total loss was only 1.19 per cent. They reported the effect of cylinder speed on unthreshed grain and external damage, thereby underlying the importance of proper adjustment. Figure 3.11 shows the relationship between cylinder speed and unthreshed grain and external damage on wheat.

McCuen (1952) reported the effect of height of cut and rate of travel upon the grain losses, thus underlying the importance of proper adjustment and skill of operator (Fig. 3.12).

G Conclusion of review

3.10 On the basis of the review made in the earlier sections, the following conclusions can be derived :

(1) In view of the increasing rate of human population, the productivity-concepts are to be incorporated on a larger scale than hitherto, in agricultural production processes.

(2) The incorporation of energy and mechanization in farm operations pave the way for increased productivity from land and labour.

(3) Harvesting and threshing operations required

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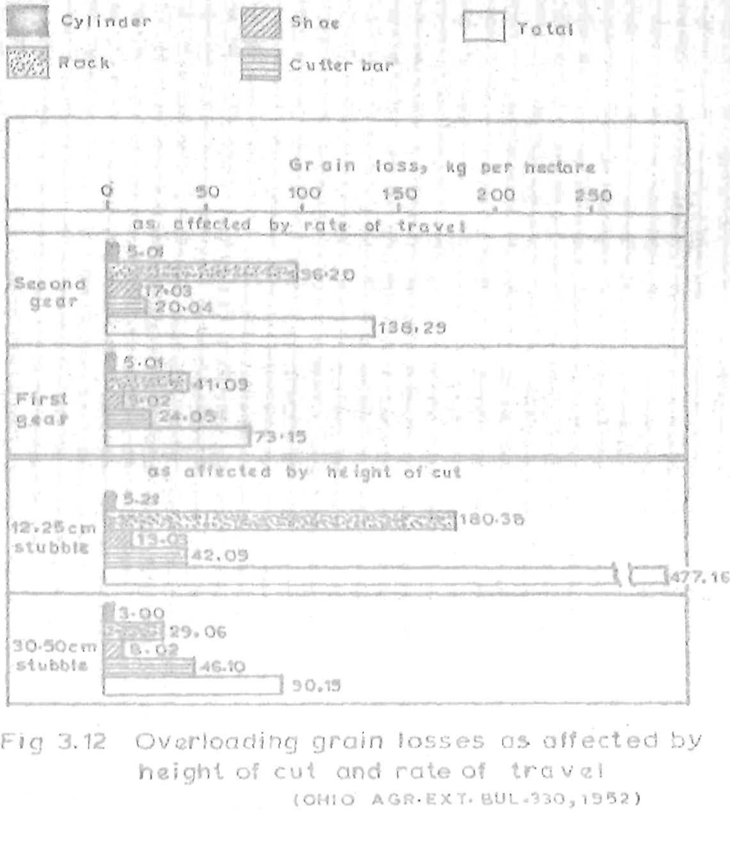


Fig 3.12 Overloading grain losses as affected by height of cut and rate of travel
(OHIO AGR.EXT. BUL.330, 1952)

for wheat need mechanization from the point of view of labour-productivity, profit, weather-risks, drudgery and timeliness of operations.

(4) The need for such mechanization of harvesting and threshing operations has been realized. With this end in view, work on the design and development of harvesting and threshing machinery has been done by different research workers in India, whose work has been reviewed.

(5) The workers are not unanimous in their approach regarding the level of mechanization to be adopted in harvesting and threshing operations.

On a critical examination of the review, it may be seen that hardly any work has been done to study the harvesting and threshing systems based on the methods employing the conventional means like sickle and animal trampling to modern machine like combine-harvester-thresher. Though different workers have touched different aspects of harvesting and threshing machinery i.e. cost, energy, losses and adjustments, labour-displacement and farmers' reaction etc., yet the information available is in piece-meal and not gathered under uniform field conditions.

This sometimes causes apprehension about the suitability of a particular harvesting and threshing system to be adopted.

Hence, as a logical step, the present study has been undertaken to develop systematic information under actual field conditions. It is envisaged that this information will be helpful in the selection and adoption of a suitable system of harvesting and threshing under specific farm situation. Also the present study, it is hoped, will provide comparative data to determine the level of mechanization to be adopted in harvesting and threshing operations for wheat under varied conditions with special reference to India.

C H A P T E R IV

HARVESTING AND THRESHING MACHINERY

CHAPTER IV

HARVESTING AND THRESHING MACHINERY

The harvesting and threshing systems of wheat crop are dependent upon the devices used to harvest and thresh and the source of power available to operate them. The implements and machinery used in the present study in these two operations are discussed below.

A Tools and machines for harvesting

4.2 Hand sickle

The most common tool for harvesting crops since time immemorial has been the sickle. The sickle is still widely used in India and other less developed countries because of its being cheap, made locally and being easy to operate. The worker is required to squat on the ground, hold the plants by the other hand. The harvested plants are tied into bundles by the same worker with a few plants. The bundle is left to be collected later usually at the end of the day. When the worker reaches the other end of the field, he turns around and again repeats the above process in opposite direction and goes on till he finishes cutting the area allotted to him.

This method is slow and causes much fatigue to the workers, specially if they are not used to this posture of sitting and working.

In another method of harvesting with sickle, the worker is required to bend while standing, hold the plants with one hand and cut the plants near the roots with the right hand with the help of sickle. This method also causes fatigue, results in considerable drudgery and is slow.

There are two types of sickles in common use in India:

(a) plain edge sickle or blade edge sickle, and

(b) serrated edge sickle or saw sickle.

For wheat harvesting, the serrated edge sickle is most commonly used. The system of manual harvesting with sickle can be improved to some extent by redesigning the sickle and manufacturing it out of better quality of steel.

The handle of the sickle is usually made of wood and the blade mostly of mild steel. The total weight of the sickle varies from 0.25 kg to 0.50 kg. Figure 4.1 shows the general shapes of hand sickles and details of construction of hand-sickles used in the Delhi territory

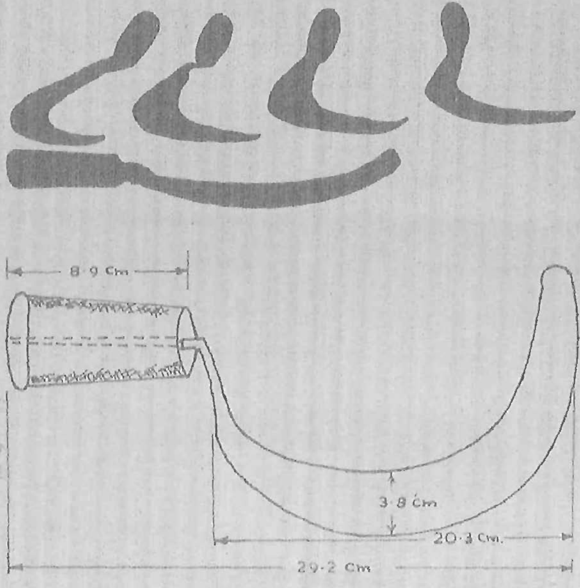


Fig 4.1 General shapes of sickles used in Delhi region

and neighbouring areas.

4.3 Reaper

In the reaper used in the present study, the cutter bar gets power transmitted from the ground wheels by means of a pair of internal spur gears and a pair of bevel gears. The power transmitting unit consists of the main axle gears, crank-shaft, crank wheel and pitman. The main axle receives power from one of the transport-wheel. A spur gear mounted on the main axle drives the spur pinion on one end of the counter-shaft in the gear box. The bevel gear keyed to the other end of the counter-shaft engages with a bevel pinion on the crank shaft. The crank wheel and the pitman are fixed on the outer end of the crank-shaft. The eccentric wheel transforms the circular motion into reciprocating motion of the knife in the cutter bar. The knife is connected to the pitman with a ball and socket joint and reciprocates within the guards. The teeth on the knife are so adjusted that they cut the crop from both the sides when the knife reciprocates, making about 1600 strokes per minute.

A platform is provided on which the cut crop falls, from where it is collected and tied into sheaves. A clutch is provided on the counter-shaft to engage or disengage the driving unit and is operated by the foot of the operator sitting on his seat. Figure 4.2 shows the wheat crop being harvested with a reaper.

Aligmment, lead and registration are the necessary checks and adjustments to be made before taking the machine to the field.

B Machines for threshing

4.4 Olpod thresher

Among the small farmers throughout wheat farming areas in India, the olpod thresher is a popular threshing machine pulled by a pair of bullocks. The use of this machine is an improvement over the indigenous method of threshing by means of bullock treading on a charge of crop spread in a circle over the threshing floor.

The olpod thresher consists of a square shaped frame with two transport wheels, usually made of cast iron. The frame is fitted with three axles with the help of side-brackets consisting of cast iron blocks with wooden bearings. Circular notched discs numbering 14 to 21 and spaced 15 cm, are mounted on these axles with steel or cast iron spacers to separate them from each other. Each disc is of 45 cm diameter and 3 mm thickness. The discs are usually made up of 10 guage steel with 2 deep

Fig. 4.2 Wheat crop being harvested with a reaper

Fig. 4.3 Wheat crop being threshed with an olpod thresher

ribs in opposite direction to ensure maximum rigidity.

The operator can sit over the wooden platform, provided as a cover on the discs and having expanded metal guard attached to it. Figure 4.3 shows the wheat crop being threshed with the help of an olpod thresher. Threshing with an olpod thresher is continued till the entire harvested heap of crop becomes a homogenous mixture of grain and bhusa (chaff).

4.5 Spike-tooth thresher - long straw making type

The threshing machine used in the study was a Pullman thresher which is an imported machine developed by O.A. Vogel in 1930. It does not make bhusa (bruised straw). It is a trailer mounted stationery thresher operated by 9.2 h.p. petrol engine.

The feeder throat on the hopper is 59.28 cm long and 34.58 cm wide. The threshing cylinder is of 29.64 cm diameter and 49.40 cm wide, having seven rows of 8 teeth spread on its cylinderical surface. The operating speed may be upto 2400 rpm with a clean-out time of 8 seconds approximately. Figure 4.4 shows the working of the Pullman thresher.

Fig. 4.4 Working of a pullman thresher

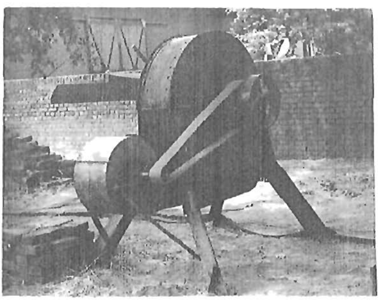


Fig. 4.5 Hammer mill type thresher without sieving and bagging arrangement (drummy thresher) - conventional type

4.6 Hammer mill type thresher without sieving and bagging arrangement (drummy thresher) - conventional type

Drummy thresher (Figure 4.5) is very popular among the small farmers of India because of its low cost. It has a threshing drum in which, generally 12 beaters are provided to thresh the crop. A winnowing fan is provided under the machine to blow off the bhusa from the grain. The grain falls through grate by gravity along with some heavier material like nodules, pods and unthreshed spikelets making the winnowing operation a necessity. There is no bagging arrangement. The machine operates at a speed of 470 to 550 rpm. The beaters are fixed to the rotor which beats the fed crop against grated bar. The beaters work in a housing which has an opening for crop-feeding. The drum diameter of the drummy thresher used in this study is 90 cm and clearance 5 cm.

A part of the grain and bhusa get mixed and usually are recycled through the blower for further cleaning. Some cleaning is also done using a broom. The process is time consuming and the person assisting in cleaning has to work in a comparatively unfavourable environment of dust and blown bhusa.

4.7 Hammer mill type thresher with sieving and bagging arrangement (Ludhiana type thresher)

Basically, the Ludhiana type thresher is also a drummy thresher as far as the basic principle of beating the crop against stationary plate or rods are concerned. It is different from the point of view of separation of grain and straw and delivery of grain. Both the operations are affected through the use of oscillating sieves and the suction created by the fans to lift or suck the bhusa from the mixture and blow it off.

The Ludhiana type thresher shown in Figure 4.6 has a drum diameter of 100 cm and a clearance of 5 cm. Threshing of the fed crop is carried inside the drum by a number of steel arms (12 No.) with beater tips mounted on a roter-beater. The mixture of grain and straw (after threshing) falls down through a grate which forms the lower part of the periphery of the drum. This mixture is received on the oscillating sieves topped by a suction duct (aspirator). Two fans are provided to clean the grain by blowing out the bhusa. These fans suck the bhusa through an aspirator and blow it off through the straw discharge outlet. The nodes and grain are separated on the oscillating sieves. Through the

Fig. 4.6 Hammer mill type thresher with sieving and bagging arrangement (Ludhiana type thresher)

oscillation of the sieves, the nodes left out on the upper sieve fall out to the ground while the grain passes down to the lower sieve. From the lower sieve, the grain passes towards an auger carrying it to a bucket type elevator for bagging.

4.8 Combined harvester-thresher

A combined harvester thresher (commonly known as combine) is a machine consisting of reaping, threshing, separating, cleaning and collecting units as components put together in a synchronized manner in order to get the maximum possible clean grain yield from the standing field crop. The flow path of grain and straw in a combine is illustrated in Figure 4.7.

The combines are classified as (i) self-propelled type, (ii) pto operated side mounted and (iii) tractor-driven trailed type.

The combine used in present study was a Vicon JF Machine which is a tractor mounted pto operated combined harvester thresher. Figure 4.8 shows a schematic arrangement of the basic functional components of the machine. Figure 4.9(a) and 4.9 (b) show the field operation of harvesting wheat with the combine.

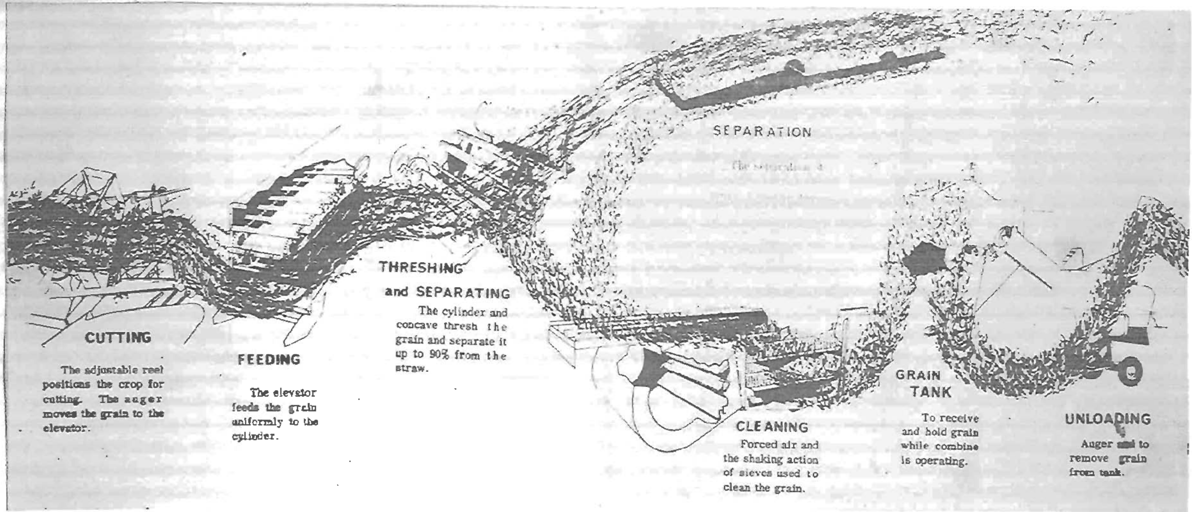


Fig. 4.7 Flow path of grain and straw in a combine

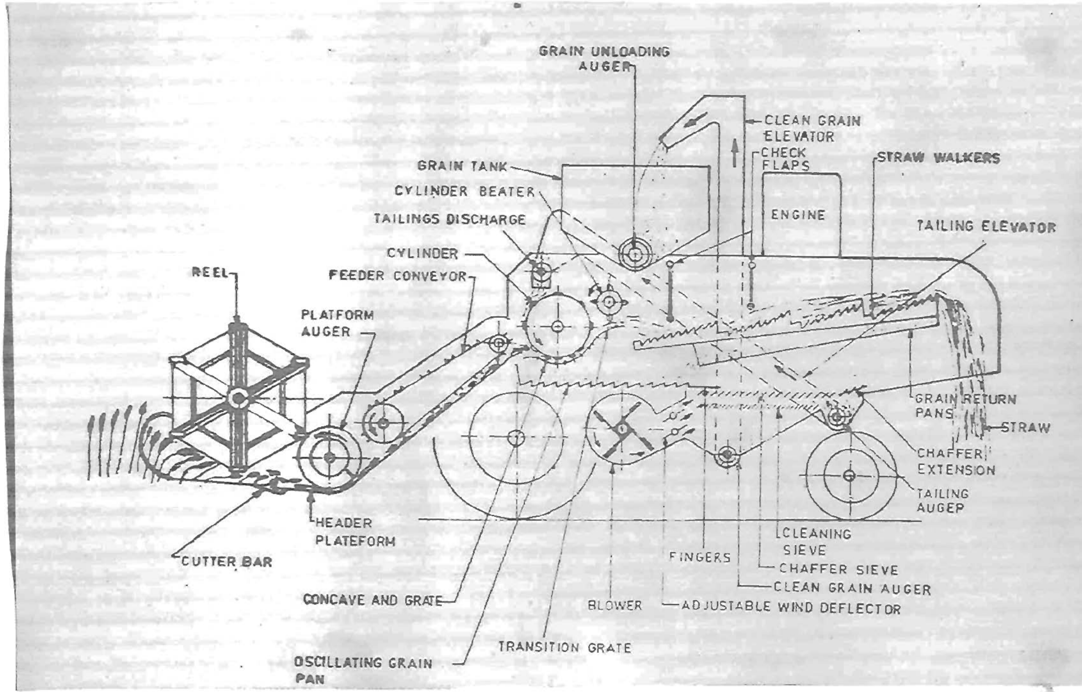


Fig. 4.8 Schematic arrangement of the basic functional components of a combine

Fig. 4.9 (a)

Field operation of tractor side mounted pto operated combine

Fig. 4.9 (b) Field operation of tractor side mounted pto operated combine

The basic functional units of a combined harvester-thresher are:

(1) header unit consisting of cutter bar, reel, header plat form, plat form auger and feeder conveyor;

(2) the threshing unit consisting of a cylinder and concave;

(3) the separating unit consisting mainly of straw-walkers, and

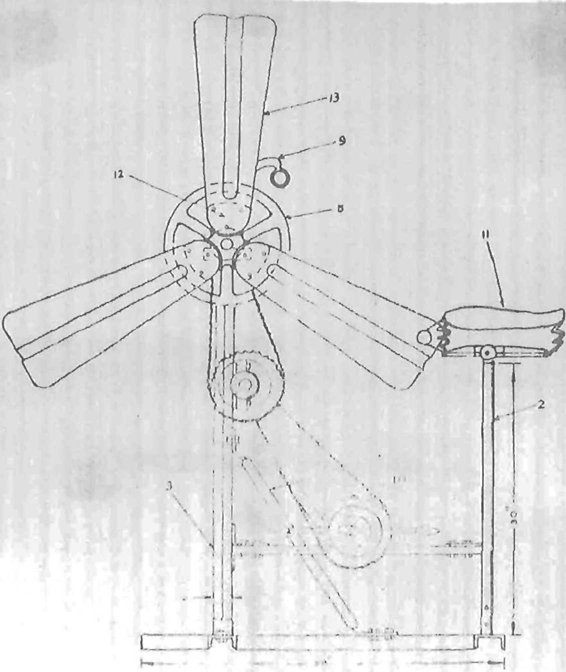
(4) the cleaning unit consisting of chaffer sieve, cleaning sieve and fan-cleaning of seed from chaff and other debris.

The specifications of the Vicon combine as provided by the manufacturer are given in Appendix B.

C Machine for winnowing

4.9 Winnowing fan

Winnowing operation is done to get clean grain from the straw and grain mix. Winnowing as such, is the process of separating grain from a mixture of grain and chaff or <u>bhusa</u> by natural air-stream or created artifically. The separation is effected by allowing the air stream to pass through the mixture falling vertically down. The chaff being lighter is blown off and the grain falls straight vertically.



MATERIALS CHART

No.	Name of parts	Material fabricated from	Size	No. of
1	2	3	4	5
1.	Frame	Channel	75cm × 40 mm	1
2.	Seat post	Angle iron	25cm × 25cm × 3mm	1
3.	Fan post	Angle iron	25cm × 25cm × 3mm	1
4.	Handle post	Angle iron	25cm × 25cm × 3mm	1
5.	Bracket	Cast iron	Casting	4

Fig. 4.10 Winnowing fan

The machine used in the present study is a 'Singh winnowing fan' weighing about 64 kg in which the fan is operated through sprockets and chians. The fan consists of 3 blades, each of which is 1160.10 cm in diameter. There is a seven-fold speed-increase through the use of a pair of sprockets and free wheels which provides a fan speed of 320 rpm. The operator sits on a seat (Fig. 4.10) and works the fan by means of pedals as in the case of an ordinary cycle.

CHAPTER V

MATERIALS AND METHODS

CHAPTER V

MATERIALS AND METHODS

The investigations reported in this thesis were conducted in 1974 and 1975 on the research farm and laboratories of the Division of Agricultural Engineering and the Water Technology Centre of the Indian Agricultural Research Institute, New Delhi.

5.2 Geographical location and climatic conditions

Delhi is situated at 28.4°N latitude and 77.1°E longitude and located at an elevation of 228 m above mean sea level. The climate is typically semi-arid and sub-tropical with the characteristic of hot summer and a cold winter. The temperature rises as high upto 46°C during the summer months while the minimum temperature falls to nearly 0°C in the winter. The daily minimum and maximum temperatures increase from February to June and decrease during July to September and drop fast from October in the winter attaining the minimum value in January. The average annual precipitation is 672 mm with heavy rains from July to September. High wind velocity is experienced from late winter onwards accompanied by an absence of rainfall. There is an abrupt rise in temperature during the spring which hastens the maturity of wheat crop. The meteorological data for the period of the present investigation recorded at the Meteorological Observatory of Indian Agricultural Research Institute, New Delhi are presented in Table 5.1. Detailed daily meteorological data are presented in Appendix A.

5.3 Policy variables

The different policies constituting the harvesting and threshing operations investigated were as follows:

I Tractor operated combine harvesting cum threshing system (designated as S-1).

II Tractor operated reaper harvesting + manual bundling + stacking + thresher (not bhusa making) + winnowing and cleaning if necessary (designated as S-2).

III Tractor operated reaper harvesting + manual bundling + stacking + hammer mill type thresher with sieving and bagging (bhusa making) + winnowing and cleaning if necessary + bagging (designated as S-3).

IV Tractor operated reaper harvesting + manual bundling + stacking + hammer mill type thresher without sieving and bagging (drummy thresher) + winnowing and cleaning + bagging (designated as S-4).

Table 5.1. Meteorological data at the experimental area, 1974-75

Sr. No.	Week ended on	Wind velocity at 08.30 in past 24 hr		Maximum temperature		Minimum temperature		Average relative humidity at 07.00 %	Average relative humidity at 14.00 %	Total weekly rainfall mm
		Range km/hr	Average km/hr	Range °C	Average °C	Range °C	Average °C			
1	2	3	4	5	6	7	8	9	10	11
1	10.11.74	4.2 - 6.7	5.6	29.0 - 31.0	29.87	9.4 - 11.5	10.75	58.85	19.71	00.0
2	17.11.74	1.4 - 4.2	2.82	28.0 - 31.0	29.32	9.0 - 13.8	11.11	73.28	22.28	00.0
3	24.11.74	1.1 - 5.3	3.02	24.5 - 28.0	25.85	4.6 - 9 .0	7.25	80.14	23.57	00.0
4	1.12.74	1.6 - 5.7	3.24	23.2 - 26.0	24.87	5.6 - 6.4	5.97	76.57	24.57	00.0
5	8.12.74	3.0 - 7.4	5.17	20.0 - 23.5	21.78	3.0 - 10.4	6.94	79.00	23.85	Tr
6	15.12.74	1.4 - 8.7	5.77	21.0 - 22.5	21.74	4.5 - 7.5	5.57	70.57	30.85	2.4
7	22.12.74	2.4 -10.7	5.81	17.0 - 18.5	18.02	3.0 - 12.2	5.55	90.42	52.71	00.0
8	29.12.74	1.6 - 4.3	3.14	19.0 - 21.6	20.22	3.5 - 7.2	5.02	86.00	34.14	00.0
9	5. 1.75	1.9 - 8.3	4.50	12.0 - 22.0	18.27	3.5 - 9.5	5.30	91.28	56.42	21.8
10	12. 1.75	2.7 - 8.1	4.74	17.0 - 19.2	18.74	3.5 - 8.4	6.45	91.14	49.42	Tr
11	19. 1.75	1.8 - 7.2	5.20	17.0 - 20.5	19.00	2.0 - 10.2	5.68	87.28	40.14	00.0
12	26. 1.75	2.6 - 9.1	5.50	14.5 - 20.2	18.12	3.8 - 10.0	6.75	90.14	52.42	00.0
13	2. 2.75	2.9 - 8.7	6.14	14.5 - 20.5	18.88	4.0 - 11.4	7.68	90.00	53.57	09.4
14	9. 2.75	2.2 - 6.9	4.97	17.2 - 23.5	20.60	3.5 - 11.5	8.12	84.57	42.14	00.0
15	16. 2.75	3.7 -10.2	6.87	18.5 - 26.0	21.95	4.5 - 12.2	8.31	80.42	37.42	00.0

Table 5.1 ... contd.

Table 5.1 contd.

1	2	3	4	5	6	7	8	9	10	11
16	23.2.75	4.5 - 8.2	6.01	18.0 - 22.0	19.98	1.0 - 8.5	5.50	71.57	40.28	00.0
17	2.3.75	1.8 - 6.1	4.01	22.0 - 29.0	25.50	6.0 -12.0	9.05	84.00	30.28	00.0
18	9.3.75	4.8 - 9.8	6.61	27.0 - 32.2	28.75	11.0 -19.2	13.80	76.14	31.85	Tr
19	16.3.75	6.4 -10.4	8.35	23.5 - 28.0	26.21	8.5 - 15.4	10.88	72.71	27.28	00.0
20	23.3.75	7.4 -12.8	9.36	27.0 - 32.0	29.14	9.0 -20.0	13.50	65.00	35.00	3.1
21	30.3.75	4.1 - 8.5	5.72	25.0 - 34.0	28.78	9.5 -15.0	11.75	63.57	35.14	7.0
22	6.4.75	3.7 - 6.9	5.70	30.0 - 38.0	34.52	15.0 -25.0	19.08	71.85	22.14	00.0
23	13.4.75	4.0 - 9.0	6.54	31.0 - 38.0	33.78	12.6 -21.0	16.58	45.42	14.57	00.0
24	20.4.75	3.2 - 7.8	6.22	33.0 - 39.0	35.80	13.0 -23.4	17.14	36.71	22.28	Tr
25	27.4.75	2.1 - 9.1	6.12	37.5 - 40.0	38.97	21.0- 24.5	22.67	49.00	23.14	Tr
26	4.5.75	7.7 -12.6	9.80	36.5 - 40.0	38.21	19.0 -25.0	20.95	42.14	20.28	Tr
27	11.5.75	3.7 -14.1	8.17	38.5 - 41.5	39.64	21.4 -24.5	23.05	41.71	19.42	00.0
28	18.5.75	8.6 -12.6	10.81	37.5 - 42.5	40.92	23.4 -30.5	27.17	43.42	29.14	Tr
29	25.5.75	4.9 -11.4	8.67	37.5 - 43.5	40.91	21.0 -28.0	24.91	47.28	32.14	00.0
30	1.6.75	6.4 -17.0	9.60	39.0 - 44.0	41.37	22.0 -29.0	26.28	45.85	31.57	5.2

V Sickle harvesting + manual bundling + stacking + hammer mill type thresher with sieving and bagging (bhusa making) + winnowing and cleaning + bagging (designated as S-5).

VI Sickle harvesting + manual bundling + stacking + hammer mill type thresher without sieving and bagging (drummy thresher) + winnowing and cleaning + bagging (designated as S-6).

VII Sickle harvesting + manual bundling + stacking + animal threshing with olped thresher + winnowing and cleaning + bagging (designated as S-7).

The above policy concept is illustrated schematically in Figure 5.1.

The above policies of operation-combination comprise the existing ones or those probable ones which could be adopted in the near future, considering the anticipated technological progress of Indian agriculture and the different levels of technology possessed by the wheat farmers in different parts of the country.

The specifications of the tractors, combine-harvester cum thresher, reaper, threshers, winnowing fan, internal combustion engine and electric motor used in conducting the experiments, are given in Appendix B.

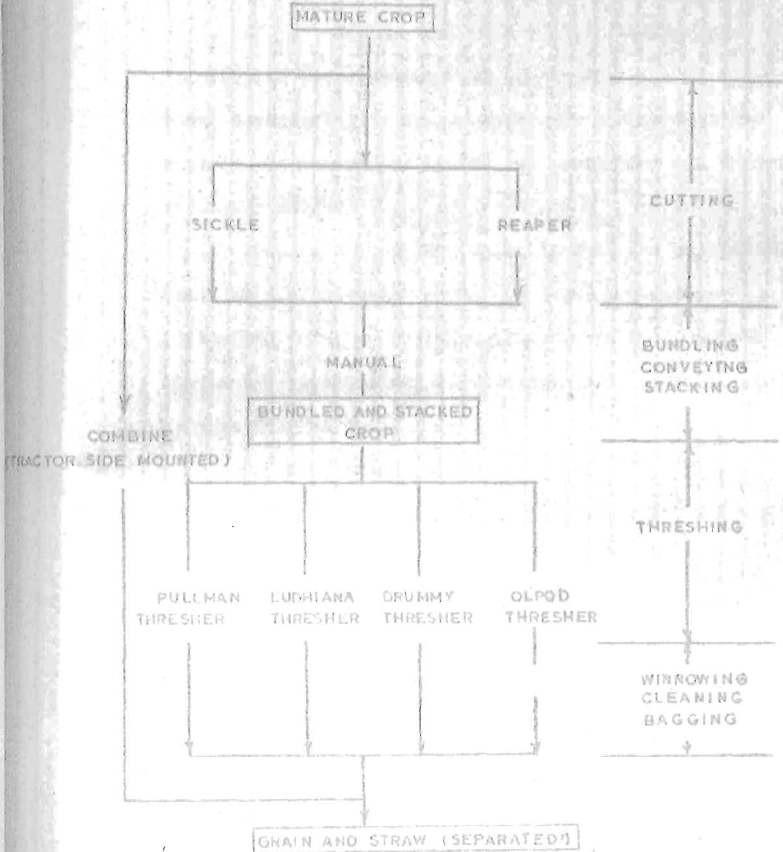


Fig 5.1 Flow chart for wheat harvesting systems

5.4 Land area allocation and preparatory tillage

An approximate land area of 1.4 hectares was allotted on the research farm of the Division of Agricultural Engineering to raise wheat crop and conduct the experiments related to systems of harvesting and threshing indicated earlier.

Preparatory tillage operations of the experimental field were carried out after the usual pre-sowing irrigation. The presowing tillage operations carried out in the experimental field are listed in Table 5.2.

B Experimental technique

5.5 Experimental details

The details of the experimental technique are given below :

(a) Two experiments titled A and B were conducted at two different sowing dates as indicated in article 5.4. Each experiment had three replications titled a,b and c. The seven treatments indicating seven policies were applied as per randomized block design. The plots have been indicated as A/S-1/a to A/S-7/c in experiment A and B/S-1/a to B/S-7/c in experiment B. A/S-3/b, for example, indicates wheat crop in plot of experiment A in the bth replication under policy 3.

Table 5.2. Details of operations and machinery used for preparatory tillage of the experimental field

Sl. No.	Operation	Machinery used	Date of operation	
			Experiment A	Experiment B
1	Presowing irrigation	Electric motor driven pumping set	2.11.74 and 3.11.74	2.12.74 and 3.12.74
2	Ploughing	Tractor operated disc plough	8.11.74	9.12.74
3	Harrowing	Tractor operated bar harrow	12.11.74	12.12.74
4	Levelling	Tractor operated leveller	15.11.74	16.12.74
5	Sowing and application of fertilizer	Tractor operated seed cum fertilizer drill	23.11.74	23.12.74
6	Layout operations	Surveying equipment tractor, with ridger	26.11.74	26.12.74

(b) Layout for experiments A and B

I	Design	Randomized block design
II	Replications in each experiment	Three
III	Total number of plots in each experiment	Twenty one
IV	Total area under both the experiments i.e. A and B	2(107.5 x 64.60) m^2 = 1.39 ha
V	Plot size	30.5 m x 6.87 m = 209.535 sq.m.
VI	Net area under plots in both the experiments	0.88 ha

(c) Treatments

	Treatments	Main machines involved
I	S-1	Vicon combine
II	S-2	Reaper and Pullman thresher
III	S-3	Reaper and Ludhiana thresher
IV	S-4	Reaper and drummy thresher
V	S-5	Sickle and Ludhiana thresher
VI	S-6	Sickle and drummy thresher
VII	S-7	Sickle and olpod thresher

(d) Layout of experiment

Figure 5.2 shows the layout plan and necessary

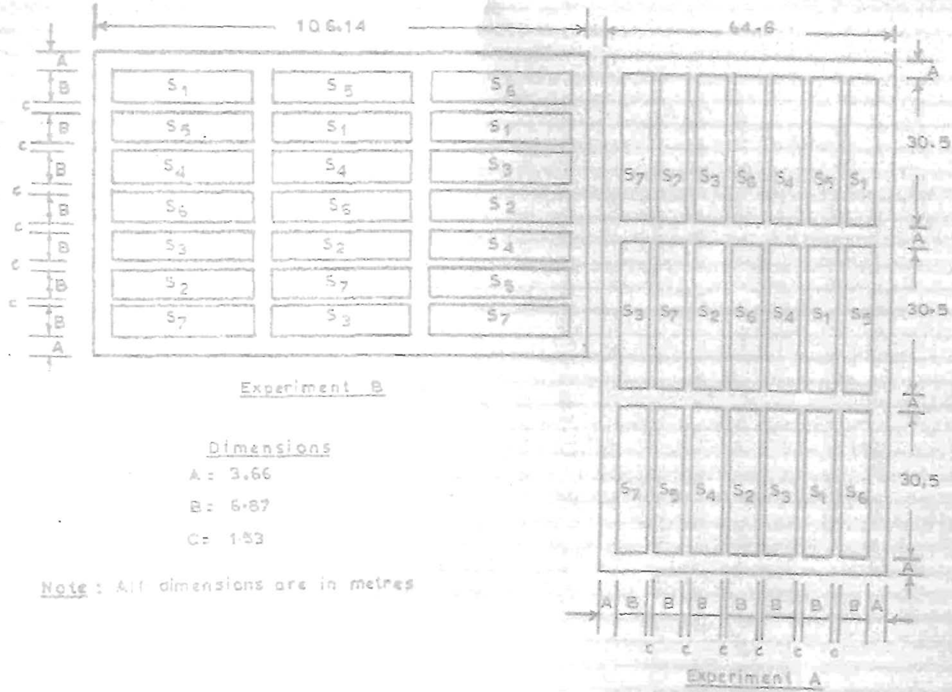


Fig 5.2 Layout of experiments A and B

details of the plots described in articles 5.4(a), 5.4(b) and 5.5(c).

5.6 Details of the crop and variety

(a) Wheat variety - Sonalika

All the seven systems of harvesting and threshing were tried with wheat as the test crop. Wheat crop was selected since it is the major and premier food grain crop of northern India. The Sonalika wheat was grown.

Sonalika wheat is a single gene dwarf variety derived from Mexican cross (II 54 x 388 x An) x (Yt.54 x N 1 DB) LR III 8327. The grains are bold and amber coloured. It is moderately resistant to all the three rusts and performs well if timely sown. This is also specifically suited to late sowing conditions in multiple cropping system.

(b) Agronomic practices

I Seed rate and spacing

A seed rate of 100 kg per hectare was used with a row to row spacing of 23 cm (Sharma _et al._, 1975; Dhillon and Singh, 1974).

II Time and method of sowing

The sowing dates for experiments A and B were 23rd November and 23rd December, 1974 respectively. The use of seed cum fertilizer drill was made to ensure uniform depth of sowing. The sowing depth was kept at 6 cm to ensure better germination (Krantz *et al.*, 1975; Dhillon and Singh, 1974).

III Fertilizer application

The names of the fertilizers and their rates of application in the experiment are given in Table 5.3. A half of the quantity of nitrogenous fertilizer required and full amount of phosphorus and potassium were applied at the time of sowing. The remaining dose of nitrogen was broadcast at the time of first irrigation (the timings of irrigation in both experiments given vide Table 5.4).

Table 5.3. Fertilizers applied

Sl. No.	Nutrient	Quantity of nutrient kg/ha	Fertilizer used	Quantity of fertilizer kg/ha
1	Nitrogen	123.50	CAN (25 %)	494
2	P_2O_5	61.75	Superphosphate (16 %)	383
3	K_2O	61.75	Muriate of potash (60 %)	49

The seed cum fertilizer drill was used for the purpose of band placement of the nitrogenous, phosphatic and potassium fertilizers at 3.81 cm depth and 3.81 cm distance from the row of seeds.

IV Interculture

One hoeing was done after 40 days from sowing in each experiment in order to control weeds.

V Irrigation schedule

Five irrigations were given to each of the experiments on the dates mentioned in Table 5.4.

Table 5.4. Irrigation schedule*

Sl. No.	Irrigation serial	Experiment A	Experiment B	Duration of irrigation in each plot** min
1	First irrigation	21.12.74 and 22.12.74	21.1.75 and 22.1.75	15
2	Second irrigation	24.12.74 and 25.1.75	12.2.75 and 13.2.75	20
3	Third irrigation	10.2.75 and 11.2.75	5.3.75 and 6.3.75	20
4	Fourth irrigation	3.3.75 and 4.3.75	20.3.75 and 21.3.75	20
5	Fifth irrigation	18.3.75 and 19.3.75	30.3.75 and 31.3.75	10

* The irrigation schedule was followed as recommended by All India Wheat Research Workers Workshop - 1971. ICAR, New Delhi.

** The discharge of irrigation pump was 600 l/min.

5.7 Preharvesting studies

I Plant population

The final plant population count was taken at randomly selected spots after throwing mild steel rod square of 100 cm side in the plot under observation before harvesting. Three observations were taken in each plot and the average plant population (Nos./sq. metre) was determined.

II Number of total and effective tillers

The number of total and effective tillers were counted at the time of harvesting the crop from three square metre area in each plot. The average number of tillers per square metre in each plot was determined for both experiments.

III Plant height

Ten plants were selected at random from each plot and their height was measured with a steel measuring tape. The average height of the plants in each plot was determined for the experiments A and B.

IV Pre-harvesting loss

Pre-harvesting loss was determined by counting the number of kernels shattered on the ground. These kernels were counted from one square metre area marked by throwing the mild steel rod square of 100 cm side at random in each plot. The average of three observations in each plot calculated and multiplied for the whole plot was determined.

V Lodging

Lodging is defined as the mass falling of the crop plants and is mostly the result of rank growth, storms or inherently weak stems. Technically, the term 'lodging' is applied to the crop which is partly or completely laid over the ground before harvest and gets more or less entangled, resulting in difficulty to harvest and increased loss due to shedding of grain. Hayes and McClelland (1928) have defined four classes of lodged plants depending on the degree of leaning towards ground i.e. by (i) 0° (ii) 20° (iii) 40° and (iv) 60° and worked out a lodging index by multiplying the number of plants in each class by the angle of lodging and dividing the product by the total number of plants. In this study lodged plants were considered those having an angle of lodging of 30° or less measured from the horizontal. Lodging of the crop in experiments A and B resulted due to adverse weather conditions on 23rd and 24th March, 1975 (Appendix A).

In the present study, the area of the lodged crop has been expressed as the percentage of total area of the crop which has lodged as per the definition of lodging in each plot and is designated as percentage lodging. The dimensions of the lodged crop were measured with a measuring tape, the lodged area calculated and then expressed as percentage of the total area of each plot. The lodging expressed in percentage is reported in Appendix C for both experiments A and B.

5.8 Studies at harvest time

I Length of earheads

Ten earheads were sampled out from the ten plants selected at random in each plot from the second and the sixth rows and their lengths measured. The average length of each earhead was calculated for each plot in both the experiments.

II Number of grains per earhead

Ten earheads from each plot were threshed in a cloth bag manually and grains, after cleaning were counted. The average number of grains per earhead was calculated.

III Thousand kernel weight (TKW)

Random samples were collected from the cleaned grains of each plot and one thousand grains were counted. The weights of these 1000 grains were recorded and the average TKW determined.

IV Yield of the plots without losses and the grain-straw ratio

A mild steel rod square of 100 cm side was thrown at random in the plot under observation. The plants were cut manually with minimum disturbance from the area enclosed by the square. The crop plants were first weighed and then manually threshed with great care and precuation. The weight of grains was again noted. Thus, three observations were taken for each plot. An average weight of crop plants per square metre and the average weight of grains per square metre was determined for each plot and then projected to determine the grain yield for the whole plot.

The weight of straw was calculated by subtracting the weight of grain from that of total produce of one square metre area from each plot.

Thus, the average grain-straw ratio in each plot of both the experiments was calculated on the basis of the following relationship :

Grain-straw ratio

$$= \frac{\text{Average weight of grain/square metre of crop plants}}{\left[\begin{array}{l}\text{Average weight of}\\ \text{crop plants per}\\ \text{square metre}\end{array}\right] - \left[\begin{array}{l}\text{Average weight of grains}\\ \text{per square metre of crop}\\ \text{plants}\end{array}\right]}$$

V Moisture content of grain

The moisture contents (dry weight basis) of the grains were determined by the standard hot air oven method at 95°C. The grains were kept in the oven till constant weight resulted. The moisture content (dry weight basis) was calculated on the basis of the following relationship:

Moisture content (dwb), percentage

$$= \frac{\text{Weight of the sample, g} - \text{Weight of dried sample, g}}{\text{Weight of dried sample, g}} \times 100$$

For weighing the samples Sartorius automatic weighing pan balance (self indicating type) was used with a least count of 0.01 g (Figure 5.3).

VI Moisture content of straw

The moisture content of straw was also calculated on dry weight basis by the standard hot air oven method at 65°C till the constant weight of straw-sample resulted. The Sartorius automatic weighing pan balance (self indicating type) was used for weighing the samples.

Calculations similar to those of article, 4.8-V were made to determine the moisture content of straw samples from the plots of experiments A and B.

VII Cutter bar (or sickle) loss

The cutter bar loss in harvesting machines (and

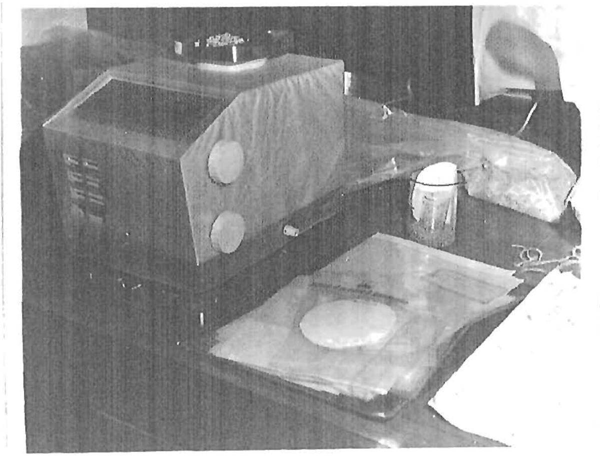


Fig. 5.3 Sartorius automatic weighing pan balance

sickle loss in the case of manual harvesting) has been defined as the grain lost in the field due to rough handling of the cutter bar (or sickle).

The cutter bar loss in each plot was determined after throwing the mild steel rod square (100 cm side) at random and collecting the amount of grain from the ground surface within the square. An average of three observations gave the total loss including the cutter bar and pre-harvest losses. The average cutter bar (sickle) loss was calculated by subtracting the amount of pre-harvest loss from the total loss thus determined.

VIII Cylinder loss

The cylinder loss in the case of the combine was determined at the time of harvesting the crop. In the case of threshers, it was determined when the crop harvested from each plot was threshed.

The cylinder loss in a threshing mechanism is the amount of grain lost over straw in the form of unthreshed heads.

This was determined by collecting the straw material discharged off the rack of the combine over a distance of 10 metres' run. The loose grain was shaken and unthreshed grain collected. This grain was threshed manually to get the kernels. The total amount was weighed and the figure was projected in terms of the total cylinder loss per plot.

IX Rack loss

The rack loss in the combine is the loose grain (threshed one) shaken out of the straw collected over a measured area.

The rack loss in each plot under S-1 was measured over a distance of 10 metres' run collecting the straw in a cloth sheet. The loose grain was shaken out and weighed. The rack loss in the whole plot was then calculated.

X Shoe loss

The shoe loss in the combine was determined by collecting the material coming from the shoe over a measured area of 10 metres' run with the help of a cloth sheet.

XI Gathering and bundling loss

In all the systems except S-1, the gathering and bundling loss was determined by collecting the earheads left behind in the plots by the workers. This may happen due to negligence, unmanageability, shattering tendency of the crop-plants or high wind. The earheads thus collected, were threshed manually and the grain weighed.

XII Transporting and conveying loss

The harvested crop from plots under S-2, S-3, S-4, S-5, S-6 and S-7 were transported to threshing floor by a tractor-trolley. The shattered grain and earheads left in the trolley were collected, threshed and cleaned. The total amount of grain was weighed and termed as transporting and conveying loss.

XIII Threshing floor loss

The harvested crop from each plot is usually kept on the threshing floor in separate bundles till it is threshed. The amount of grain lost due to birds, rodents, shattering etc. is termed as threshing floor loss.

The indirect method of calculation shown below has been used to determine the threshing floor loss:

$$L_{tf} = G_1 - G_2 - L$$

in which,

L_{tf} = threshing floor loss per plot, kg

G_1 = grain yield before using the system, kg

G_2 = grain yield obtained after the performance of the system in the plot, kg

L = all types of losses in the plot due to harvesting, threshing, transporting and bagging etc., kg.

XIV Height of stubbles

The height of the stubbles enclosed within a square metre (using steel square method) was measured and the average height of stubbles from three observations was determined in each plot of both the experiments.

XV Effective field capacity

The effective field capacity of a machine is a function of the rated width of machine, the percentage of rated width actually utilized, the speed of travel and the amount of field time lost during the operation (Bainer *et al.*, 1963). It is defined as the actual average rate of coverage by the machine based upon the total field time (Bainer *et al.*, 1963) and is expressed in hectares per hour.

The effective field capacity was determined for combine, reaper and labourer with sickle for harvesting. The time-data was collected for each plot in both the experiments. A stop-watch was used for keeping the time and a dial weighing balance (Plat form type) was used for weighment.

5.9 Operational studies

These studies were made to determine the operational time involved in various operations in each system right from the harvesting operations to the transporting of the grain for storage as applied to each plot in both the experiments.

These studies were conducted to determine the time involved in each plot for the operations like harvesting, gathering and bundling, loading and unloading the trolley, carrying to thresher, threshing, winnowing, bagging and transporting to storage and thereby to find out the total time for the system as applied to each plot. Stop watches were used to keep the time-data records.

5.10 Studies related to threshing

Apart from the studies made in S-1 to determine the cylinder loss, rack loss and shoe loss, the studies related to threshing involved the following :

a. threshing loss

b. grain content of the tailings

c. cleanliness of grain

d. visible seed damage

e. invisible seed damage.

The methodology and description of the above studies are given as follows:

I Grain content of the tailings

The straw was blown away upto a distance of 5 metres from the straw outlet. The samples of straw were collected at the distances of 0-1 m and 1-2 m. The samples were cleaned for grain and weighed. The test was conducted for each thresher at the speed of threshing drum as recommended by the manufacturer.

II Cleanliness of grain

The cleanliness of grain was determined by weighing the actual amount of threshed grain from the grain-outlet and expressing it as the percentage of total amount. The method of calculation is given below:

Cleanliness (percentage)

$$= \frac{\text{Weight of the sample, (kg)} - \text{Impurities or foreign material (kg)}}{\text{Weight of the sample (kg)}} \times 100$$

III Visible seed damage

The visible seed damage is a function of the moisture content of the grain, speed of threshing drum and the variety of the crop. It was calculated by taking three samples of known weights of threshed grains from each plot yield at the speed of operation of the threshing drum from which the cracked or visibly damaged grains were separated and weighed. The amount of visibly damaged seeds was calculated by taking an average of these three samples from each plot-yield. The visible seed damage was expressed as the ratio of the weight of the visibly cracked seeds to the weight of sample of seeds taken at the recommended speed of operation. It is expressed as a percentage.

IV Invisible seed damage

Invisible seed damage from each plot was calculated with the help of germination test. Visibly strong and healthy seeds were taken and germination test was carried out. Three samples, each consisting of 50 seeds from the grain threshed at recommended speed of operation of the threshing drum were taken. The average damage was determined and expressed as percentage (Fig. 5.4).

The seeds were placed in petri dishes between moistened blotting papers. The germinated seeds were counted and thereby invisible damage was calculated and expressed in percentage.

Failure of germination may be due to factors other than invisible seed damage. The approach used in the determination of invisible seed damage assumes that seeds fail to germinate only due to invisible seed damage caused by machine operation.

5.11 Fuel consumption

For fuel consumption test, the oil tank of the engine was filled upto the top.

In case of harvesting machines, after harvesting each plot under S-1, S-2, S-3 and S-4, diesel oil was filled upto the top of the tank from a measuring cylinder. The amount of diesel oil required to refill the tank was noted. This gave the amount of diesel oil consumed. From

Fig. 5.4 Germination test

the data, the fuel consumption per harvested plot was calculated.

Similarly for threshing machines the topping up method (mentioned above) was used to measure the fuel consumption for threshing each plot under S-2, S-3 and S-5.

In case of S-4 and S-6, the drummy thresher was operated by an electric motor. The duration of operation was noted with the help of a stop watch. The energy consumed for threshing the plot yield was determined from the difference in the readings of the energy-meter.

5.12 Cost of operation

The total cost of operation of each policy comprised the costs of operation of harvesting and threshing machinery and the cost of labour involved. Accordingly the unit cost of operation was determined as follows:

$$Cu = \frac{Fc}{X} \times Oc$$

in which Cu = unit cost of operation expressed either as Rs./hr or Rs./ha.

Fc = fixed cost of the machine, Rs./annum

Oc = overhead cost of operational charges, Rs./hr or Rs./ha.

X = no. of hours or hectares for which machine is used per annum.

The data collected from the field studies of experiments A and B and the market reports were used for making assumptions regarding depreciation, interest, shelter, taxes, insurance and labour charges in order to calculate the cost of operation of each system. Method of calculation is given in Appendix D.

The data about the prevailing rates of custom service and the prices collected from neighbouring areas are reported in Appendix E.

C Statistical analysis

5.13 The various data recorded in the experiments were analysed statistically by analysis of variance of randomized block design as per procedure given by Cochran and Cox (1957) wherever it was considered necessary. The standard error of mean was calculated for each item of study and the critical differences at 5 % level were computed for comparing the treatment means, wherever F-test was found to be significant. The analysis of pooled data of yield, losses and operational time for both experiments are presented vide Appendices F, G and H respectively.

CHAPTER VI

RESULTS AND DISCUSSION

CHAPTER VI

RESULTS AND DISCUSSION

The treatment of this chapter can be grouped broadly into the following classes :

A Studies on the plant characteristics before the harvesting and threshing operations. These studies include (a) pre-harvesting studies and (b) studies at harvesting time.

B Determination of the grain losses accruing at different levels of processing of wheat crop by the operations involved in harvesting and threshing systems.

C Studies related to the height of stubbles left in the field after the harvesting of the crop.

D Determination of effective field capacity/performance of harvesting and threshing machines.

E Operational studies related to the time involved in the performance of different operations during the course of application of the policies of harvesting and threshing.

F Labour requirement.

G Studies related to threshing in different policies of harvesting and threshing.

H Studies related to the cost of operation of each policy of harvesting and threshing.

The details of the results of the aforementioned studies are reported and discussed in the following paragraphs.

6.2 Studies on the plant characteristics

Pre-harvesting studies of the following characteristics of the crop in both the experiments were made:

I Plant population

II Number of total and effective tillers

III Plant height

IV Pre-harvesting loss due to natural factors like grain-shredding, wind and birds etc.

V Lodging

The following studies of the plant characters in both the experiments were made at the time of harvesting:

I Length of earheads

II Number of grains per earheads

III Thousand kernel weight

IV Yield of plots without losses

V Grain straw ratio

VI Moisture content of grain

VII Moisture content of straw

The results of these studies are presented in Table 6.1 in which the mean values of plant characteristics under different policies of harvesting and threshing in both the experiments are given.

On a careful perusal of Table 6.1, it is noted that the differences in plant characters like plant population, number of total and effective tillers, plant height, pre-harvesting loss, lodging, length of earhead, thousand kernel weight, yield of plots without losses, grain-straw ratio and moisture contents of grain and straw within the same experiment are non-significant. That means the crop conditions in each experiments were uniform and didnot differ significantly. This was but expected because of the uniformity of agronomic and operational practices applied in each experiment. This further makes clear that the futuristic studies like studies on grain loss and operational time in the two experiments i.e. A and B, will be influenced only by the performance of the harvesting and threshing policy and not by any pre-harvesting factor capable of influencing grain loss and operational time.

From Table 6.1 it may be concluded that though the

Table 6.1. Mean values of plant characteristics in plots to be harvested and threshed under different policies in experiments A and B

Sr. No.	Policy	Plant population no./m^2		Number of total and effective tillers no.		Plant height cm		Pre-harvesting loss q/ha		Lodging* %		Length of earhead cm	
		A	B	A	B	A	B	A	B	A	B	A	B
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	S - 1	44	67	9.67	8.67	94.00	76.00	0.45	0.39	49.23	5.05	11.17	11.17
2	S - 2	52	73	9.67	7.33	93.00	73.66	0.48	0.41	33.33	13.87	11.33	11.00
3	S - 3	44	78	9.67	7.33	93.66	81.00	0.47	0.40	47.21	5.73	11.33	10.17
4	S - 4	44	77	10.00	7.66	94.66	79.66	0.45	0.40	46.26	7.42	11.00	10.67
5	S - 5	45	81	9.67	8.00	93.66	79.66	0.46	0.40	43.29	27.38	12.13	9.67
6	S - 6	55	77	10.00	7.66	93.00	83.33	0.47	0.40	47.21	19.15	11.17	9.17
7	S - 7	51	75	10.30	7.00	93.33	77.66	0.44	0.42	45.30	13.87	11.16	11.00
Average		48	75	10.00	8.00	93.61	78.71	0.46	0.40	44.54	13.21	11.33	10.40
F-test at 5%		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.Em ±		2.8577	3.0450	0.4512	0.4985	1.1477	3.5941	0.01431	0.0176	5.67	7.09	3.0984	0.6397

* The lodging data has been presented in angular transformations.

P.T.O.

Table 6.1 contd.

Sr. No.	Policy	Number of grains per earhead no.		Thousand kernel weight g		Yields of plots without losses q/ha		Grain-straw ratio no.		Moisture content of grain (dwb) %		Moisture content of straw (dwb) %	
		A	B	A	B	A	B	A	B	A	B	A	B
		15	16	17	18	19	20	21	22	23	24	25	26
1	S - 1	37	40	44.50	50.97	41.85	42.81	0.5645	0.6883	9.77	10.20	6.02	4.56
2	S - 2	40	38	44.20	50.60	42.99	52.88	0.6077	0.6857	8.82	10.46	6.00	5.07
3	S - 3	40	38	42.83	50.83	42.82	55.39	0.5930	0.7003	8.88	9.72	5.95	4.88
4	S - 4	37	42	45.00	51.13	46.32	49.87	0.6569	0.6970	9.53	10.91	5.76	4.64
5	S - 5	40	33	44.63	50.40	46.79	41.69	0.5783	0.6187	9.20	10.27	5.91	4.58
6	S - 6	38	33	44.63	50.57	38.68	51.88	0.6291	0.6933	9.95	10.47	5.30	4.98
7	S - 7	39	39	44.63	51.03	46.63	47.93	0.5793	0.6858	7.63	9.97	5.03	4.20
Average		39	37	44.33	50.79	43.73	48.92	0.6012	0.6813	9.11	10.29	5.71	4.70
F-test at 5%		N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.Em ±		0.8261	4.4069	0.0934	0.7761	2.15	5.09	0.0608	0.0200	0.5339	0.7828	0.2782	0.2562

plant characters did not differ significantly within the same experiment, there is a difference in the same plant character between experiments A and B. It is evident in the case of lodging. On an analysis of the pooled data on yield without losses from the plots of both the experiments (Appendix F), it is clear that there was significant difference between the yields of both the experiments. The average yield obtained from experiment B is more than that of experiment A. This difference, might be due to the greater extent of lodging in experiment A than that in B which shows that lodging affected yield adversely. This is especially true in this case considering that there was a difference of one month in sowing dates of experiments A and B, yet the grain yield without losses in experiment B was greater than that in experiment A by 6.46 quintals per hectare.

6.3 Studies on grain losses

The following types of grain losses were determined during the period of conducting studies on the performance of harvesting and threshing systems in both the experiments:

I Cutter bar loss

II Cylinder loss

III Rack loss

IV Shoe loss

V Gathering and bundling loss

VI Transporting and conveying loss

VII Threshing floor loss

VIII Weighing and bagging loss

The results of the studies are presented in Table 6.2 and Figure 6.1. Table 6.2 shows the mean values of different types of grain losses occuring in different systems of harvesting and threshing in experiments A and B.

It is evident from Table 6.2 that the cutter bar losses, and the gathering and bundling losses differ significantly within each experiment. These differences resulted due to different modes of harvesting in the different systems of harvesting and threshing for the former and human factor in the latter. It may be noted that the system having tractor side mounted operated combine-harvester-thresher (S-1) is different from the policies employing reaper as harvesting machine (i.e. S-2, S-3 and S-4) and the policies employing sickle harvesting (i.e. S-5, S-6 and S-7). It is inferred from the analysis that the cutter bar loss in S-1 in both the experiments A and B differed significantly from the other

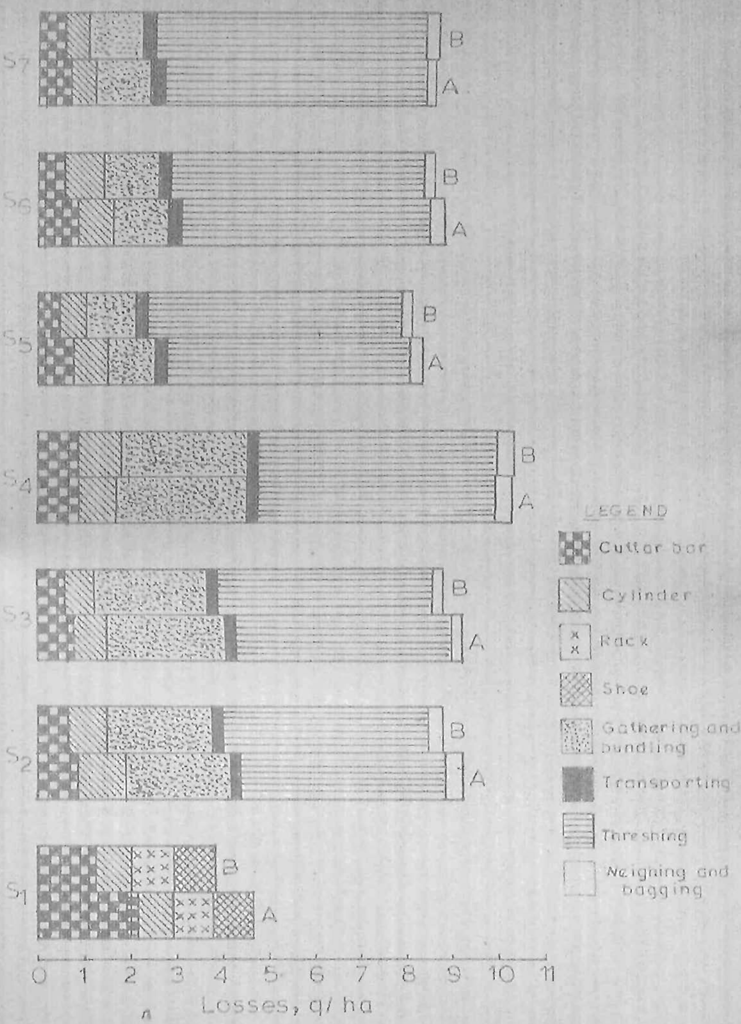


Fig 6.1 Types of losses in different policies under harvesting and threshing systems in experiments A and B

Table 6.2. Mean values of different types of losses in experiments A and B

Sr. No.	Policy	Cutterbar loss q/ha		Cylinder loss q/ha		Rack loss q/ha		Shoe loss q/ha		Gathering and bundling loss q/ha	
		A	B	A	B	A	B	A	B	A	B
1	2	3	4	5	6	7	8	9	10	11	12
1	S - 1	2.18 (46.58)*	1.24 (32.37)**	0.77 (16.45)	0.75 (19.58)	0.86 (18.38)	0.93 (24.28)	0.87 (18.59)	0.91 (23.77)	0.0 (0.0)	0.0 (0.0)
2	S - 2	0.87 (9.42)	0.64 (7.26)	1.03 (11.16)	0.84 (9.52)	-	-	-	-	2.29 (24.81)	2.31 (26.19)
3	S - 3	0.77 (8.30)	00.60 (6.75)	0.73 (7.86)	0.64 (7.20)	-	-	-	-	2.59 (27.91)	2.47 (27.78)
4	S - 4	0.87 (8.42)	0.87 (8.41)	0.88 (8.52)	0.92 (8.90)	-	-	-	-	2.85 (27.59)	2.80 (27.08)
5	S - 5	0.77 (9.21)	0.41 (5.04)	0.75 (8.97)	0.68 (8.35)	-	-	-	-	1.06 (12.68)	1.06 (13.02)
6	S - 6	0.83 (9.40)	0.53 (6.15)	0.80 (9.06)	0.82 (9.52)	-	-	-	-	1.21 (13.70)	1.20 (13.94)
7	S - 7	0.67 (7.79)	0.57 (6.57)	0.54 (6.28)	0.57 (6.57)	-	-	-	-	1.20 (13.95)	1.20 (13.84)
Average		0.9965	0.70	0.79	0.74	-	-	-	-	1.87*	1.84*
F-test at 5%		Sig.	Sig.	SN.S.	N.S.	-	-	-	-	Sig.	Sig.
S.Em ±		0.1480	0.1131	0.1048	0.0937	-	-	-	-	0.1354	0.0931
C.D. at 5 %		0.4562	0.3484	-	-	-	-	-	-	0.4173	0.2368

* S-1 was not considered in ANOVA.
** Figures in brackets indicate percentage of the total loss.

P.T.O.

Table 6.2 contd.

Sr. No.	Policy	Transporting and conveying loss q/ha		Threshing floor loss q/ha		Weighing and bagging loss q/ha		Total losses q/ha		Total losses expressed as percentage of yield without losses (%)		
		A	B	A	B	A	B	A	B	A	B	Avg. of A and B
		13	14	15	16	17	18	19	20	21	22	23
1	S - 1	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	4.68 (100.00)	3.83 (100.00)	11.18	8.95	10.06
2	S - 2	0.24 (2.60)	0.24 (2.72)	4.59 (49.74)	4.58 (51.93)	0.21 (2.27)	0.21 (2.38)	9.23 (100.00)	8.82 (100.00)	21.47	16.68	19.07
3	S - 3	0.22 (2.37)	0.22 (2.47)	4.74 (51.08)	4.71 (52.98)	0.23 (2.48)	0.25 (2.82)	9.28 (100.00)	8.89 (100.00)	21.67	16.05	18.86
4	S - 4	0.22 (2.13)	0.22 (2.13)	5.27 (51.02)	5.28 (51.06)	0.24 (2.33)	0.25 (2.42)	10.33 (100.00)	10.34 (100.00)	2 2.30	20.73	21.51
5	S - 5	0.24 (2.87)	0.24 (2.95)	5.31 (63.52)	5.50 (67.57)	0.23 (2.75)	0.25 (3.07)	8.36 (100.00)	8.14 (100.00)	17.87	19.52	18.69
6	S - 6	0.27 (3.07)	0.27 (3.14)	5.49 (62.17)	5.54 (64.34)	0.23 (2.60)	0.25 (2.91)	8.83 (100.00)	8.61 (100.00)	22.83	16.59	19.71
7	S - 7	0.26 (3.02)	0.26 (3.00)	5.71 (66.39)	5.82 (67.13)	0.22 (2.57)	0.25 (2.89)	8.60 (100.00)	8.67 (100.00)	18.44	18.09	18.26
Average		0.24*	0.24*	5.19*	5.24*	0.23*	0.24*	8.47	8.18	19.39	16.66	-
F-test at 5 %		Sig.	Sig.	N.S.	Sig.	N.S.	N.S.	Sig.	Sig.	Sig.	Sig.	-
S.Em ±		0.0	0.0	0.2702	0.2685	0.0082	0.0095	0.3262	0.2692	0.9495	1.8375	-
C.D. at 5 %		0.0	0.0	-	0.8272	-	-	1.0052	0.8294	2.9253	5.6614	-

* S-1 was not considered in ANOVA.

systems. The chief cause for the higher loss under S-1 in experiment A may be the lodged condition of the crop in this experiment.

The cutter bar loss, in the case of S-2, S-3 and S-4 does not vary significantly within these policies, the reasons for this being the application of same mode of harvesting and non-significant difference in lodged condition of the crop under these systems. Similarly, the cutter bar loss in S-5, S-6 and S-7 does not vary significantly within these policies but differs significantly from the cutter bar loss in S-1.

A comparison of the mean values of cutter-bar loss in experiments A and B indicate that figures for the same system were higher in experiment A than those in experiment B. This makes the effect of lodging clearly discernable, especially in view of the significant difference between the lodging phenomena in both the experiments (Appendix C).

An examination of the data on cutter bar loss in various policies of harvesting and threshing in experiment B reveals the same trend as in experiment A. The cutter bar loss in S-1 differs significantly from that of the rest of the policies but the difference in the figures for cutter bar loss between the other policies viz. S-2, S-3, S-4, S-5, S-6 and S-7, are non-significant amongst themselves.

On the basis of the above, the following conclusions may be made on the cutter bar loss :

(a) The loss is the highest in S-1.

(b) It does not differ significantly between the other policies involving two different modes of harvesting.

(c) It is influenced by the lodged condition of the crop.

The extent of the cutter bar loss within the same system, may be influenced by such extraneous factors like machine - adjustments and the skill of the operator, apart from the field conditions. These factors were not accounted for in the present study as they were considered to be constant during the period of study.

The data on cylinder loss in different policies of harvesting and threshing under experiments A and B in Table 6.2 makes it clear that there was no significant difference in cylinder loss within the policies in both experiments A and B.

The data for gathering and bundling loss in Table 6.2 reveals that there is a significant difference within the policies. On a critical examination of the figures, the following points are evident:

(a) There is no significant difference in the gathering and bundling loss between S-2 and S-3, S-3 and S-4 in experiments A, but there is significant difference between S-2 and S-4 which may be due to lodging or variation in human-factor (Appendix J) responsible for gathering, bundling and tying.

(b) There is no significant difference in the mean values for gathering, bundling and tying loss in S-5, S-6 and S-7 but these figures differ significantly from those of S-2, S-3 and S-4. That means, the gathering and bundling loss is greater in the case of reaper-harvesting than that of sickle harvesting.

(c) The same trend is evident in experiment B if the corresponding figures in experiment B are examined.

The losses due to transporting and conveying, threshing floor and weighing and bagging do not differ significantly (as evident from Table 6.2) within the systems in both the experiments, except that of threshing floor loss in experiment B. Threshing floor losses are dependent upon the incidence of bird and rodent damage and natural shredding. In the case of experiment B, this might have affected the losses adversely.

The total loss of grain in a policy is a sum of some or all the losses mentioned earlier like cutter bar loss, gathering and bundling loss, transporting and conveying loss, threshing floor loss and weighing and bagging loss. In the policy S-1, the combine-harvester-thresher performs simultaneous functions of harvesting, threshing, cleaning and bagging. Therefore, the system is free from the losses like gathering and bundling, transporting and conveying, threshing floor and weighing and bagging losses. Systems S-2 to S-7 do not have shoe and rack loss. The column of total losses in Table 6.2, shows that the difference in the total losses within the policies in both the experiments is significant. Within the same experiment, this is due to preponderance of one policy over the other while in between the experiments the lodging of the crop may be attributed as the contributing factor. This becomes evident from the fact that total losses in experiment A constituted 19.39 per cent of the total yield, while in experiment B these constituted 16.66 per cent. This difference in losses might be resulting due to the difference in the extents of lodging incident. However, it might be pointed out that on an analysis of the pooled data of total losses in both the experiments, the difference in the total losses in both the experiments was not significant, though the difference in cutter bar loss in both the experiments was significant. This suggests that, in general, the cutter bar losses are influenced specifically by the incidence of lodging more than the total losses. However, the general difference is evident (Table 6.2; Appendix G).

On an evaluation of all the policies regarding losses, it is clear from the Tables 6.2 and 6.3 and figures 6.1, 6.2, 6.3 and 6.4 that S-1 has the minimum total loss considering the average of both the experiments being 10.06 per cent of the total yield without losses. The S-4 has the maximum total losses, the figure for which being 21.51 per cent of the total.

The Table 6.2 shows the break up structure of total losses in all the seven policies in both the experiments with figures of percentage loss in parentheses for the purpose of evaluation of losses in different systems. Figure 6.1 shows the type of losses in each policy of harvesting and threshing.

Table 6.3 and Figure 6.3 present the losses expressed as percentage of the yield without losses and

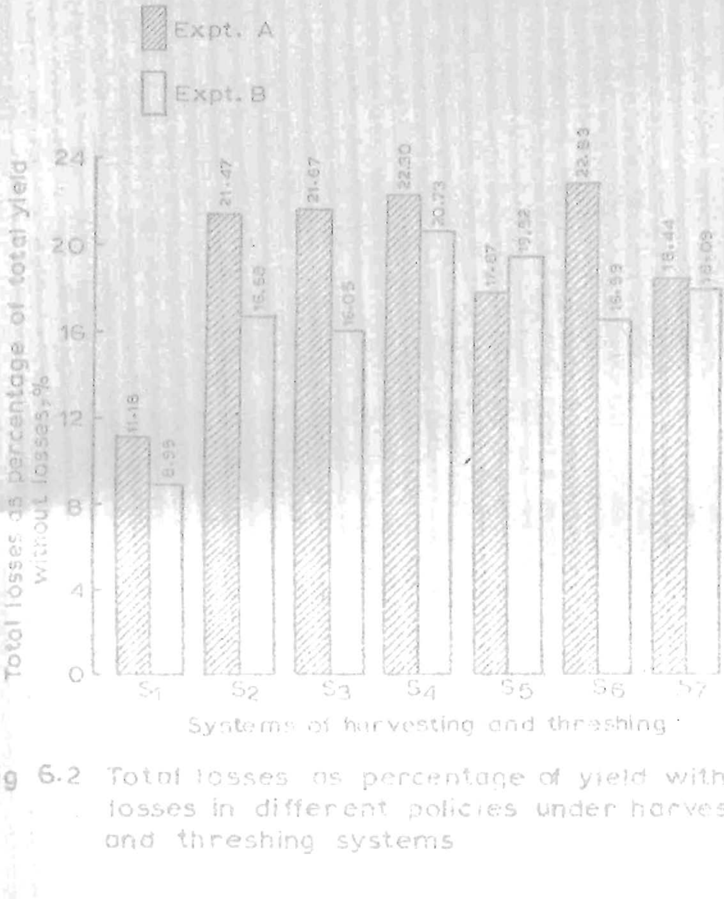


Fig 6.2 Total losses as percentage of yield without losses in different policies under harvesting and threshing systems

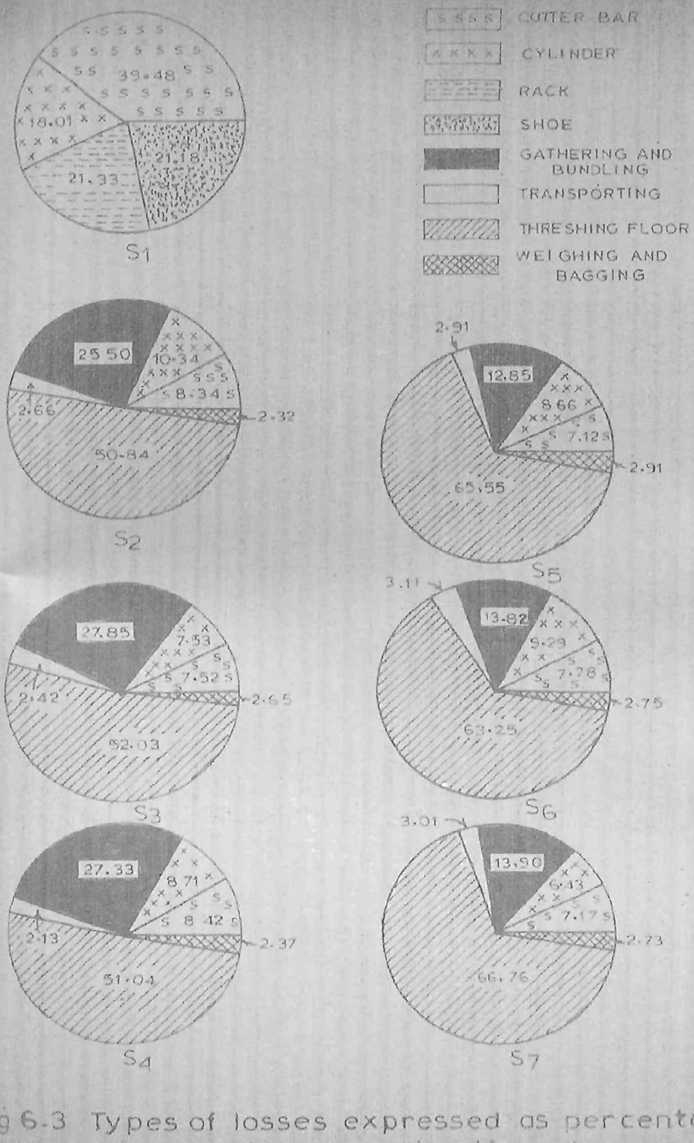
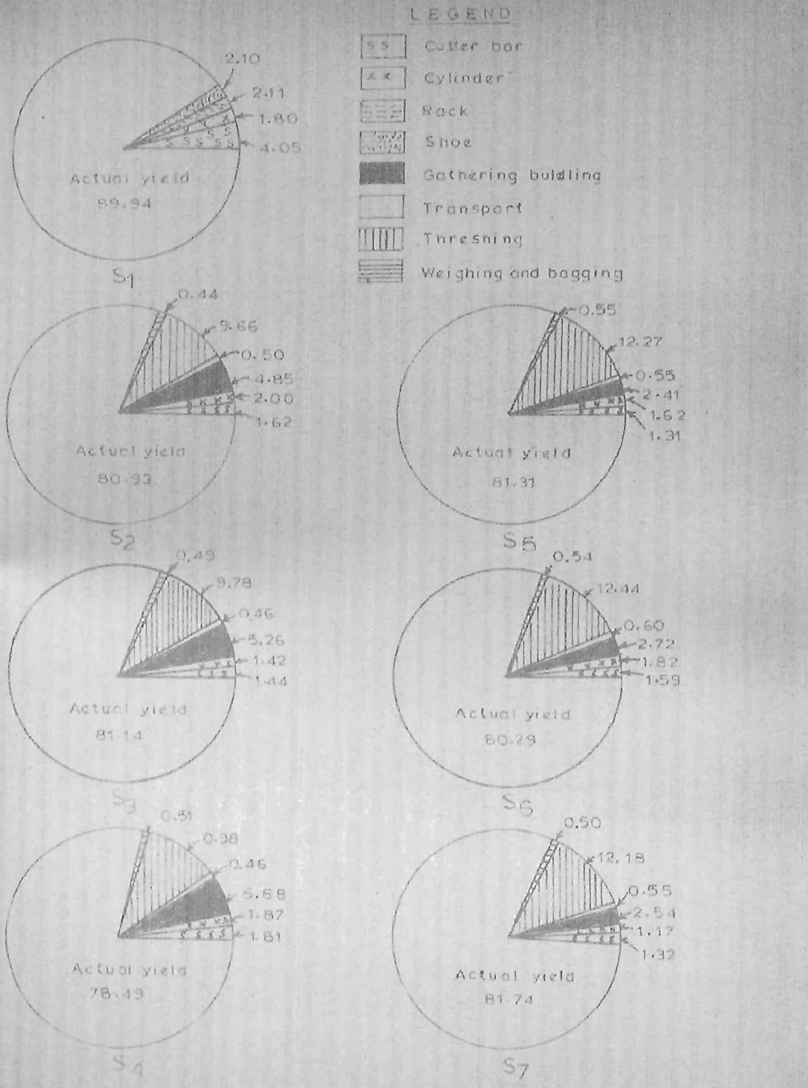


Fig 6.3 Types of losses expressed as percentage of total loss in each policy (based on average loss of both experiments)



6.4 Grain losses expressed as percentages of total yield in each policy under harvesting and threshing systems

Table 6.3. Losses expressed as percentage of the yield without losses and average percentage losses of experiments A and B

Sr. No.	Policy	Cutterbar loss %			Cylinder loss %			Rack loss %			Shoe loss %			Gathering and bundling loss %		
		A	B	Avg	A	B	Avg	A	B	Avg	A	B	Avg	A	B	Avg
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	S - 1	5.21	2.90	4.05	1.84	1.75	1.80	2.05	2.17	2.11	2.08	2.12	2.10	0.00	0.00	0.00
2	S - 2	2.02	1.21	1.62	2.40	1.59	2.00	0.00	0.00	0.00	0.00	0.00	0.00	5.33	4.37	4.85
3	S - 3	1.80	1.08	1.44	1.70	1.15	1.42	0.00	0.00	0.00	0.00	0.00	0.00	6.05	4.46	5.26
4	S - 4	1.88	1.74	1.81	1.90	1.84	1.87	0.00	0.00	0.00	0.00	0.00	0.00	6.15	5.61	5.88
5	S - 5	1.64	0.98	1.31	1.60	1.65	1.62	0.00	0.00	0.00	0.00	0.00	0.00	2.27	2.54	2.41
6	S - 6	2.15	1.02	1.59	2.07	1.58	1.82	0.00	0.00	0.00	0.00	0.00	0.00	3.13	2.31	2.72
7	S - 7	1.44	1.19	1.32	1.16	1.19	1.17	0.00	0.00	0.00	0.00	0.00	0.00	2.57	2.50	2.54

P.T.O.

Table 6.3 contd.

Sr. No.	Policy	Transporting loss %			Threshing floor loss %			Weighing and bagging loss %			Total losses %		
		A	B	Avg	A	B	Avg	A	B	Avg	A	B	Avg
		18	19	20	21	22	23	24	25	25	27	28	29
1	S - 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.18	8.94	10.06
2	S - 2	0.56	0.45	0.51	10.68	8.66	9.67	0.49	0.40	0.45	21.47	16.68	19.07
3	S - 3	0.51	0.40	0.46	11.07	8.50	9.78	0.54	0.45	0.49	21.67	16.04	18.86
4	S - 4	0.47	0.44	0.46	11.38	10.59	10.98	0.52	0.50	0.51	22.30	20.72	21.51
5	S - 5	0.51	0.58	0.55	11.35	13.19	12.27	0.49	0.60	0.55	17.86	19.52	18.69
6	S - 6	0.70	0.52	0.61	14.19	10.68	12.44	0.59	0.48	0.54	22.83	16.59	19.71
7	S - 7	0.56	0.54	0.55	12.24	12.14	12.19	0.47	0.52	0.50	18.44	18.08	18.26

percentage losses of experiments A and B.

Figure 6.3 depicts the type of losses expressed as percentage of total loss in each policy, based on the average loss in both the experiments. It may be observed that the threshing floor loss is a major contributing factor to total loss in each policy, except S-1, which is solely due to the delay in completing the threshing operation.

6.4 Height of stubbles left after harvesting in plots under different systems in experiments A and B

The height of the stubbles is dependent on the type of machine or tools used for harvesting, the crop condition at the time of harvesting and skill of the operator. Table 6.4 shows the height of stubbles left in the plots after the use of a harvesting machine or tool under different systems. The results reveal that the difference in the height of stubbles for different policies in both the experiments is significant. The maximum height of stubbles is in S-1 in both the experiments followed by the height of stubbles is in S-5, S-6 and S-7. The significant difference between the height of stubbles in S-1 compared to other systems. This is due to the incidence of lodging

Table 6.4. The height of stubles left in plots after harvesting under different policies in experiments A and B

Sl. No.	Policy	Machine/ tool used	Height of stubbles Experiment A cm	Experiment B cm
1	S - 1	Tractor side-mounted combine	13.21	24.33
2	S - 2	Tractor side-mounted reaper	5.39	4.41
3	S - 3	Tractor side-mounted reaper	5.29	4.54
4	S - 4	Tractor side-mounted reaper	5.30	5.09
5	S - 5	Sickle	4.63	4.27
6	S - 6	Sickle	4.33	4.15
7	S - 7	Sickle	4.31	3.77
		Average	6.06	7.22
		F-test at 5 %	Sig.	Sig.
		S. Em. ±	0.7088	0.5595
		C.D. at 5 %	2.1837	1.7238

in experiment A because of which the height of cutter bar of the combine was adjusted low. The height of cutter bar in the combine could be adjusted from 5 cm to 46 cm. However, low height adjustment was not advisable due to increased load on the machine.

6.5 Effective field capacity of harvesting machines and effective performance of threshing machines

In each system considerable time is involved in completing the individual operations of harvesting and threshing. In view of this, the effective field capacity of harvesting machines and effective performance of the threshing machines have special significance, as ultimately influencing the overall performance of a system and its cost of operation. Tables 6.5 and 6.6 show the results of the observations made in relation to the effective field capacity of harvesting machines and effective performance of threshing machines. It is evident from Table 6.5 that there is significant difference in the effective field capacities of tractor-side mounted pto operated combine, reaper operated with tractor and sickle-harvesting in both the experiments. This suggests the suitability of a particular method in a specific situation.

Table 6.5. Effective field capacity of harvesting machines employed in different policies in experiments A and B

Sr. No.	Policy	Machine/tool used	Effective field capacity Expt. A ha/hr	Effective field capacity Expt. 2 ha/hr	Average of A and B
1	S - 1	Tractor side-mounted combine reaper operated with tractor	0.1783	0.1859	0.1821
2	S - 2	Tractor side-mounted combine reaper operated with tractor	0.1480	0.2101	
3	S - 3	Tractor side-mounted combine reaper operated with tractor	0.1462	0.2077	0.1778
4	S - 4	Tractor side-mounted combine reaper operated with tractor	0.1469	0.2084	
5	S - 5	Sickle	0.0088	0.0067	
6	S - 6	Sickle	0.0109	0.0116	0.0122
7	S - 7	Sickle	0.0250	0.0103	
		F-test at 5 %	Sig.	Sig.	
		S.Em. ±	0.003605	0.006164	
		C.D. at 5 %	0.011106	0.018989	

Table 6.6. Effective performance (threshing capacity) of threshing machines used for threshing in different policies in experiments A and B

Sr. No.	Policy	Machine alongwith source of power	Machine performance			
			Experiment A		Experiment B	
			Throughput q/hr	Grain output q/hr	Throughput q/hr	Grain-output q/hr
1	S - 1	-	-	-	-	-
2	S - 2	Spike tooth thresher with petrol engine	1.69	0.61	1.68	0.79
3	S - 3	Hammer mill type thresher producing short straw*	7.88	2.39	7.74	3.90
4	S - 4	Hammer mill type thresher producing short straw**	4.78	1.75	4.82	2.03
5	S - 5	Hammer mill type thresher producing short straw*	7.98	3.59	7.83	2.47
6	S - 6	Hammer mill type thresher producing short straw**	4.68	1.33	4.73	2.60
7	S - 7	Olpod thresher operated by a pair of bullocks	0.94	0.38	0.95	0.36
	F-test at 5 %		Sig.	Sig.	Sig.	Sig.
	S.Em. ±		0.1410	0.3224	0.1371	0.4041
	C.D. at 5 %		0.4342	0.9931	0.4222	1.2448

* Hammer mill type thresher producing short straw with sieving and bagging attachment was operated by MF-1035 tractor.

** Hammer mill type thresher producing short straw but without sieving and bagging attachment, was operated by an electric motor of 5.595 kw.

In experiments A and B, however, one notices the significant difference in effective field capacities in S-5 and S-7, though the method of harvesting is the same. This may be because of the variation in the working capacity of the worker, which, in general, depends upon the factors like age, weight, experience, willingness to do a particular job and other extraneous factors like working conditions.

Table 6.6 shows the effective performance (threshing capacity) of the threshing machines used in different policies in experiments A and B. The machine performance is given in terms of through put (q/hr) and grain output (q/hr). The difference in the threshing capacities of all the threshers is significant. The hammer mill type thresher producing short straw has highest throughput (q/hr) and highest grain-output (q/hr) while the throughput and grain-output are lowest in the case of olpod thresher. The trend is similar in both the experiments. This suggests that a particular type of thresher will be suitable to a specific situation, depending upon the requirement of throughput, desired grain-output and timeliness.

6.6 Operational studies

Operational studies were conducted to determine the time involved in various operations required in a particular policy.

The following timings were determined in each policy on operation-combination.

I Operational time to harvest.

II Operational time to gather the bundle and tie it.

III Operational time to load the trolley.

IV Operational time to transport the crop material to the threshing floor.

V Operational time to unload the trolley.

VI Operational time to carry the crop material to thresher

VII Operational time to thresh.

VIII Operational time to winnow.

IX Operational time to bag

X Operational time to transport the threshed grain to storage

XI Total operational time to harvest and thresh.

The results of these studies are presented in Table 6.7 and figure 6.5. Table 6.7 shows the mean values

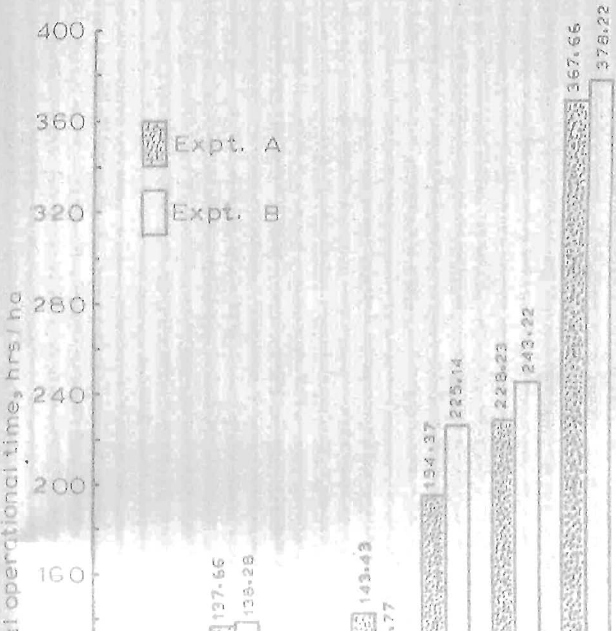


Fig 6.5 Total operational time taken by different policies under harvesting and threshing systems in experiments A and B

Table 6.7. Mean values of time-elements involved per hectare - crop produce in different operations in experiments A and B

Sr. No.	Policy	Harvesting hr		Gathering, bundling and tying hr		Loading the trolly hr		Transporting to the threshing floor hr		Unloading the trolley hr	
		A	B	A	B	A	B	A	B	A	B
1	2	3	4	5	6	7	8	9	10	11	12
1	S - 1	5.61	5.38	-	-	-	-	-	-	-	-
2	S - 2	6.76	4.77	44.94	55.83	2.52	4.34	7.31	5.81	3.21	3.46
3	S - 3	6.86	4.83	46.40	43.56	1.92	3.91	7.31	5.81	3.21	3.46
4	S - 4	6.82	4.81	51.11	30.09	2.25	4.35	7.31	5.81	3.21	3.46
5	S - 5	113.21	148.67	50.14	43.00	2.22	2.97	7.31	5.81	3.21	3.46
6	S - 6	99.69	98.63	40.55	64.91	2.43	3.01	7.31	5.81	3.21	3.46
7	S - 7	119.85	98.89	42.68	53.27	3.58	2.66	7.31	5.81	3.21	3.46
F-test at 5 %		Sig.	Sig.	N.S.	Sig.	N.S.	N.S.	-	-	-	-
S.Em. ±		7.3662	10.8721	5.8190	6.1666	0.5106	0.5877	-	-	-	-
C.D. at 5 %		22.6961	33.4979	-	18.9999	-	-	-	-	-	-

P.T.O.

Table 6.7 contd.

Sr. No.	Policy	Carrying to thresher hr		Threshing, (lifting and feeding) hr		Winnowing hr		Bagging hr		Transporting to storage hr		Total operational time hr	
		A	B	A	B	A	B	A	B	A	B	A	B
		13	14	15	16	17	18	19	20	21	22	23	24
1	S - 1	-	-	-	-	-	-	1.39	1.45	3.48	4.08	10.48	10.91
2	S - 2	2.01	2.09	65.75	56.47	-	-	1.45	1.49	3.71	4.02	137.66	138.28
3	S - 3	1.92	1.67	14.58	12.19	-	-	1.65	1.61	3.38	3.71	87.23	80.75
4	S - 4	2.07	1.68	20.68	19.88	44.01	45.39	1.79	1.77	4.18	3.53	143.43	120.77
5	S - 5	1.97	2.18	11.40	13.78	-	-	1.79	1.80	3.12	3.47	194.37	225.14
6	S - 6	1.89	1.77	23.06	16.97	44.41	43.45	1.85	1.68	3.83	3.53	228.23	243.22
7	S - 7	2.14	2.00	105.52	112.69	77.81	90.61	2.78	6.07	2.78	2.76	367.66	378.22
F-test at 5 %		N.S.	N.S.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	N.S.	Sig.	Sig.	Sig.
S.Em. ±		0.2046	0.2216	8.0509	3.9679	7.0861	3.3517	0.1533	0.3320	0.3223	0.2526	5.0891	11.6460
C.D. at 5 %		-	-	24.8055	12.2254	21.8329	10.3268	0.4725	1.0229	-	0.7783	15.6801	35.8827

of time elements involved per hectare crop produce in different operations in each policy in experiments A and B. There is a significant difference in time-requirement for harvesting in the different policies under study. The data reveal that the maximum time-requirement to harvest in S-7 followed by S-5 and S-6. The minimum time-requirement is in S-1. On a critical examination of the data, it is clear that the difference is not significant amongst the policies involving combine-operation (S-1) and the policies involving reaper-operation (i.e. S-2, S-3, and S-4) but they differ significantly from the policies having sickle harvesting (i.e. S-5, S-6 and S-7). This may be due to the difference in effective field capacities of machines and tool used for harvesting the crop.

On a study of the time requirement for gathering, bundling, and tying (Table 6.7), the data reveal that there is no significant difference in policies S-2, S-3, S-4, S-5, S-6 and S-7 in experiment A but there is significant difference in time-requirement in these operations in these policies in experiment B. The main reason for this may be the variation in human factor, weather conditions at the time of harvesting plots in experiment B (which was harvested one month later than A), and comparatively more yield of plots in experiment B (Appendices J and K and Table 6.1 for yield without losses).

In the overall time requirement, the time taken for transporting the produce from a plot to the threshing floor has also to be included. However, the variation in the time factor for different systems being purely due to the different distances of their corresponding plots from the threshing floor, they were averaged out and then added to the overall time (Table 6.7).

Similarly, the time taken for unloading the trolley has also to be included in the overall time requirement. However, the variation in the time factor for different policies being due to non-technical grounds (in this case human-factor), the time-requirements for unloading the trolley were averaged out and then added in the overall time requirement (Table 6.7).

An analysis of the time-requirement for carrying the harvested crop to the thresher reveals that no significant difference exists in the different policies in both the experiments.

The analysis of the time-requirement for threshing which actually is composed of lifting and feeding operations, reveals significant difference among the policies in both the experiments. This difference may be due to the employment of a particular type of threshing-machine in a policy, which varied in almost all policies. The exceptions were S-3 and S-5 using hammer mill type thresher with sieving and bagging attachment and S-4 and S-6 using hammer mill type thresher without sieving and bagging attachment. In between S-3 and S-5, and between S-4 and S-6 the difference in time requirement for threshing was not significant. However, the data suggest the biggest time-requirement for threshing is in S-7 and the least in S-5 (S-1 is excluded as in this case threshing is done simultaneously with harvesting).

The additional time requirement for winnowing is in S-4, S-6 and S-7. The data presented in Table 6.7 reveal that there is significant difference in S-4 and S-7, and S-6 and S-7 but no significant difference in S-4 and S-6. The results are alike in experiments A and B. This suggests that S-7 requires the maximum time and hence results in maximum labour requirement, followed by the other two policies using hammer-mill type threshers without sieving and bagging attachment.

The data for time-requirement for bagging in both the experiments (Table 6.7) reveal that there is signi-fiacant difference among the policies. The time required for bagging is maximum in S-7 while in other policies there is no such difference.

The analysis of the data for the transporting of grain to storage reveals that there is no significant difference in experiment A but in experiment B, the difference in time requirement in different policies is significant.

Table 6.7, columns 23 and 24 sum up the mean values of time-elements of operations required in each policy in both the experiments. The data reveal that there is significant difference in total operational time in each experiment. In both the experiments, S-1 has the least number of hours required to complete all the operations while in the case of S-7, the total operational time required is maximum. These important features of total operational time in each policy in both the experiments, are depicted in Figure 6.5. It is evident that S-1 (the modern technological system) requires almost one-thirty fifth (1/35th) amount or 3 per cent of the time required for S-7 (the traditional system).

Table 6.8 presents the mean values of the time period per quintal of grain basis involved in different operations in experiments A and B. The figures in parentheses in Table 6.8 indicate the time required in percentage of total time required for all the operations in a policy per quintal basis in both the experiments.

The data in Table 6.8 reveal the following:

(i) The minimum total operational time required per quintal of grain basis is in S-1 being 0.2503 and 0.2547 hour, respectively, in experiments A and B. Out of this, approximately 50 per cent time is required for harvesting and the rest in bagging and transporting the grain to storage.

(ii) The maximum total operational time required per quintal of grain basis is in S-7 being 7.8914 and 7.8841 hours, respectively, in experiments A and B.

(iii) The rest of the systems excluding S-1 and S-7) occupy intermediate positions in regard to their total operational time requirement per quintal basis ranging from 1.0368 and 1.4572 hours for S-3 in experiments A and B to 5.8997 and 4.6877 hours for S-5 in experiments A and B, respectively.

Table 6.8. Mean values of time elements per quintal of grain basis involved in different operations in experiments A and B

Sl. No.	Policy	Harvesting hr/q		Gathering bundling and tying hr/q		Loading the trolley hr/q		Transporting to threshing floor hr/q		Unloading the trolley hr/q		Carrying to thresher hr/q	
		A	B	A	B	A	B	A	B	A	B	A	B
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	S-1	0.1340 (53.53)	0.1256 (49.31)	-	-	-	-	-	-	-	-	-	-
2	S-2	0.1572 (4.91)	0.0902 (3.45)	1.0453 (32.65)	1.0557 (40.38)	0.0586 (1.83)	0.0820 (3.14)	0.1700 (5.30)	0.1098 (4.19)	0.0746 (2.33)	0.0654 (2.51)	0.0467 (1.46)	0.0395 (1.52)
3	S-3	0.1602 (15.45)	0.0871 (5.98)	0.0836 (8.06)	0.7864 (53.96)	0.0448 (4.32)	0.0705 (4.83)	0.1707 (16.46)	0.1048 (7.19)	0.0749 (7.22)	0.0624 (4.28)	0.0448 (4.32)	0.0301 (2.06)
4	S-4	0.1472 (4.76)	0.0964 (3.98)	1.1034 (35.63)	0.6033 (24.91)	0.0485 (1.57)	0.0872 (3.60)	0.1578 (5.09)	0.1165 (4.82)	0.0693 (2.24)	0.0693 (2.87)	0.0446 (1.44)	0.0336 (1.39)
5	S-5	2.4195 (58.24)	3.5660 (66.03)	1.0715 (25.79)	1.0314 (19.11)	0.0474 (1.14)	0.0712 (1.32)	0.1562 (3.77)	0.1393 (2.58)	0.0686 (1.65)	0.0829 (1.54)	0.0421 (1.01)	0.0522 (0.97)
6	S-6	2.5773 (43.68)	1.9011 (40.56)	1.0483 (17.76)	1.2511 (26.68)	0.0628 (1.07)	0.0580 (1.24)	0.1889 (3.20)	0.1119 (2.38)	0.0829 (1.40)	0.0666 (1.42)	0.0488 (0.82)	0.0341 (0.72)
7	S-7	2.5702 (32.59)	2.0632 (26.14)	0.9152 (11.60)	1.1114 (14.08)	0.0767 (0.97)	0.0554 (0.71)	0.1567 (1.98)	0.1212 (1.54)	0.0688 (0.88)	0.0721 (0.91)	0.0458 (0.58)	0.0417 (0.52)

Note: Figures in parentheses indicate percentage time of the total time required to complete all the operations involved in a system to give a quintal of grain-yield.

Table 6.8. .. contd.

Table 6.8. contd.

Sr. No.	Policy	Threshing (lifting and feeding) hr/q		Winnowing hr/q		Bagging hr/q		Transporting to storage hr/q		Total operational time hr/q	
		A	B	A	B	A	B	A	B	A	B
		15	16	17	18	19	20	21	22	23	24
1	S - 1	-	-	-	-	0.0332 (13.26)	0.0338 (13.27)	0.0831 (33.21)	0.0953 (37.42)	0.2503 (100.00)	0.2547 (100.00)
2	S - 2	1.5294 (47.77)	1.0678 (40.84)	-	-	0.0337 (1.06)	0.0281 (1.07)	0.0862 (2.69)	0.0760 (2.90)	3.2017 (100.00)	2.6145 (100.00)
3	S - 3	0.3404 (32.84)	0.2200 (15.10)	-	-	0.0385 (3.72)	0.0290 (2.00)	0.0789 (7.61)	0.0669 (4.60)	1.0368 (100.00)	1.4572 (100.00)
4	S - 4	0.4464 (14.42)	0.3986 (16.46)	0.9501 (30.68)	0.9101 (37.59)	0.0386 (1.25)	0.0354 (1.46)	0.0902 (2.92)	0.0707 (2.92)	3.0961 (100.00)	2.4211 (100.00)
5	S - 5	0.2436 (5.87)	0.3305 (6.12)	-	-	0.0382 (0.92)	0.0431 (0.79)	0.0666 (1.61)	0.0832 (1.54)	4.1537 (100.00)	5.3998 (100.00)
6	S - 6	0.5961 (10.11)	0.3271 (6.98)	1.1478 (19.46)	0.8375 (17.87)	0.0478 (0.82)	0.0323 (0.69)	0.0990 (1.68)	0.0680 (1.46)	5.8997 (100.00)	4.6877 (100.00)
7	S - 7	2.2629 (28.70)	2.3511 (29.79)	1.6686 (21.18)	1.8904 (23.96)	0.0596 (0.76)	0.1274 (1.62)	0.0596 (0.76)	0.0575 (0.73)	7.8841 (100.00)	7.8914 (100.00)

Figure 6.6 shows a comparison of time requirement for an individual operation in percentage of total time required in a policy. The figure shows that major contribution to increased time requirement is made by gathering, binding and tying, threshing and winnowing operations in all the systems except in S-1. Winnowing operations necessitate additional time requirement in S-4, S-6 and S-7.

6.7 Labour requirement

Table 6.9 shows the labour required for operating the harvesting and threshing machine. The maximum labour requirement for one single machine is in the case of the reaper. This is because, apart from the operator and helper, six persons are required to cope up with the work of lifting the harvested material, bundling and tying it.

It may be noted here that reapers could not become popular in India partly because of this reason i.e. additional labour requirement for short periods in addition to the high cost involved in the policy. The farmers, on one hand, found it difficult to employ labour for short periods of harvesting with reaper and on the other hand, the labourers preferred to have more gainful employment throughout the harvesting season available in the case of

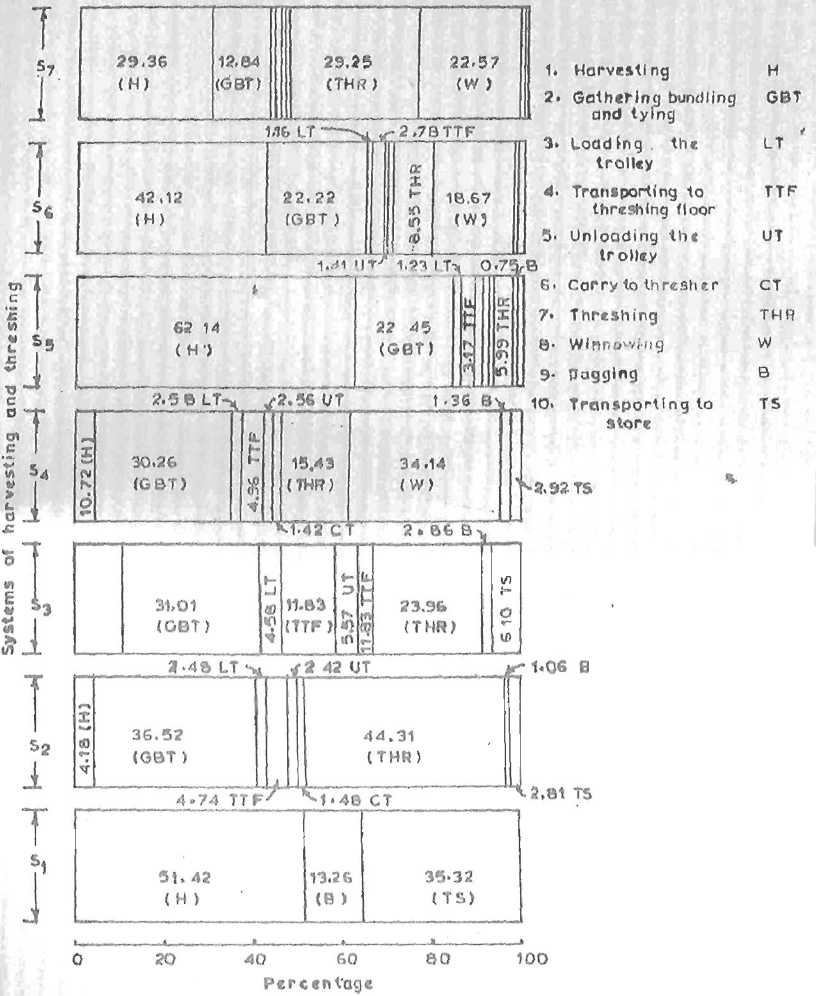


Fig 6.6 Time taken by individual operation expressed as percentage of total time involved in each policy (average of experiments A and B)

Table 6.9. Labour requirement[1] for operating, harvesting and threshing machines employed in experiments A and B

Sl. No.	Machine used	Skilled labour No.	Non-skilled labour No.
1	Tractor-side mounted combine	-	1
2	Reaper	-	8
3	Sickle	-	1
4	Spike tooth thresher with engine	-	4
5	Hammer mill type with attachments	-	4
6	Hammer mill type without attachments	-	4
7	Olpod thresher	-	3
8	Winnowing fan	-	3
9	Tractor - any type	1	-

[1] Total labour requirement for a machine comprizes the non-skilled labour and the skilled labour required to operate the power-unit.

manual harvesting with sickle was practiced.

6.8 Studies related to threshing in different policies of harvesting and threshing

In this set of studies, the performance of threshers used in different policies in experiments A and B was examined against the speed of operation recommended by the manufacturers. The parameters studied were grain-straw ratio, quantity of crop material threshed per minute, grain-output, cylinder loss, grain content of tailings, cleanliness of grain, and visible and invisible seed damage.

The observations and results regarding these parameters are presented in Tables 6.10 to 6.15.

The data in Table 6.10 indicate the grain-straw ratio, quantity of crop material in kilograms per plot, time taken in minutes per plot produce and grain-output in kilograms per plot. As expected, there was no difference in the experiments with regard to grain-straw ratio and yield per plot etc.

The analysis of the data reveals the following:

(i) There is significant difference in the time (minutes) taken in threshing the produce/plot between the policies in both the experiments.

Table 6.10. Studies related to performance of threshers used in different policies in experiments A and B

Sr. No.	Policy	Thresher used	Grain straw ratio No.		Quantity of crop-material kg/plot		Time taken in threshing min/plot		Grain-output kg/plot	
			A	B	A	B	A	B	A	B
1	S-2	Spike tooth thresher*	0.608	0.686	233.33	197.67	82.66	71.00	71.19	92.75
2	S-3	Hammer mill type thresher**	0.593	0.700	241.33	198.00	18.33	15.33	70.74	97.95
3	S-4	Hammer mill type thresher***	0.657	0.697	207.00	201.00	26.00	25.00	75.89	83.35
4	S-5	Hammer mill type thresher**	0.578	0.619	188.33	227.00	14.33	17.33	80.98	70.79
5	S-6	Hammer mill type thresher***	0.630	0.693	226.66	168.00	29.00	21.33	63.04	91.21
6	S-7	Olpod thresher	0.579	0.686	206.00	202.61	132.66	141.66	80.16	82.77
		F-test at 5 %	N.S.	N.S.	N.S.	N.S.	Sig.	Sig.	N.S.	N.S.
		S.Em. ±	0.064	0.0200	28.4248	16.3304	10.1214	4.9884	3.9506	11.0305
		C.D. at 5 %	-	-	-	-	31.1849	15.3695	-	-

* Spike tooth thresher operated with petrol engine.
** Hammer mill type thresher with shieving and bagging attachment operated by tractor (32 hp).
*** Hammer mill type thresher without sieving and bagging attachment operated by electric-motor.

(ii) There is no significant difference in the grain-output per plot for different policies in both the experiments.

This suggests that the time taken in threshing is mainly dependent upon the machine-method used. Thus, the overall performance of a policy is influenced by the machine-performance.

Table 6.11 shows the results of the studies related to threshing in the different systems in experiments A and B.

The analysis of the data reveals the following:

(i) There is no significant difference in the mean values of cylinder loss in all the systems.

(ii) The grain content of tailings is maximum in S-2 and minimum in S-3 when the samples are collected from a distance of 0-1 metre, measured from the blow-off end of the thresher. The same trend is apparent in experiment B.

(iii) The grain content of tailings is maximum in S-6 in both the experiments and minimum in S-2 when samples are collected from a distance of 1-2 metres, measured from the blow-off end of the thresher in both the experiments.

(iv) There is significant difference in the

Table 6.11. Studies related to threshing in different policies in experiments A and B

Grain-straw ratio : 0.601 (A)
0.681 (B)

Moisture content of grain (dwb) : 9.11 % (A)
10.29 % (B)

Sr. No.	Policy	EXPERIMENT A: Cylinder loss q/ha	EXPERIMENT A: Grain content of tailings From a distance of 0-1 m %	EXPERIMENT A: Grain content of tailings From a distance of 1-2 m %	EXPERIMENT A: Cleanliness of grain %	EXPERIMENT A: Visible seed damage %	EXPERIMENT A: Invisible seed damage %	EXPERIMENT B: Cylinder loss q/ha	EXPERIMENT B: Grain content of tailings From a distance of 0-1 m %	EXPERIMENT B: Grain content of tailings From a distance of 1-2 m %	EXPERIMENT B: Cleanliness of grain %	EXPERIMENT B: Visible seed damage %	EXPERIMENT B: Invisible seed damage %
1	S-1	0.77	-	-	95.65	4.66	5.00	0.75	-	-	99.02	4.73	5.66
2	S-2	1.03	77.23	0.04*	97.30	7.73	9.00	0.84	75.84	0.05*	95.28	9.47	10.00
3	S-3	0.73	1.50	1.31*	94.03	9.02	8.66	0.64	0.99	1.13*	96.38	9.17	9.66
4	S-4	0.88	73.08	22.89**	84.05	1.93	8.33	0.92	74.03	24.40**	83.25	1.55	8.00
5	S-5	0.75	0.91	1.02*	91.99	8.33	9.66	0.68	1.02	1.23*	93.37	8.53	9.00
6	S-6	0.80	72.80	23.63**	89.11	3.24	6.00	0.82	72.50	24.47**	96.29	3.61	6.66
7	S-7	0.54***	-	-	94.90	3.58	4.66	0.57***	-	-	94.41	3.40	5.00
F-test at 5%		N.S.	-	-	Sig.	Sig.	Sig.	N.S.	-	-	N.S.	Sig.	Sig.
S.Em. ±		0.1048	-	-	2.3721	0.4588	0.8164	0.0937	-	-	3.0282	0.4109	0.7958
C.D. at 5 %		-	-	-	7.3085	1.4136	2.5154	-	-	-	-	1.2660	2.4519

* Grain content of tailings is expressed as blow-off losses
** Grain content of tailings collected from ground surface between 1-2 m and includes blow-off loss.
*** Unthreshed kernels placed as cylinder loss in case of threshing with olpod thresher.

cleanliness of grain within the policies in experiment A. The maximum cleanliness was obtained in S-2 and the minimum in S-4. However, there is no significant difference in cleanliness of grain within the policies in experiment B.

(v) There is significant difference in visible as well as the invisible seed damage between the policies in both the experiments.

In both the experiments the maximum visible damage was observed to be in S-2, S-3 and S-5 while the invisible damage was observed in all these systems as also in S-4 respectively. The lowest values of visible damage was noticed in S-4 and while that of invisible damage in S-7.

From the point of view of minimum seed certification standards for wheat (Appendix L) the quality of grain output from all the policies was acceptable from the germination point of view.

Tables 6.12, 6.13, 6.14 and 6.15 show that observed data related to speed of operation, weight of crop material, grain-output, time taken in threshing, fuel consumption and grain-distribution. These tables present data with regard to the performance of spike-tooth thresher producing long

Table 6.12. Performance of spike-tooth thresher producing long straw

Grain-straw ratio : 0.6467 (Avg) Moisture content of grain (dwb) : 9.64 % (Avg)

Sl. No.	Field plot No.	Speed of operation rpm	Weight of crop material kg	Grain output kg	Time taken in threshing min	Fuel consumption l	Grain distribution expressed as percentage of total material in specified region	
							Upto 1 m from straw outlet %	Beyond 1 m (blow off loss) %
1	A/S-2/a	650	306	67.50	109	3.43	85.23	0.03
2	A/S-2/b	640	257	64.58	91	2.52	63.70	0.05
3	A/S-2/c	660	137	81.48	48	1.59	70.75	0.03
4	B/S-2/a	635	225	121.97	85	1.71	78.05	0.04
5	B/S-2/b	645	165	99.92	60	1.44	69.25	0.05
6	B/S-2/c	650	203	56.37	68	1.87	80.23	0.05
	Average	647	215.50	81.97	76.83	2.09	74.53	0.04
	Average throughput,		q/hr:	1.69				
	Average grain output,		q/hr:	0.64				
	Average fuel consumption, l/hr:			1.63 (Petrol)				

Table 6.13. Performance of hammer mill type thresher with sieving and bagging attachment producing short straw

Grain-straw ratio : 0.6225 (Avg) Moisture content of grain (dwb) : 9.53 % (Avg)

Sl. No.	Field plot No.	Speed of operation rpm	Weight of crop material kg	Grain output kg	Time taken in threshing min	Fuel consumption l	Grain distribution expressed as percentage of total material in specified region	
							Upto 1 m from straw outlet %	Beyond 1 m (blow off loss) %
1	2	3	4	5	6	7	8	9
1	A/S-3/a	485	206	67.12	16	2.36	2.30	0.95
2	A/S-3/b	480	211	76.43	16	2.61	0.60	1.27
3	A/S-3/c	490	307	68.66	25	3.76	1.59	1.71
4	A/S-5/a	490	238	81.18	19	1.58	0.98	0.85
5	A/S-6/b	510	168	71.17	13	2.05	1.32	1.30
6	A/S-6/c	485	159	90.60	11	1.62	0.44	0.90

Table 6.13 .... contd.

Table 6.13 contd.

1	2	3	4	5	6	7	8	9
7	B/S-3/a	510	223	87.32	17	1.83	1.33	2.00
8	B/S-3/b	485	191	82.09	15	1.23	1.20	0.55
9	B/S-3/c	490	180	124.43	14	1.76	0.45	0.85
10	B/S-5/a	480	223	90.67	18	1.10	0.78	0.95
11	B/S-5/b	510	189	63.55	15	1.50	0.98	1.70
12	B/S-5/c	485	269	58.15	19	1.53	1.30	1.05
	Average	492	213.67	80.11	16.33	1.91	1.11	1.17

Average throughput, q/hr : 7.85

Average grain-output, q/hr : 2.94

Average fuel consumption, l/hr : 7.01 (Diesel)

Table 6.14. Performance of hammer mill type thresher without sieving and bagging attachment producing short straw

Grain straw ratio : 0.6690 (Avg)   Moisture content of grain (dwb): 10.21 %

Sr. No.	Field plot No.	Speed of operation	Weight of crop material	Grain out-put	Time taken in thre-shing	Energy consumed	Grain distribution expressed as percentage of total material present in specified region: Under concave area	Upto 1 m from con-cave end	Between 1 and 2m from con-cave end	Beyond 2m from concave end
		rpm	kg	kg	min	kwh	%	%	%	%
1	2	3	4	5	6	7	8	9	10	11
1	A/S-4/a	490	223	76.70	28	1.20	81.72	76.26	19.03	2.24
2	A/S-4/b	500	182	62.69	23	0.98	80.89	70.49	20.90	2.31
3	A/S-4/c	475	216	88.29	27	1.39	87.20	72.50	22.30	1.90
4	A/S-6/a	500	262	58.83	33	0.92	86.69	71.30	24.20	2.29
5	A/S-6/b	490	231	65.82	30	1.03	80.65	72.50	20.50	2.20
6	A/S-6/c	490	187	64.47	24	1.01	85.92	74.60	20.70	1.00

Table 6.14 ... contd.

Table 6.14 contd.

1	2	3	4	5	6	7	8	9	10	11
7	B/S-4/a	510	223	95.42	28	1.50	83.30	75.10	22.50	1.50
8	B/S-4/b	490	144	67.56	18	1.06	86.56	74.00	21.30	2.30
9	B/S-4/c	500	236	87.08	29	1.37	79.70	73.00	23.50	2.10
10	B/S-6/a	500	150	106.81	19	1.68	82.10	72.90	22.60	2.00
11	B/S-6/b	480	176	92.88	23	1.49	80.50	73.10	23.50	2.10
12	B/S-6/c	495	178	73.94	22	1.16	81.00	71.50	21.00	2.20
	Average	493	200.67	78.37	25.33	1.23	83.02	73.10	21.83	2.01

Average throughput, q/hr : 4.75

Average grain output, q/hr : 1.86

Average energy consumption, kwh : 2.91

Table 6.15. Performance of olpod thresher operated by a pair of bullocks

Grain-straw ratio : 0.6325 Moisture content of grain (dwb) : 8.80 %

Sl. No.	Field plot No.	Weight of crop material kg	Grain output kg	Time taken in threshing min	Throughput q/hr	Grain-output q/hr
1	A/S-7/a	261	80.78	174	0.90	0.28
2	A/S-7/b	190	71.76	120	0.95	0.36
3	A/S-7/c	168	87.94	104	0.97	0.51
4	B/S-7/a	203	104.46	128	0.95	0.49
5	B/S-7/b	232	76.12	139	1.00	0.33
6	B/S-7/c	237	67.74	158	0.90	0.26
		215.17	81.47	137.17	0.94	0.36

straw (Table 6.12), hammer mill type threshers with and without sieving and bagging attachment producing short straw (Table 6.13 and 6.14) and olpod thresher (Table 6.15).

A perusal of data reveals the following :

(i) The spike tooth thresher at the recommended speed of operation showed an average throughput of 1.69 quintals per hour, average grain-output of 0.64 quintal per hour and average fuel consumption of 1.63 litres per hour.

(ii) The hammer mill type thresher with sieving and bagging attachment producing long straw at recommended speed showed an average through put of 7.85 quintals per hour, average grain output of 2.94 quintals per hour and average fuel consumption of 7.01 litres per hour.

(iii) The hammer mill type thresher without sieving and bagging attachment producing short-straw showed an average throughput of 4.75 quintals per hour, average grain-output of 1.86 quintals per hour and electric energy consumption of 2.91 kwh at recommended speed.

(iv) The olped thresher operated by a pair of bullocks showed an average throughput of 0.94 quintal per hour and average grain output of 0.36 quintal per hour.

6.9 Studies related to the cost of operation involved in each policy of harvesting and threshing

The cost of data of machinery employed for harvesting, threshing and winnowing operations are presented in Table 6.16. In this table, the figures for effective field capacity are based on actual observations and seems to be less than the similar figures obtained from field studies. This is likely due to limited amount of experimental area, crop-material and extra-precautions taken during the course of data-collection. The purchase-cost data was collected from manufacturers, Department of Farm Operations and Management (I.A.R.I.) and the local market. The values of fixed-cost items have been assumed on the basis of literature consulted, discussions with farmers and agricultural engineers and informations collected from different places (Appendix E). The figures for fuel consumption and oil and lubericants are based on field observations during the course of the experiments. The wages of the operator and labourers are based on the rates prevalent in the Delhi-area in the 1975.

The cost data of trailer and different power units used for operating the machines for harvesting and threshing has been summarized in Table 6.17. The remarks mentioned

Table 6.16. Cost data of machinery employed for harvesting, threshing and winnowing operations

Sr. No.	Item	Unit	Machines/tool used							
			Side mounted tractor drawn combine	Reaper	Sickle	Spike tooth type thresher[1]	Hammer mill type thresher with sieving and bagging	Hammer mill type thresher without sieving and bagging	Olpod thresher	Winnowing fan
1	2	3	4	5	6	7	8	9	10	11
1	Effective field capacity(C)	ha/hr	0.19	0.18	0.01	0.64	2.94	1.86	0.36	0.81
2	Purchase cost (P)	Rs	38000.00	3200.00	6.00	20000[@]	5500.00	1760.00	650.00	350.00
3	Salvage value(S)	Rs	3800.00	320.00	0.00	2000.00	550.00	176.00	65.00	35.00
4	Economic life (L)	Year	10	10	6	10	10	10	10	10
5	Annual average use	hours	200	200	250	250	250	250	250	150
6	Depreciation (D)	Rs/yr	3420.00	288.00	1.00	1800.00	495.00	158.40	58.50	31.50
7	Interest (I)	Rs/yr	2090.00	176.00	0.30	1100.00	302.50	96.80	35.75	19.25
8	Insurance (Ir)	Rs/yr	380.00	32.00	-	200.00	55.00	17.60	6.50	3.50
9	Taxes (T)	Rs/yr	760.00	-	-	-	-	-	-	-

Table 6.16 .... contd.

Table 6.16 contd.

1	2	3	4	5	6	7	8	9	10	11
10	Housing (H)	Rs/yr	570.00	48.00	-	300.00	82.50	26.40	9.75	5.25
11	Repair and maintenence (RM)	Rs/hr	19.00	1.60	0.02	8.00	2.20	0.70	0.26	0.23
12	Fuel consumption (F)	1/hr	3.20*	1.68*	-	1.63*	7.01*	2.91** kwh	-	-
13	Oil and lubricants (OL)	1/hr	0.09*	0.07*	-	0.04*	0.07*	-	-	-
14	Wages of operator	Rs/hr	1.88[1]	1.88[1]	-	-	1.88[1]	-	-	-
15	Wages of labour	Rs/hr	0.82	0.82	1.50	0.82	0.82	0.82	0.82	0.82

@ Import price including the cost of power-unit. The locally made thresher of the same type and size with power unit costs Rs. 15000.00.

* Fuel, oil and lubricants' consumption figures for the power units respectively employed as sources of power.

** Electrical energy consumption in kilowatt hour.

1 Wages of the tractor driver.

Table 6.17. Cost data of the trailer and different power-units used for operating the machines for harvesting and threshing

Sl. No.	Item	Unit	Trailer	Tractor (32 hp)	Tractor (22 hp)	Elect. motor with starter and energy meter	A pair of bullocks
1	Purchase cost (P)	Rs	7060.00	46760.00	39000.00	2690.00	3200.00*
2	Salvage value (S)	Rs	706.00	4676.00	3900.00	269.00	-
3	Economic life (L)	Year	10	10	10	10	-
4	Annual avg. use	hour	1000	1000	1000	1000	-
5	Depreciation	Rs/yr	635.40	4208.40	3510.00	242.10	-
6	Interest	Rs./yr	388.30	2571.80	2145.00	147.95	-
7	In, T, H charges	Rs/yr	317.70	2104.20	1755.00	121.05	-
8	Repair and maintenance	Rs/hr	0.71	4.68	3.90	0.27	-
9	Fuel consumption	l/hr	-	3.50	2.50	-	-
10	Oil and lubri.	l/hr	-	0.07	0.06	-	-
11	Wages of operator	Rs/hr	1.88	1.88	1.88	-	-

* The hiring charges of a pair of bullocks are Rs. 2.05 per hour.

earlier about Table 6.16 hold true for the data presented in Table 6.17 also.

Table 6.18 summarizes the results of cost-calculations made to determine the cost of operation of different machines or tool and power units used in experiments A and B. The table is self-explanatory and shows the comparative figures for different machines either in terms of cost of operation in rupees per hectare or rupees per quintal

Table 6.19 shows the average total cost of operations of different policies of harvesting and threshing of wheat. The figures in parentheses indicate the cost of individual operations as percentages of the total cost of the policy. The figures are based on averages of experiments A and B. This was done because there was no significant differences in experiments A and B as far as the total time of operations and total losses were concerned (Appendices G and H).

The following inferences may be drawn from Table 6.19 :

(i) The system involving the use of tractor-side mounted pto operated combine (S-1) has the minimum cost of operation i.e. Rs. 407.15 per hectare.

(ii) The policy comprizing reaper harvesting and

Table 6.18. Cost of operation of different machines/tool and power units used in experiments A and B

Sr. No.	Machine	Eff. field capacity ha/hr	Annual hr use hr	Fixed cost per year Rs/yr	Operation cost Rs/hr	Power unit employed	Cost of operation of power unit Rs/hr	Total cost of operation of machine Rs/hr	Total cost of operation of machine Rs/ha
1	2	3	4	5	6	7	8	9	10
1	Tractor side mounted combine	0.19	200	7220.00	19.82	Tractor (32 hp)	20.63	76.55	402.89
2	Tractor operated reaper	0.18	200	544.00	8.16	Tractor (22 hp)	14.38	25.26	140.33
3	Sickle	0.01	250	1.30	1.52	Labourer	-	1.52	152.00
4	Spike tooth thresher with engine	0.64 q/hr	250	3400.00	17.20	Petrol engine	-	30.80	48.12*
5	Hammer mill type thresher with sieving and delivery components - short straw producing	2.94 q/hr	250	935.00	5.48	Tractor (32 hp)	25.58	34.80	11.84*
6	Hammer mill type thresher without sieving and delivery attachments	1.86 q/hr	250	299.20	3.98	Elect. motor (7.5 hp)	1.30	6.48	3.48*

* Total cost of operation is given in terms of Rs per quintal grain-output.

Table 6.18 ... contd.

Table 6.18 contd.

1	2	3	4	5	6	7	8	9	10
7	Olpod thresher (bullock drawn)	0.36 q/hr	250	68.25	2.72	A pair of bullocks	2.05**	5.02	13.94
8	Winnowing fan	0.81 q/hr	150	59.50	2.69	Human	-	3.09	3.81
9	Trailer	-	1000	1341.40	0.71	Tractor (22 hp)	15.40	17.45	-
10	Tractor - 32 hp	-	1000	8884.40	12.49	-	-	21.37	-
11	Tractor - 22 hp	-	1000	5655.00	9.74	-	-	15.39	-
12	Elect. motor - 7.5 hp	-	1000	511.10	0.79	-	-	1.30	-
13	A pair of bullocks	-	-	-	-	-	-	2.05**	-

** Hiring charges for a pair of bullocks estimated on the basis of the informations collected vide Appendix B.

Table 6.19. Average total cost of operations of different systems of harvesting and threshing of wheat.

Sr. No.	Policy	Harvesting	Gathering, bundling and tying	Loading the trolley	Unloading the trolley	Carrying to thresher**	Threshing (Lifting and feeding)	Winnowing	Bagging	Transporting to storage	Total cost of the system
		OPERATIONS									
		Rs/ha	Rs/ha	Rs/ha	Rs/ha	Rs/ha	Rs/ha	Rs/ha	Rs/ha	Rs/ha	Rs/ha
1	S-1	402.89 (98.95)*	-	-	-	-	-	-	1.16 (0.28)	3.10 (0.76)	407.15
2	S-2	140.33 (6.76)	41.31 (1.99)	2.78 (0.13)	2.20 (0.11)	1.68 (0.08)	1882.19 (90.71)	-	1.20 (0.06)	3.17 (0.15)	2074.86
3	S-3	140.33 (21.49)	36.88 (5.65)	2.39 (0.37)	1.92 (0.29)	1.47 (0.23)	465.79 (71.33)	-	1.33 (0.20)	2.90 (0.44)	653.01
4	S-4	140.33 (30.82)	33.92 (7.45)	2.70 (0.59)	2.68 (0.59)	1.54 (0.34)	131.41 (28.86)	138.12 (30.33)	1.46 (0.32)	3.16 (0.69)	455.32
5	S-5	152.00 (23.76)	38.18 (5.97)	2.12 (0.33)	3.38 (0.53)	1.70 (0.27)	438.13 (68.49)	-	1.47 (0.23)	2.70 (0.42)	639.68
6	S-6	152.00 (32.18)	43.24 (9.15)	2.23 (0.47)	3.56 (0.75)	1.47 (0.31)	129.69 (27.45)	135.73 (28.73)	1.45 (3.06)	3.01 (6.37)	472.38
7	S-7	152.00 (15.02)	39.34 (3.89)	2.56 (0.25)	2.66 (0.26)	1.69 (0.17)	547.70 (54.12)	260.20 (25.71)	3.64 (0.36)	2.27 (0.22)	1012.06

* Figures in parentheses indicate percentage cost of operation of the total cost of the system.

** Carrying to thresher means the time involved in taking crop material to thresher from stacks on threshing floor.

Note: The total cost of operation does not include the cost of transportation of the crop material from plot to threshing floor with tractor-trailer.

spike-tooth thresher (imported) i.e. S-2 has the maximum cost of operation of Rs. 2072.86 per hectare.

(iii) The other policies (excluding S-1 and S-2) in order of their costs of operation are as follows:

	Policy	Cost of operation Rs/ha
(a)	Reaper harvesting, threshing with hammer mill type thresher without sieving and bagging attachment and plus winnowing (S-4)	455.32
(b)	Sickle harvesting, threshing with hammer mill type thresher without sieving and bagging attachment and plus winnowing (S-6)	472.38
(c)	Sickle harvesting, threshing with hammer mill with sieving and bagging attachment (S-5)	639.68
(d)	Reaper harvesting, threshing with hammer mill type thresher with sieving and bagging attachment (S-3)	653.01
(e)	Sickle harvesting, threshing with olpad thresher (S-7)	1012.06

The abovementioned results have been presented in Figure 6.7.

6.10 The optimality of the system

An overall evaluation and comparison of all the seven systems of harvesting and threshing has been made in Table 6.20 from the points of view of (a) losses in

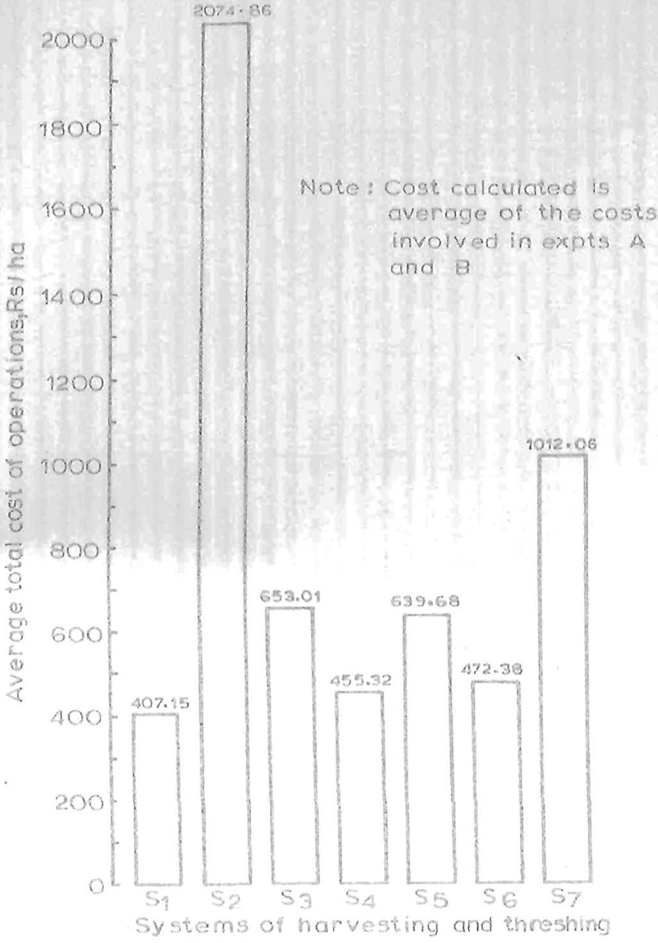


Fig 6.7 A comparison of total costs of operations involved in each policy under harvesting and threshing systems

Table 6.20. The optimality of a policy of harvesting and threshing of wheat

Policy / Criteria	S-1	S-2	S-3	S-4	S-5	S-6	S-7	Reference
1 Losses; %	10.06[1]	19.07	18.86[3]	21.51	18.69	19.71	18.26[2]	Table 6.2 and Table 6.3
2 Time required; hr/ha	10.69[1]	137.97	83.99[2]	132.10[3]	209.75	235.72	372.94	Table 6.7
3 Cost of operation*; Rs./ha	407.15[1]	2074.86	653.01	455.32[2]	639.68	472.38[3]	1012.06	Table 6.19
4 Initial investment**	84760	62200	47,700	47300[3]	10886[3] ***	5106[2]	3906[1]	Table 6.16 and Table 6.17

* The cost of operation of trailer is not included.
** The price of trailer/bullock cart is not included.
(1), (2) and (3) indicate the ranks in order of the systems under specific criteria.
*** includes the cost of electric motor of 15 hp. (Rs. 5380).

percentage of the total yield (b) time required (c) cost of operation and (d) initial investment required to own a particular system.

It is evident from Table 5.20 that from the criteria of losses, the time required and the cost of operation, the policy having tractor-drawn combine harvester thresher (S-1) is the optimal one. The figures for the aforementioned criteria, being, respectively, 10.06 per cent, 10.69 hours per hectare and Rs. 407.15 per hectare. On the other hand, the second and third best systems of harvesting and threshing from the point of view of losses appear to be, respectively, the system having sickle-harvesting and threshing with olpod thresher (S-7) and the system having reaper-harvesting and threshing with hammer mill type thresher with sieving and bagging attachment (S-3). However, it is also evident that the losses in S-1 are almost half of the losses incurring in other systems of harvesting and threshing. Thus, it seems to be logical to recommend the adoption of S-1 over the rest of the systems as far as the losses are concerned. It must be pointed out that with the advancement of technology among the farmers, these losses can be further reduced.

Keeping in view the criterion of the time required per hectare, the data presented in Table 6.20 reveal that the total number of hours required in the policy having tractor-drawn pto operated combine are 10.69. The second best system appears to be the system having reaper harvesting and threshing with the hammer mill type thresher with sieving and bagging attachment (S-3), followed by the policy having sickle-harvesting and threshing with hammer mill type thresher without sieving and bagging arrangement (S-4).

It may be noted that the time required in S-3 and S-4 are, respectively, almost 8 and 12 times the time required in S-1. It is also evident from Table 6.20 that the least efficient method in this respect is S-7 — the policy incorporating sickle harvesting and threshing with olpod thresher, in which almost 35 times more time is required per hectare.

Considering the comparative cost figures of the costs of operation of all the seven policies, the policy having tractor-side mounted pto operated combine (S-1) is least costly followed by the policy having reaper harvesting and threshing with the hammer mill type thresher without sieving and bagging attachment (S-4) and the policy having sickle harvesting and threshing with hammer mill type thresher without sieving and bagging attachment (S-6). In this case, the costs of operation of S-4 and S-6 are, respectively, almost 1.12 and 1.16 times that of S-1. However, if the gain of <u>bhusa</u> (bruised straw) is considered by the farmer as additional and necessary requirement, then its cost must be taken into account for comparing different systems. As earlier mentioned S-1 and S-2 do not make <u>bhusa</u>. The sale price of machine-threshed <u>bhusa</u> by the farmer at the time of harvest was approximately Rs. 7.50 per quintal in 1975. The straw-yield per hectare corresponding to an average yield in each policy in both the experiments (i.e. yield without losses at corresponding grain-straw ratio) is given in Table 6.21. Considering the losses in each system as given in Table 6.20, the corresponding straw-yields per hectare were calculated to be as shown in Table 6.21. The cost of <u>bhusa</u> calculated at the rate of Rs. 7.50 per quintal has been shown in Table 6.21.

The nett cost of operation of adopting a particular policy on harvesting and threshing policy will be dependent upon:

(a) cost of operation

(b) cost due to losses as disadvantage

(c) cost of bhusa as additional advantage.

Table 6.21. The quantity of bhusa obtained under individual policies and its cost.

S.No.	Policy	Quantity of bhusa obtained q/ha	Cost of bhusa @ Rs. 7.50/q Rs./ha
1	S - 1	0.00	0.00
2	S - 2	0.00	0.00
3	S - 3	62.00	465.00
4	S - 4	56.00	420.00
5	S - 5	61.00	457.50
6	S - 6	56.00	420.00
7	S - 7	61.00	457.50

Table 6.22 indicates these costs. The nett cost of operation, calculated in terms of these costs has been determined as follows :

Nett cost of operation (Rs/ha)

= Cost of operation (Rs/ha) + Cost due to losses (Rs/ha) - Price of bhusa (Rs/ha)

Therefore taking into account the nett cost of operation, these policies of operation combinations in harvesting and threshing policies would be ranked in the following order:

I Combine-harvesting and threshing system (S-1)

II Sickle harvesting, threshing with hammer mill type thresher without sieving and bagging attachment, winnowing (S-6)

III Sickle harvesting, threshing with hammer mill type thresher with sieving and bagging attachment (S-5)

IV Reaper harvesting, threshing with hammer mill type thresher without sieving and bagging attachment, winnowing (S-4)

V Reaper harvesting, threshing with hammer mill type thresher with sieving and bagging attachment (S-3)

VI Sickle harvesting, animal threshing with olpod thresher, winnowing fan (S-7)

Table 6.22. Nett cost of operation under individual policies

S.No.	Policy	Cost of operation* Rs./ha	Cost due to losses Rs./ha	Cost of bhusa (being advantage of the policy) Rs./ha	Nett cost of operation Rs./ha
1	S - 1	407.15	+ 447.12	0.00	854.27
2	S - 2	2074.86	+ 959.83	0.00	3034.69
3	S - 3	653.01	+ 972.43	- 465.00	1160.44
4	S - 4	455.32	+ 1086.25	- 420.00	1121.57
5	S - 5	639.68	+ 868.18	- 457.50	1050.36
6	S - 6	472.38	+ 937.08	- 420.00	989.46
7	S - 7	1012.06	+ 906.50	- 457.50	1461.06

* Refer Appendix N for the cost of operation in Rs./q.

VII Reaper harvesting, threshing with spike tooth thresher (imported) (S-2)

It is to be mentioned here that the cost of operation of S-1 is dependent upon the effective field capacity of the harvesting machine which, as mentioned earlier, was low in experiment fields. The field studies at the farmers' fields have shown the effective field capacity of a tractor-drawn pto operated combine to be varying between 0.30 to 0.40 hectare per hour. During the course of the experiments, the effective field capacity was determined to be 0.19 hectare per hour. That means, with the effective field capacity becoming double that of the experimental area, the cost of operation per hectare may be reduced to almost Rs. 200.00 per hectare.

Therefore, in the light of the experimental evidence, it can be concluded that S-1 has the least nett cost of operation whether making of bhusa is a consideration or not. In case, the grain and bhusa (as well) being the desired final products, the policy comprizing sickle harvesting, threshing with hammer mill type thresher without sieving and bagging attachment plus winnowing (S-6) would have the least cost of operation.

Leaving aside S-2 being exceptional, because of two factors, namely, (i) thresher not capable of producing bhusa and (ii) the machine having very high cost due to the reasons of being imported and operated by petrol engine, S-7 can be compared with S-1 and S-4 for overall performance. To compare S-7 with S-1 on one hand and with S-6 on the other would be both natural and desirable because S-7 is the most widely followed policy in the wheat-growing areas of the country.

On the basis of the data presented in Tables 6.20 and 6.21 and 6.22, the following conclusions can be arrived at after due comparisons amongst S-1, S-4 and S-7:

I S-1 is the best policy from points of view of minimum loss and maximum timeliness (requiring minimum time per hectare) and also of minimum nett cost of operation.

II S-6 is the second best policy from point of view of minimum cost and the best among partially mechanized policies in case grain and bhusa are desired products, though the total time required per hectare is 22 times more than that of S-1.

III S-7 is the second best policy from point of view of losses, though losses differ significantly from those of S-1. It has the highest cost of operation whether <u>bhusa</u> is a desired product or not. It is also the least efficient policy from point of view of the time required per hectare.

Therefore, it can be safely and logically argued that the system incorporating sickle harvesting, olpod thresher and winnowing fan does not suit the demand of modern farm-technology where multiple-cropping, and timeliness and efficiency of operations are the paramount considerations.

The only point favourable to S-7 is the requirement of initial investment. The constraint of initial investment by the farmer is to be given due consideration. It is clear from Table 6.20 that on the one hand S-1 and S-6 require the initial investments to the tune of Rs. 84760 and Rs. 5106 respectively, and on the other hand S-7 requires the initial investment of Rs. 3906. That means, the combine-harvesting threshing policy (S-1) requires almost 22 times and policy of sickle harvesting with hammer mill type thresher without sieving and bagging arrangement (S-6) requires 1.31 times more capital as initial investment than that required by the system having sickle harvesting with olpod thresher (S-7).

The above conclusions pose the question of the capacity of the farmers to have this initial investment to the extent of above Rs. one lakh to adopt S-1. Out of this only Rs. 40,000 are required to own the combine-harvester thresher. The rest of the amount is required for a tractor which is used in multiple ways as a source of power for various farm operations effecting their productivity. However, a sum of Rs. 40,000 is still a big amount which is usually beyond the capacity of an average farmer. This factor acts as a barrier inspite of the other advantages of the system.

Thus, considering the aforementioned facts, the problem of selecting a suitable policy leads to the selection of any one policy from amongst S-1, S-6 and S-7. The selection of any particular policy to a specific farm situation can also be considered from several points of view. These include productivity, timeliness of operations, protection of produce against weather-hazards, fire and theft, investment capacity of the farmer and labour displacement.

Each policy out of the policies S-1, S-6 and S-7 is discussed in details keeping in view the points mentioned earlier.

As far as the points of productivity, timeliness of operations, protection of produce against weather hazards, fire and theft are concerned, the merits of S-1 evidently would outweigh those of others even though this was not specifically varified in this study. This is because it results in almost half the losses compared to those of S-6 and S-7, and require 4.53 per cent time of S-6 and 2.84 per cent time of S-7.

If this policy (S-1) is considered from the multiple-cropping point of view, a reference to Appendix M makes evident that multiple cropping involving the use of more than 3 crops gives a profit of 128 per cent over the expenditure involved. This can be made possible only when harvesting and sowing operations do not overlap necessitating the timeliness of operation. Thus, advanced farm-technology involving the use of multiple cropping justifies the use of S-1.

Justification of the use of S-1 poses the question whether S-1 be used through private ownership or custom-service.

Private-ownership involves the question of initial investment of about Rs. 1 lakh. A reference to Table 1.2 and 6.16 makes it evident that for an annual use of 200 hrs per year for a combine-harvester thresher an area of 38 hectares is required and the number of operational holdings havng this much or greater area constitute only 11.89 per cent of the total. Therefore, for a great majority of farmer, the question of private ownership is beyond their capacity. Therefore, in this connection it is suggested that farmers' service co-operatives with sufficient government loans and subsidies be set up in order to provide custom-hiring facilities for the combine-harvester thresher. This would prove a boon for small farmers to enable them to go for more productive farming. This view is further supported by a study titled "Economic analysis on multiple cropping in Haryana" (Singh _et al._, 1973) according to which "adoption of multiple cropping would require more funds for financing agricultural operations. Small farms would not be able to follow the multiple cropping on recommended lines unless adequate and timely supply of credit at reasonable rate of interest is made available to them." It has been further argued in the said study (Singh _et al._, 1973) that an efficient and economic custom service organization has to be developed to meet the demands of multiple-cropping technology.

Regarding the displacement of labour, a study in

Punjab (Mittal, 1975) has pointed out that reapers and combines displace the labour as follows :

(i) Tractor front mounted reaper (labour for binding and threshing)	30 persons/machine
(ii) Tractor side mounted combine	60 persons/machine

Therefore, the above study, which was not an exhaustive evaluation, brings to light the point that the question of labour-displacement has to be considered not from farmer's profit point of view but from a wider national angle so as to avoid socio-economic imbalances.

In this connection it would be worthwhile to refer to the studies made in Punjab which is a major wheat growing state and also more mechanized than the rest of wheat growing areas in India. It has been pointed out that if a combine-harvesting threshing system is considered to be a part of an overall mechanized system on a farm which actually it is, the complimentary effects of adopting this system can not be overlooked. Evidence (P.E.O., 1969-70) exists to show the superiority of tractor-farms over bullock farms. The studies in Punjab, Andhra Pradesh and Tamilnadu (P.E.O., 1969-70) reveal that in the case of tractor farms, cropping intensity increases with the rise of farm-sizes. In Ferozepur District, the employment of labour among the sample farms increased from 51.38 man-days per cropped (planted) hectare in 1954-55 to 60.52 man-days in 1969-70 or by 18 per cent, despite a decline in labour input for wheat owing mainly to the wide-spread use of mechanical threshers (Kahlon et al., 1971). The rate of rise in total farm employment has been much higher owing, among other things, to the rise in the cropping intensity (Kahlon et al., 1971) from 117 in 1954-55 to 130 in 1969-70.

Thus, it is apparent that in view of the complimentary effects of farm-mechanization in general, on the adoption of other inputs to farming, the adoption of combine-harvesting threshing is much helpful and contributory to have multiple cropping.

Now, S-6 in relation to S-1 and S-7, has twice the losses of S-1 and almost equal to S-7 (non-significant difference), requires 22 times the time required by S-1 and 63 per cent of the time required by S-7 (Table 6.20). The nett cost of operation is almost 1.16 times of S-1 and 67.72 per cent of S-7. The labour-displacement is almost negligible. The initial investment required is 5.95 per cent of that required for S-1 and 1.31 times more than that required by S-7.

Therefore, taking an overall view of all the policies of harvesting and threshing, the following can be inferred:

I The grain losses can be brought about to minimum with the adoption of the combine-harvesting threshing policy (S-1). This may effect the saving of grain worth Rs. 525.00 per hectare (at 10 per cent losses in S-1 and 20 per cent losses in other policies, assuming the yield of wheat as 50 quintals per hectare and the price of wheat Rs. 105.00 per quintal).

II The time required is minimum in S-1 offering the advantage of maximum timeliness, not only to the operation of harvesting and threshing but also to facilitate other operations to be performed at the proper time.

III The nett cost of operation is minimum in the case of S-1.

IV Initial investment in S-1 is maximum which calls for government subsidy, incentives to farmers and governmental policies to help make the service-cooperatives to enable the farmers to hire the machines.

V Combines displace labour, but because of the complimentary effects like timeliness of operations and increased crop-intensity etc., the displaced labour is absorbed. However, in case of the introduction of combines, on a big scale, steps must be taken simultaneously to have agro-based industries like dairying, poultry, piggery and agro-service centres. The local entrepreneur may be encouraged to manufacture combines in India rather than importing them. This will open up fresh avenues for increased employment opportunities. Agriculture, thus, could be made more intensive to have increased productivity per unit of land and labour.

VI Policy S-1 is recommended in those places where (a) the know-how for advanced farming-technology exists among the farmers, (b) there is no constraint due to initial investment, (c) the custom-hiring facilities are present and (d) the question of bhusa is not the consideration.

VII Policy S-6 holds an intermediate position among the policies studied. It is recommended where (a) the question of getting bhusa is a main consideration, (b) labour is available and its utilization is a consideration and (c) capacity to invest exists.

VIII Under the farming conditions of subsistence-level and abject poverty and with no constraint due to labour, there is no alternative except that of S-7, though it has the highest cost of operation and is the least efficient system.

C H A P T E R   VII

SUMMARY AND CONCLUSIONS

CHAPTER VII

SUMMARY AND CONCLUSIONS

During the course of the study reported in this thesis, the harvesting and threshing systems of wheat were analyzed and evaluated from the points of view of (a) total losses (b) total time required (c) cost of operation and (d) initial investment required. These systems were analyzed from the view-point of having several alternatives termed as policies. Each policy consisted of a group of operations performed by selected harvesting and threshing machines or methods as alternatives. Each policy could be selected under a specific crop situation. These policies consisted the following operation-combinations :

System	Policy	Operation-combination
A. Fully mechanized system	S-1	Combining with tractor-operated combine-harvester cum thresher
B. Partially mechanized system	S-2	Reaper-harvesting, manual bundling, stacking, threshing with spike tooth thresher (not bhusa making), bagging
	S-3	Reaper harvesting, manual bundling, stacking, threshing with hammer mill type thresher (bhusa producing) with sieving and bagging arrangement

System	Policy	Operation-combination
	S-4	Reaper-harvesting, manual bundling, stacking, threshing with hammer mill type thresher (bhusa producing) without sieving and bagging, winnowing
	S-5	Sickle harvesting, mannual bundling, stacking, threshing with hammer mill type thresher (bhusa producing) with sieving and bagging
	S-6	Sickle harvesting, manual bundling, stacking threshing with hammer mill type thresher (bhusa producing) without sieving and bagging, winnowing
C. Non-mechanized system	S-7	Sickle harvesting, manual bundling, stacking, threshing with bullock-drawn olpod thresher, winnowing.

To evaluate and ascertain the optimality of a policy, two field experiments, each with three replications and two different dates of sowing were laid out.

Sonalika variety of wheat was grown in both the experimental fields under similar agronomic practices.

The policies on harvesting and threshing were studied and evaluated under the field conditions existing at the experimental site.

The investigations yielded the following principal results.

1. The total grain losses on account of cutter bar, cylinder, rack, shoe, gathering and bundling, threshing floor and weighing and bagging vary from 10.06 per cent to 21.51 per cent in the seven policies on harvesting and threshing systems of wheat. The lowest value of total grain loss was found to be in S-1 and the highest value in S-4.

2. The total time required to complete all operations is minimum in policy S-1 involving combine harvesting and threshing (10.69 hrs/ha). Due to this there is maximum advantage of timeliness of the operations not only to the operation of harvesting and threshing but to the other farm operations which can be performed at the proper time. The second best method from the point of view of timeliness is policy S-3, though it requires almost 8 times more time than that required by S-1.

3. The nett cost of operation, taking into account the cost of operation, cost of <u>bhusa</u> and cost of losses, is minimum in the case of S-1. The second best policy from the view point of nett cost of operation is S-6.

4. Initial investment in S-1 is maximum which calls for governmental subsidy, incentives to farmers and

governmental policies to help make the serxice-cooperatives to enable the farmers to hire agricultural machinery.

5. Combines displace labour, but because of the complimentary effects like timeliness of operations and increased crop-intensity etc., the displaced labour is absorbed. However, in case of the introduction of combines on a big scale, steps should be taken simultaneously to have agro-based industries.

6. Policy S-1 involving combined harvesting and threshing system is recommended in those places where (a) the know-how for advanced farming technology exists among the farmers, (b) there is no constraint due to initial investment, (c) the custom-hiring facilities are present and (d) the question of <u>bhusa</u> is not the consideration.

7. Policy S-6 holds an intermediate position among the policies studied. It is the second best policy from the view points of nett cost of operation and initial investment. It is recommended where (a) the question of getting <u>bhusa</u> is a main consideration, (b) labour is available and its utilization is a consideration and (c) the capacity to invest exists.

8. Under the farming conditions of subsistence level and abject poverty and with no constraint due to labour, there is no alternative except that of S-7, though it has the highest cost of operation and is the least efficient system. Replacement of policy S-7 with S-6 or S-1 is desirable and is in the national interest from the points of view of productivity in farming operations in general and multiple cropping in particular.

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A P P E N D I C E S

APPENDIX A

Meteorological data at the I.A.R.I., New Delhi for the period from November, 1974 to 1st June, 1975

Sr. No.	Date	Avg. wind velocity at 08.30 past 24 hours km	Maximum temperature °C	Minimum temperature °C	Relative humidity 07.00 %	Relative humidity 14.00 %	Rainfall in past 24 hours ending at 08.30 IST mm
1	2	3	4	5	6	7	8
1	1.11.74	2.4	31.0	13.0	71	16	0.0
2	2.11.74	2.6	31.4	10.5	60	22	0.00
3	3.11.74	3.2	30.2	10.2	67	18	0.0
4	4.11.74	5.9	29.0	11.2	57	24	0.0
5	5.11.74	5.8	29.0	11.5	55	22	0.0
6	6.11.74	5.2	29.5	10.5	59	16	0.0
7	7.11.74	6.7	29.8	10.2	47	15	0.0
8	8.11.74	6.4	30.2	11.0	53	17	0.0
9	9.11.74	5.0	30.6	9.4	65	22	0.0
10	10.11.74	4.2	31.0	11.5	76	22	0.0
	Average in the week	5.6	29.87	10.75	58.85	19.71	0.0

Appendix A contd.

Appendix .. contd.

1	2	3	4	5	6	7	8
11	11.11.74	1.4	31.0	13.0	78	23	0.0
12	12.11.74	3.4	31.0	13.8	84	31	0.0
13	13.11.74	3.0	30.5	13.0	78	22	0.0
14	14.11.74	3.7	28.0	9.0	73	26	0.0
15	15.11.74	2.2	28.0	8.4	80	15	0.0
16	16.11.74	1.9	28.8	11.0	45	16	0.0
17	17.11.74	4.2	28.0	9.6	75	23	0.0
	Average in the week	2.82	29.32	11.11	73.28	22.28	0.0
18	18.11.74	2.4	26.0	8.4	83	17	0.0
19	19.11.74	1.1	28.0	9.0	77	27	0.0
20	20.11.74	1.6	27.0	8.8	95	22	0.0
21	21.11.74	2.6	26.0	7.0	68	26	0.0
22	22.11.74	5.3	24.5	8.0	56	22	0.0
23	23.11.74	4.8	25.0	5.0	97	25	0.0
24	24.11.74	3.4	24.5	4.6	85	26	0.0
	Average in the week	3.02	25.85	7.25	80.14	23.57	0.0

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
25	25.11.74	4.5	25.0	6.0	69	28	0.0
26	26.11.74	1.6	25.2	6.4	86	24	0.0
27	27.11.74	1.9	25.0	6.0	87	27	0.0
28	28.11.74	2.6	26.0	6.0	72	27	0.0
29	29.11.74	3.5	24.5	5.6	91	27	0.0
30	30.11.74	2.9	25.2	6.0	70	23	0.0
	Total (for month)	105.4	838.9	273.6	2159	671	0.0
	Average (in the month)	3.5	28.0	9.1	72	22	
31	1.12.74	5.7	23.2	5.8	61	16	0.0
	Average in the week	3.24	24.87	5.97	76.57	24.57	0.0
32	2.12.74	3.0	23.5	8.5	73	11	0.0
33	3.12.74	7.4	23.0	10.4	72	40	Tr
34	4.12.74	4.5	22.8	7.2	91	25	0.0
35	5.12.74	6.9	21.8	7.0	94	28	0.0
36	6.12.74	5.3	20.2	3.0	69	19	0.0
37	7.12.74	5.4	20.0	6.0	65	20	0.0
38	8.12.74	3.7	21.2	6.5	89	24	0.0
	Average in the week	5.17	21.78	6.94	79	23.85	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
39	9.12.74	1.4	22.0	7.5	89	24	0.0
40	10.12.74	2.3	22.5	4.5	70	27	0.0
41	11.12.74	5.8	21.5	4.5	55	27	0.0
42	12.12.74	8.6	21.5	6.2	67	23	0.0
43	13.12.74	7.8	22.2	6.0	70	50	0.0
44	14.12.74	5.8	21.0	5.3	80	44	0.0
45	15.12.74	8.7	21.5	5.0	63	21	2.4
	Average in the week	5.77	21.74	5.57	70.57	30.85	
46	16.12.74	10.7	18.5	5.0	95	84	Tr
47	17.12.74	10.3	18.0	12.2	90	70	2.3
48	18.12.74	2.4	18.0	6.8	100	69	0.0
49	19.12.74	4.0	17.0	5.3	100	48	0.0
50	20.12.74	3.5	18.0	3.4	91	40	0.0
51	21.12.74	5.6	18.5	3.2	82	35	0.0
52	22.12.74	4.2	18.2	3.0	75	23	0.0
	Average in the week	5.81	18.02	5.55	90.42	52.71	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
53	23.12.74	3.8	20.0	4.0	84	33	0.0
54	24.12.74	4.3	20.0	3.5	81	36	0.0
55	25.12.74	2.9	19.0	4.3	97	30	0.0
56	26.12.74	2.4	19.0	4.0	83	37	0.0
57	27.12.74	3.5	20.6	6.0	80	34	0.0
58	28.12.74	1.6	21.4	6.2	88	38	0.0
59	29.12.74	3.5	21.6	7.2	89	31	0.0
	Average in the week	3.14	20.22	5.02	86	34.14	
60	30.12.74	5.1	21.5	6.0	89	31	0.0
61	31.12.74	4.0	21.2	4.5	83	32	0.0
	Total (in the month)	154.1	638.4	178.0	2515	1070	4.7
	Average (in the month)	5.0	20.6	5.7	81	35	
62	1.1.75	8.3	22.0	9.5	97	97	18.4
63	2.1.75	5.3	12.0	3.5	99	72	3.4
64	3.1.75	1.9	16.2	4.8	97	65	0.0
65	4.1.75	4.0	17.0	3.8	88	47	0.0
66	5.1.75	2.9	18.0	5.0	86	51	0.0
	Average in the week	4.5	18.27	5.30	91.28	56.42	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
67	6.1.75	3.7	18.2	3.5	94	37	0.0
68	7.1.75	2.7	19.2	4.5	88	38	0.0
69	8.1.75	3.4	20.0	8.4	70	45	Tr
70	9.1.75	4.2	19.4	8.2	92	47	Tr
71	10.1.75	6.1	18.8	7.2	100	71	0.0
72	11.1.75	8.1	17.0	7.2	97	62	0.0
73	12.1.75	5.0	18.6	6.2	97	46	0.0
	Average in the week	4.74	18.74	6.45	91.14	49.42	
74	13.1.75	7.2	19.0	5.6	88	41	0.0
75	14.1.75	5.9	19.5	4.2	85	33	0.0
76	15.1.75	5.8	20.0	8.6	83	65	0.0
77	16.1.75	1.8	17.0	10.2	93	45	0.0
78	17.1.75	4.5	20.5	6.0	99	39	0.0
79	18.1.75	6.2	18.0	3.2	84	31	0.0
80	19.1.75	5.0	19.0	2.0	79	27	0.0
	Average in the week	5.2	19.00	5.68	87.28	40.14	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
81	20.1.75	2.6	18.0	5.4	91	34	0.0
82	21.1.75	4.6	19.0	8.5	71	41	0.0
83	22.1.75	9.1	19.0	10.0	90	55	0.0
84	23.1.75	6.7	20.2	9.4	97	91	0.0
85	24.1.75	2.7	14.5	5.2	100	58	0.0
86	25.1.75	7.7	17.2	5.0	85	41	0.0
87	26.1.75	5.1	19.0	3.8	97	47	0.0
	Average in the week	5.5	18.12	6.75	90.14	52.42	
88	27.1.75	6.6	18.8	4.8	83	37	0.0
89	28.1.75	5.3	20.5	7.0	83	45	0.0
90	29.1.75	8.7	20.0	7.5	86	45	0.0
91	30.1.75	5.8	20.4	10.5	93	93	Tr
92	31.1.75	5.9	14.5	11.4	100	70	9.4
	Total in the month	162.8	570.5	200.10	2792	1616	
	Average in the month	5.25	18.40	6.45	90.02	52.12	
93	1.2.75	2.9	19.5	8.6	97	36	0.0
94	2.2.75	7.8	18.5	4.0	88	49	0.00
	Average in the week	6.14	18.88	7.68	90	53.57	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
95	3.2.75	6.7	17.2	3.5	79	43	0.0
96	4.2.75	4.8	19.0	6.2	94	48	0.0
97	5.2.75	4.5	17.5	9.0	74	34	0.0
98	6.2.75	6.9	21.5	11.5	81	38	0.0
99	7.2.75	3.8	22.5	7.2	88	35	0.0
100	8.2.75	2.2	23.5	9.5	88	39	0.0
101	9.2.75	5.9	23.0	10.0	88	58	0.00
	Average in the week	4.97	20.60	8.12	84.57	42.14	
102	10.2.75	10.2	21.0	10.0	93	39	0.0
103	11.2.75	6.1	21.2	9.0	90	33	0.0
104	12.2.75	6.1	22.0	6.0	86	35	0.0
105	13.2.75	6.4	26.0	12.2	63	46	0.0
106	14.2.75	9.0	26.0	10.5	73	24	0.0
107	15.2.75	3.7	19.0	4.5	91	62	0.0
108	16.2.75	6.6	18.5	6.0	67	23	0.0
	Average in the week	6.87	21.95	8.31	80.42	37.42	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
109	17.2.75	8.2	18.0	1.0	75	22	0.0
110	18.2.75	8.2	18.0	3.0	70	32	0.0
111	19.2.75	4.5	20.4	4.8	80	46	0.0
112	20.2.75	5.0	18.5	8.5	77	51	0.0
113	21.2.75	5.4	22.0	8.0	87	33	0.0
114	22.2.75	5.1	21.0	6.2	48	58	0.0
115	23.2.75	5.7	22.0	7.0	64	40	0.0
	Average in the week	6.01	19.98	5.50	71.57	40.28	
116	24.2.75	3.8	22.0	6.0	81	29	0.0
117	25.2.75	4.5	24.0	7.0	94	30	0.0
118	26.2.75	3.7	24.2	8.0	94	24	0.0
119	27.2.75	3.2	26.0	8.0	91	24	0.0
120	28.2.75	1.8	26.8	12.0	52	35	0.0
	Total (in the month)	152.70	598.80	207.20	2253	1066	
	Average (in the month)	5.45	21.38	7.4	80.46	38.07	
121	1.3.75	6.1	29.0	11.0	90	44	0.0
122	2.3.75	5.0	26.5	11.4	86	26	0.0
	Average in the week	4.01	25.5	9.06	84	30.28	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
123	3.3.75	9.8	27.0	11.0	74	30	0.0
124	4.3.75	6.4	28.8	14.2	75	25	0.0
125	5.3.75	7.2	32.2	19.2	70	44	Tr
126	6.3.75	6.7	30.0	15.0	91	27	Tr
127	7.3.75	6.1	28.8	12.2	80	48	0.0
128	8.3.75	5.3	27.0	13.0	64	18	0.0
129	9.3.75	4.8	27.5	12.0	79	31	0.0
	Average in the week	6.61	28.76	13.8	76.14	31.86	0.0
130	10.3.75	10.4	27.8	15.4	71	50	Tr
131	11.3.75	8.2	28.0	15.0	78	29	0.0
132	12.3.75	6.6	26.5	10.5	71	15	0.0
133	13.3.75	8.0	24.2	8.5	82	30	0.0
134	14.3.75	10.4	25.5	9.2	67	27	0.0
135	15.3.75	6.4	26.00	8.6	65	23	0.0
136	16.3.75	8.5	27.5	9.0	75	17	0.0
	Average in the week	8.36	26.21	10.88	72.71	27.28	0.0

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
137	17.3.75	7.4	28.0	10.5	66	19	0.0
138	18.3.75	9.3	28.0	10.0	57	17	0.0
139	19.3.76	-	27.0	9.0	64	45	0.0
140	20.3.75	-	29.0	12.0	57	31	0.0
141	21.3.75	9.3	30.0	15.0	50	36	0.0
142	22.3.75	8.0	32.0	20.0	63	39	0.0
143	23.3.75	12.8	30.0	18.0	98	58	3.1
	Average in the week	9.36	29.14	13.5	65	35	0.44
144	24.3.75	5.3	34.0	15.0	61	54	7.0
145	25.3.75	6.7	26.0	12.0	74	35	0.0
146	26.3.75	7.0	25.0	9.5	76	37	0.0
147	27.3.75	4.4	26.5	9.5	65	32	0.0
148	28.3.75	4.1	28.5	10.0	66	31	0.0
149	29.3.75	8.5	30.0	12.8	57	30	0.0
150	30.3.75	4.1	31.5	13.5	46	27	0.0
	Average in the week	5.73	28.79	11.76	63.57	35.14	1.00
151	31.3.75	6.6	31.0	25.0	52	25	0.0
	Total (in the month)	209.4	876.80	397	2170	1000	10.1
	Average (in the month	7.22	28.28	12.80	70	32.25	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
152	1.4.75	5.6	32.5	15.0	73	22	0.0
153	2.4.75	6.9	30.0	17.5	77	23	0.0
154	3.4.75	6.3	36.0	15.5	68	23	0.0
155	4.4.75	3.7	38.0	17.6	81	25	0.0
156	5.4.75	5.1	37.2	21.0	66	15	0.0
157	6.4.75	5.7	37.0	22.0	86	22	0.0
	Average in the week	5.7	34.52	19.08	71.85	22.14	
158	7.4.75	4.0	38.0	21.0	49	13	0.0
159	8.4.75	5.9	35.0	19.0	46	11	0.0
160	9.4.75	6.9	31.5	15.6	62	13	0.0
161	10.4.75	7.2	31.0	12.6	45	14	0.0
162	11.4.75	8.0	31.5	15.0	42	27	0.0
163	12.4.75	9.0	34.0	16.0	43	15	0.0
164	13.4.75	4.8	35.5	19.0	31	9	0.0
	Average in the week	6.54	33.78	16.88	45.42	14.57	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
165	14.4.75	5.6	35.6	18.0	51	16	0.0
166	15.4.75	7.8	35.0	17.0	34	20	0.0
167	16.4.75	7.5	33.0	13.0	39	17	0.0
168	17.4.75	5.7	34.0	14.2	30	17	0.0
169	18.4.75	7.2	36.5	15.4	36	21	0.0
170	19.4.75	3.2	37.5	19.0	33	31	0.0
171	20.4.75	6.6	39.0	23.4	34	34	Tr
	Average in the week	6.22	35.80	17.14	36.71	22.28	
172	21.4.75	8.6	38.8	24.0	44	29	0.0
173	22.4.75	2.1	39.5	21.0	58	24	0.00
174	23.4.75	3.9	39.6	24.5	29	32	0.0
175	24.4.75	7.7	37.5	21.6	45	25	0.0
176	25.4.75	9.1	38.4	22.6	42	16	0.0
177	26.4.75	7.2	39.0	21.0	64	17	Tr
178	27.4.75	4.3	40.0	24.0	61	19	0.0
	Average in the week	6.12	38.97	22.67	49.00	23.14	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
179	28.4.75	10.4	36.5	20.0	42	15	0.0
180	29.4.75	10.2	37.0	19.5	42	12	0.0
181	30.4.75	8.2	37.0	20.0	36	17	0.0
	Total (in the month)	194.40	1081.10	565	1489	594	
	Average (in the month)	6.48	36.03	18.83	49.63	19.80	
182	1.5.75	7.7	39.0	20.2	40	18	0.0
183	2.5.75	9.1	40.0	23.0	41	23	0.0
184	3.5.75	10.4	40.0	25.0	41	29	0.0
185	4.5.75	12.6	38.0	19.0	53	28	Tr
	Average in the week	9.80	38.21	20.95	42.14	20.28	
186	5.5.75	4.6	38.5	22.0	50	22	0.0
187	6.5.75	3.7	39.0	23.4	57	13	Tr
188	7.5.75	6.3	39.0	22.6	38	12	0.0
189	8.5.75	11.2	38.5	21.4	33	16	0.0
190	9.5.75	14.1	40.0	24.0	34	23	0.0
191	10.5.75	9.5	41.0	24.5	41	23	0.0
192	11.5.75	7.8	41.5	23.5	39	27	0.0
	Average in the week	8.17	39.64	23.05	41.71	19.42	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
193	12.5.75	10.4	42.0	23.4	31	24	0.0
194	13.5.75	12.6	42.5	25.4	34	24	0.0
195	14.5.75	13.1	42.5	29.5	39	24	0.0
196	15.5.75	12.5	42.5	30.5	36	31	0.0
197	16.5.75	8.8	39.5	30.2	51	34	0.0
198	17.5.75	8.6	40.0	27.0	62	32	0.0
199	18.5.75	9.7	37.5	24.2	51	35	Tr
	Average in the Week	10.81	40.92	27.17	43.42	29.14	
200	19.5.75	11.4	37.5	21.6	53	29	0.0
201	20.5.75	7.8	40.0	21.0	48	27	0.0
202	21.5.75	7.4	43.5	28.0	42	24	0.0
203	22.5.75	11.0	43.0	26.2	46	37	0.0
204	23.5.75	7.2	40.0	25.6	45	32	0.0
205	24.5.75	4.9	40.0	26.0	41	37	0.0
206	25.5.75	11.0	42.4	26.0	56	39	0.0
	Average in the week	8.67	40.91	24.91	47.28	32.14	

Appendix A contd.

Appendix A contd.

1	2	3	4	5	6	7	8
207	26.5.75	7.5	40.8	27.0	46	41	0.0
208	27.5.75	7.5	39.0	23.0	50	42	0.0
209	28.5.75	7.0	42.0	28.0	33	19	0.0
210	29.5.75	6.4	42.8	29.0	41	17	0.0
211	30.5.75	11.7	44.0	28.0	41	17	Tr
212	31.5.75	17.0	42.0	27.0	41	39	Tr
	Total (in the month	290.50	1258	775.20	1354	838	
	Average (in the month)	9.37	40.58	25.00	43.67	27.03	
213	1.6.75	10.1	39.0	22.0	69	46	5.2
	Average in the week	9.60	41.37	26.28	45.85	31.57	-

APPENDIX B

Important specifications of tractors, engine, electric-motor, combine, threshers and winnowing fan used in the harvesting and threshing systems

1 MF 1035 tractor

- Manufactured by:	M/s Tractors and Farm Equipment Limited, Madras
- Engine-type :	Diesel
- Bore :	89 mm
- Stroke:	127 mm
- Displacement :	2.36 litres
- Compression ratio:	16.5 : 1
- Firing order :	1, 2, 3
- hp :	32 bhp at 2000 rpm 28.4 dbhp
- Electrical system:	12 volts
- Power take off:	Spline - 34.9 mm Control - 3 position shift lever reduction between engine speed and pto shaft - 2.78 : 1

Fill up data :

- Cooling system:	7.5 litres
- Fuel tank capacity:	34 litres

...contd.

Appendix B contd.

- Transmission : 30.28 litres
- Steering gear box: 0.946 litres
- Engine sump: 7.3 litres
- Air-cleaner bowl: 0.43 litres
- Electrical system: 12 V
- Voltage control regulator Lucas RB-108
- Battery: AMCO type 3A57TD Two 6 volt, 115 Amp. hour Capacity at 10 hour discharge rate, connected in series, Specific gravity - fully charged 1.25 - 1.3 (16°C)

2 Zetor 2011 - tractor

- Manufactured by/ dealer: M/s Hindustan Machine Tools Limited, P.O. Pinjore, Distt. Ambala
- Engine type: Diesel, WC
- bhp : 22
- rpm at normal engine speed : 2000
- No. of cylinders : 2
- Compression ratio: 17 : 1
- Fuel tank capacity: 40
- Weight in kg 1300
- Number of speeds -
  - forward 10
  - reverse 2
- Maximum speed 24 km/hr

..... contd.

Appendix B contd.

3 Gasolene engine fitted on spike tooth type thresher (Pullman thresher)

- Manufactured by:	Wisconsin Motor Corporation, Milwaukee 4, Wisconsin (USA)
- Model:	AENLD Sl. No. 4401028
- Type :	Wisconsin air-cooled single cylinder engine
- Cylinder volume :	376.26 cm^3
- Fuel consumption :	1.63 l/hr
- Fuel tank cap.:	6.75 litres
- Fuel :	Good quality of garolene (74 octane no.)
- Lubricating oil :	Summer - SAE 30 + 49°C to 4.5°C
	Winter - SAE 20-20W + 4.5°C to — 15°C
- Lubricating method:	Force feed cum splash type
- Spark plug :	Champion No. 8 commercial - 64K

- Horse-power :

rpm	hp
1600	4.5
2000	5.8
2400	7.0
2800	7.9
3200	8.2

The hp given is for an atmospheric pressure and temperature of 76 cm and 15.55°C at sea level.

..... contd.

Appendix B contd.

4 Electric motor

- Manufactured by :	M/s. Jyoti Ltd., Baroda
- Make :	AC motor - induction type
- hp :	7.5
- rpm :	1440
- Voltage :	400/440 V
- Current :	10.50 A
- Cycles/sec:	50
- Phase :	3
- Serial No. :	22870
- Frame :	MOI - 1 E 4009 A

5 Energy meter

- Manufactured by :	M/s. Electra plant, Bulgaria
- Make :	Type IEA 4 - 3 TH, 4 wire meter
- Volts :	400/440 V
- Fuel load ampere :	3 x 30 A
- Revolutions/kwh :	80
- Phase :	3
- Serial no. :	9166005

...... contd.

Appendix B contd.

6 Starter

- Manufactured by :	M/s. Siemens India.
- Make :	DOL starter LBO/K915 SP 1114 - 1
- Kilowatts :	7.5
- Voltage :	415 V
- Phase :	3
- Cycles/sec :	50
- Amperes :	6A - 12A
- Coil :	320 V 420 V

7 Tractor side mounted pto operated combine

- Manufactured by :	M/s. Vicon Ltd., Lavelle Road, Bangalore
- Width of cut :	1.5 m
- Drum speed :	860 - 1460 rpm
- Speed of pick up reel	Infinitely variable, 16 - 40 m/sec.
- Stubble height :	5 cm - 46 cm
- Power requirement :	35 hp and above
- Driving speed :	2 - 6 km/hr
- Weight :	1150 kg
- Overall length (with torpedo)	6.63 m

.... contd.

Appendix B contd.

- Width (with tractor): 2.90 m
- Width (without tractor) : 2.00 m
- Combing capacity : 0.30 - 0.40 ha/hr
- Stationery threshing capacity : 15 - 20 q/hr

8 Hammer mill type thresher with sieving and bagging

(Ludhiana type thresher)

- Manufactured by : M/s. Friends Own Foundary Workshop, Gill Road, Ludhiana
- Diameter of threshing drum : 1 m
- Overall length : 2.147 m
- Overall width : 1.245 m
- Blow off outlet : 21 cm x 26 cm

9 Hammer mill type thresher without sieving and bagging

(drummy type thresher)

- Manufactured by: M/s. Land Equipment Corporation, 37, Narwala, Karol bagh, New Delhi.
- Model : Everest thresher cum winnower
- Diameter of threshing drum : 0.90 m

.... contd.

Appendix B contd.

10 Spike tooth type thresher (Pullman thresher)

- Manufactured by : M/s. Bill's Welding Pullman, Washington (U.S.A.)
- Size of feeder throat : 61 cm x 35.5 cm
- Threshing cylinder : 30.5 cm(dia.) x 50.80cm(length)
- Speed of cylinder : 2400 rpm (maximum)
- Overall dimensions : 2.43 m (length)
  1.02 m (width)
  2.13 m (height)
- Operated by : 9.2 hp petrol engine.

11 McCormick reaper

- Manufactured by : Imported one*
- Size of wheels : 0.80 m (with lugs)
- Length of cutter bar : 1.33 m
- Type of drive : Ground traction

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* The reaper was loaned from Agronomy Division, I.A.R.I. The original papers including operator's manual were not traceable as the reaper was imported long back.

APPENDIX C

(a) Lodging in experiments A and B

Sl. No.	Policy	Lodging, %			
		Experiment A		Experiment B	
		Actual figures (Avg.)	Angular transformations (Avg.)	Actual figures (Avg.)	Angular transformations (Avg.)
1	S - 1	56.9	49.23	0.30	5.05
2	S - 2	29.5	33.33	5.3	13.87
3	S - 3	53.4	47.21	0.5	5.73
4	S - 4	51.7	46.26	1.2	7.42
5	S - 5	46.5	43.23	20.6	27.38
6	S - 6	53.4	47.21	10.2	19.15
7	S - 7	50.0	45.30	5.2	13.87
	F-test at 5 %		N.S.		N.S.
	S.Em. ±		6.78		7.08
	C.D. at 5 %		-		-

(b) Pooled data analysis of lodging in experiments A and B

Experiment	Angular transformation	Percentage	S.Em.	C.D. at 5 %
Experiment A	44.55	48.7		
			± 2.56	7.45
Experiment B	13.21	4.7		

APPENDIX D

Method of calculation of the cost of operation

1 $Cu = \frac{Fc}{X} + Oc$

in which Cu = Unit cost of operation

Fc = Annual fixed cost, Rs/yr

X = Number of hours for which machine is used in a year

Oc = Operational cost, Rs/hr

2 Fixed cost per annum comprises the following :

(a) Depreciation (Rs/year) $= \frac{P - S}{L}$

in which P = Initial cost of a machine, Rs.

S = Salvage value, Rs.

L = Life in years

(b) Interest (Rs/year) $= \frac{(P + S)^{i}}{2}$

in which i = Annual rate of interest, per cent

(c) Insurance, Rs/yr = 0.01 P

(d) Taxes, Rs/yr = 0.02 P

(e) Housing, Rs/yr = 0.015 P

..... contd.

Appendix D contd.

3 Operational cost per hour comprises the following :

(a) Repair and maintenence per hour = 0.10 P/X

(b) Cost of fuel = Fuel consumption (l/hr) x Cost of fuel (per litre)

(c) Cost of oil and lubricants

(d) Wages of labour per hour

(i) skilled

(ii) non-skilled

4 Cost of power unit per hour :

(excluding items 3 b and 3 c)

5 Cost of operation of a machine per hectare

$$= \frac{\text{Unit cost of operation, Rs/hr}}{\text{Effective field capacity, ha/hr}}$$

APPENDIX E

Cost data about harvesting and threshing of wheat collected from different places

Sl. No.	Item	Places from where informations were collected						Estimates by Director, (Agr. Imp.), Min. of Food & Agri., New Delhi	Estimated cost/charges adopted for cost-calculations, if necessary
		Nazafgarh (Delhi)	Chhaprauli (Meerut Distt.)	Baraut (Meerut Distt.)	Gurusar (Faridkot Distt.)	Sirsa	Shahdara		
1	2	3	4	5	6	7	8	9	10
1	Hiring charges for a pair of bullocks of medium size (Rs/day)	30	15	14	30	50	25	20	20.50
2	Hiring charges for a tractor of 30-35 hp size (Rs/hr)	30	25	24	30	20	25	30	26.00
3	Hiring charges* for a Ludhiana type thresher (requiring 30-35 hp tractor); Rs/hr	5.00	2.25	1.00	6.00	6.00	6.00	9.0	5.00

Appendix E contd.

Appendix E contd.

1	2	3	4	5	6	7	8	9	10
4	Hiring charges for a combine, Rs/hr	-	-	375	-	-	-	350	375
5	Market price of <u>bhusa</u>, Rs/q								
	a. Animal threshed	30	30	30	18	25	25	-	26.00
	b. Machine threshed	25	27	27	16	20	20	-	22.00
6	Wages per day								
	a. Skilled labour	10	8	10	12	10	10	-	10.00
	b. Non-skilled labour	6	5	5	10	8	8	-	6.50
7	Cost of a pair of bullock, Rs	4000	3000	2500	-	3500	-	-	3250.00

* Hiring charges do not include the cost of operation of power unit.

APPENDIX F

Pooled data analysis of yield in experiments A and B

Sr. No.	Experiment	Yield without losses kg/plot
1	Experiment A	91.63
2	Experiment B	102.51
	F-test at 5 %	Sig.
	S.Em. ±	3.31
	C.D. at 5 %	9.62

Sr. No.	Policy	Yield without losses kg/plot
1	S - 1	88.70
2	S - 2	100.46
3	S - 3	102.90
4	S - 4	100.78
5	S - 5	92.70
6	S - 6	94.87
7	S - 7	99.08
	F-test at 5 %	N.S.
	S.Em. ±	5.73
	C.D. at 5 %	-

APPENDIX G

Pooled data analysis of losses in experiments A and B

Experiment	Total losses kg/plot	Cylinder loss kg/plot	Cutter bar loss kg/plot
1 Experiment A	17.79	1.65	2.09
2 Experiment B	17.14	1.56	0.86
F-test at 5 %	N.S.	N.S.	Sig.
S.Em. ±	0.229	0.07578	0.0822
C.D. at 5 %	-	-	0.24

Sr. No.	Policy	Cutter bar loss in experiment A kg/plot	Cutter bar loss in experiment B kg/plot
1	S-1	4.57	0.82
2	S-2	1.82	0.86
3	S-3	1.61	0.83
4	S-4	1.83	0.83
5	S-5	1.62	0.85
6	S-6	1.75	0.83
7	S-7	1.40	0.88
Interaction			
F-test at 5 %		Sig.	
S.Em. ±		0.22	
C.D. at 5 %		0.63	

APPENDIX H

Pooled data analysis of time-elements in operations in experiments A and B

S.No.	Experiment	Harvesting time min	Gathering, bundling and tying time min	Threshing time min	Total operational time min
1	Experiment A	64.44	49.56	43.28	210.01
2	Experiment B	65.77	52.20	41.66	215.09
	F-test at 5 %	N.S.	N.S.	N.S.	N.S.
	S.Em. ±	4.712	2.644	3.019	5.542
	C.D. at 5 %	-	-	-	-

APPENDIX J

Details about the workers employed in the harvesting and threshing operations

Sl. No.	Name of the worker	Age yr.	Weight kg	Education	Training	Experience yr.
1	Ram Shreshtha Pandit	25	66.40	Metric	-	4*
2	Kamal Poddar	24	46.60	IV pass	-	5*
3	Shiva Bhajan	23	47.50	V pass	-	3*
4	Swami Nath	23	52.50	VII pass	-	4*
5	Surinder Singh	27	46.00	IV pass	-	4½*
6	Om Prakash	25	61.00	III pass	-	4*
7	Hoshiar Singh	33	48.00	III pass	-	4*
8	Harpal Singh	27	52.50	Illt.	-	9*
9	Mata Badal	24	42.50	Illt.	-	3*
10	Dayanand	40	45.00	Illt.	3 day training in combine harvest	7*
11	Balwant Singh	45	62.00	VII Pass	Army tech. training	20*
12	Man Singh	55	64.8	Illt.	-	20*
13	Md. Ainul	29	50.5	I pass	-	4*
14	Maha Singh	28	58.0	VI	-	4*
15	Arjun Singh	24	57.0	VII pass	-	7*
16	Prabhu	38	54.5	IV pass	Driver's licence	10**
17	Deep Chand	39	55.8	Literate	-	14**
18	Raghubir Singh	38	52.0	V pass	Driver's licence	11**

* Non-skilled worker ** Skilled labour

APPENDIX K

Systems, specifications and machines used in different policies of harvesting and threshing operations

Sr. No.	Policy	Plot no. in experiment A	Date of machine use	Plot no. in experiment B	Date of machine use*	Machine/tool used to complete operation of harvesting and threshing
1	S-1	A/S-1/a,b,c	15.4.75	B/S-1/a,b,c	5.5.75	MF 1035 tractor + Vicon combine + tractor trolley
2	S-2	A/S-2/a,b,c	R: 16.4.75 P: 18.4.75 & 19.4.75	B/S-2/a,b,c	R: 6.5.75 P: 24.5.75	Zetor 2011 tractor + reaper + tractor trolley + Pullman thresher
3	S-3	A/S-3/a,b,c	R: 17.4.75 L: 23.4.75	B/S-3/a,b,c	R: 6.5.75 L: 23.5.75	Zetor 2011 tractor + Reaper + tractor trolley + MF 1035 tractor + Ludhiana thresher
4	S-4	A/S-4/a,b,c	R: 18.4.75 D: 23.4.75	B/S-4/a,b,c	R: 6.5.75 D: 23.5.75	Zetor 2011 tractor + reaper + tractor trolley + drummy thresher with elect. motor + winnowing fan
5	S-5	A/S-5/a,b,c	S: 22.4.75 L: 27.4.75	B/S-5/a,b,c	S: 8.5.75 L: 22.5.75	Sickle harvesting + tractor trolley + Ludhiana thresher + Tractor MF 1035
6	S-6	A/S-6/a,b,c	S: 23.4.75 D: 30.4.75	B/S-6/a,b,c	S: 8.5.75 D: 20.5.75	Sickle harvesting + tractor trolley + drummy thresher with elect. motor + winnowing fan
7	S-7	A/S-7/a,b,c	S: 25.4.75 O: 28.4.75,& 29.4.75	B/S-7/a,b,c	S: 9.5.75 O: 14.5.75, 15.5.75,& 16.5.75	Sickle harvesting + tractor trolley + olpod thresher operated by bullocks + winnowing fan

Note: R, P, L, D and O indicate respectively, reaper, pullman thresher, Ludhiana type thresher, drummy thresher and olpod thresher.

APPENDIX L

Extract from Indian Minimum Seed Certification Standards prepared and published by the Central Seed Committee, Deptt. of Agri., Ministry of Food, Agriculture, Community Development and Cooperation, New Delhi - March, 1971 and corrected upto date.

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Minimum seed certification standards for wheat (Triticum spp.)

Seed Standards

Factor	Standards for each class	
	Foundation	Certified
Pure seed (Minimum)	98.0 %	98.0 %
Inhert matter (Maximum)	2.0 %	2.0 %
Other crop seeds (Maximum)	10/kg	0.10 %
*Objectionable weed seeds (Maximum)	2/kg	5/kg
Nematode gatts of tundu/ earcockle or seeds infected by Karnal bunt (maximum)	0.10 % (by number)	0.50 %
Germination (minimum)		
Barley, oats and wheat	85 %	85 %
paddy	80 %	80 %
Moisture (maximum)	12.0 %	12.0 %
For vapour-proof containers (maximum)	8.0 %	8.0 %

* Objectionable weeds are the same as given at IV.B above

APPENDIX M

Economics of different crop rotations in multiple cropping*

Rotations	Expenditure Rs/ha	Income Rs/ha		Profit %
		Gross	Nett	
Maize - Potato - Wheat - Moong	7,872	17,933	10,061	128
Maize - Potato - Wheat - Cowpeas	7,295	17,759	10,464	143
Maize - Wheat - Moong	3,359	6,366	3,007	89
Maize - Wheat	2,784	5,532	2,748	99
Maize - Toria - Wheat	3,327	4,277	950	29

* Adopted from : Economics of Regional Practices in Multiple Cropping by Sandhu _et al_. (1973).

APPENDIX N

Cost of operation of individual policies in rupees per quintal

Sr. No.	Policy	Grain-output (after deducting losses) q/ha	Cost of operation Rs/ha	Cost of operation per quintal[1] Rs
1	S - 1	38.07	407.15	10.69
2	S - 2	38.79	2074.86	53.49
3	S - 3	39.84	653.01	16.39
4	S - 4	37.75	455.32	12.06
5	S - 5	35.97	639.68	17.78
6	S - 6	36.36	472.38	12.99
7	S - 7	38.65	1012.06	26.18

[1]Note: The cost of bhusa has not been taken into account in calculating the cost of operation per qunital.