HARVEST AND POST HARVEST LOSSES OF MAJOR CROPS AND LIVESTOCK PRODUCE IN INDIA

S.K. Nanda
R.K. Vishwakarma
H.V.L. Bathla
Anil Rai
P. Chandra

All India Coordinated Research Project on Post Harvest Technology (ICAR)

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S. K. Nanda
Project Coordinator, AICRP on Post Harvest Technology (ICAR)
CIPHET, Ludhiana

R. K. Vishwakarma
Scientist, Central Institute of Post Harvest Engineering and Technology, Ludhiana

H.V.L. Bathla
Rtd Head (Sample Survey Division),
Indian Agricultural Statistics Research Institute, New Delhi

Anil Rai
Head (Bio-Informatics Division),
Indian Agricultural Statistics Research Institute, New Delhi

P. Chandra
Director, Central Institute of Agricultural Engineering, Bhopal

All India Coordinated Research Project on Post Harvest Technology
(Indian Council of Agricultural Research)

First Printed : September 2012

Citation :

Nanda, SK, RK Vishwakarma, HVL Bathla, A Rai and P Chandra (2012). Harvest and Post Harvest Losses of Major Crops and Livestock Produce in India. All India Coordinated Research Project on Post Harvest Technology, (ICAR), Ludhiana.

Published by :

Dr. S. K. Nanda

Project Coordinator, AICRP on PHT (ICAR),

CIPHET, P.O. PAU, Ludhiana - 141 004, India

Phone : +91-161-2308672

E-mail : pcpht2012@yahoo.com, sk_nanda4578@sify.com

Type set by :

Ms. Sunita Rana, AICRP on PHT

Printed at :

M/s Ashok Printers

3801/1, Pritam Nagar, Model Town, Ludhiana (India).

डा. एस. अय्यप्पन
सचिव एवं महानिदेशक
Dr. S. AYYAPPAN
SECRETARY & DIRECTOR GENERAL

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि मंत्रालय, कृषि भवन, नई दिल्ली 110 114
GOVERNMENT OF INDIA
DEPARTMENT OF AGRICULTURAL RESEARCH & EDUCATION
AND
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
MINISTRY OF AGRICULTURE, KRISHI BHAVAN, NEW DELHI 110 114
Tel.: 23382629, 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

FOREWORD

Post harvest losses in food production to consumption value chain have been a cause of great concern in enhancing the food availability for domestic as well as export purposes. While studies in ICAR have been going on to develop suitable technologies to minimize the post harvest losses, the extent of such post harvest losses has been a matter of conjecture. The Council, therefore, instituted a study to obtain reliable estimates of post harvest losses for major food produce on all India basis.

It is for the first time in the country that such a comprehensive study has been carried out utilizing the most appropriate methodologies. The results of this study have been helpful in identifying the critical on-farm operations as well as storage and handling operations where losses are high for the selected crops and commodities. The study has also clearly brought out the commodities where post harvest loss minimization efforts need to be made on priority.

I congratulate the large number of scientists, research managers and field workers who carried out this, much needed, effort. I also greatly appreciate the inputs from a large spectrum of professionals and policy makes at the stage of finalizing the report. I hope the report is well received both in spirit and content.

(S. Ayyappan)

Dated the 3rd September, 2010
New Delhi

PREFACE

Profitability is at the core of the issues related to the growth and sustainability of Indian agriculture. Globalization of economy and dismantling of geographical barriers to trade have necessitated that agriculture be competitive. Therefore, agricultural production and post harvest operations need to be critically examined and inefficiencies weeded out. Losses in post harvest operations have been significantly reducing the farm profitability and food availability. Since no authentic estimates at national level were available, a comprehensive study was instituted by the ICAR to gain the first hand Information on the reasons and the extent of such post harvest losses.

The study has been a joint effort between the All India Coordinated Research Project on Post Harvest Technology and Indian Agricultural Statistics Research Institute (IASRI), New Delhi. Considering that the study was needed to be carried out on all India basis, stratified multilevel sampling technique was adopted. They study included both crops, full cropping cycle was targeted to collect data. On-farm operations and subsequent transport and storage in various channels in unorganized sector formed the base for the study. Minimization of losses in these operations should directly benefit the farmers and rural entrepreneurs.

The methodology and the results were critically examine by a committee of experts chaired by Dr. A. Alam, Ex-Vice Chancellor, SKUAST, Srinagar. The study has been duly scrutinized by different Subject Matter Divisions of ICAR. A presentation was made to Secretary, DARE & DG, ICAR on June 06, 2010 before the report was finally presented to the Parliamentary Standing Committee on Agriculture on June 10, 2010. Subsequently, the results of the study have been shared in a meeting of secretaries of Department of Agriculture and Cooperation, Department of agriculture Research and Education, representatives of Food Corporation of India, Central warehousing Cooperation on July 13, 2010 and the meeting of Directors of ICAR institutes on July 16, 2010. Clearly the study has been discussed extensively and intensively. The study report in its present form has the suggestions of all the interactions incorporated.

Being the first effort of its own kind, there are several concerns that could not be addressed. Post harvest losses take place due to weather aberrations in isolated locations could not be included. Then post harvest losses occur on account of market gluts and the study did not account for such situations. Dearth of storage facilities, proper handling or transport also lead to post harvest loses. Such losses are highly variable in time and space coordinates ad therefore, did not form a component of the present study. Specialized efforts would need to be instituted for taking them into consideration.

The results of studies being reported here shall help in prioritizing the R & D agenda, determining the impact of technological and policy interventions as well as developing suitable policy framework. It is in this context that the report needs to be shared with all stakeholders. We at ICAR have begun in focus our efforts towards developing suitable post harvest technologies for minimization of the losses. We also intend to continue refining our loss assessment methodology and periodically carry out such studies to ascertain the extent of impact that the interventions have made.

The authors of the report and the whole team of workers from all courses of AICRP on PHT and IASRI, who have made it possible to bench mark the post harvest losses for major crops and livestock produce in the country, deserve appreciation.

(M.M. Pandey)
Dy.Director General (Engg.)
ICAR, New Delhi.

New Delhi
September 03, 2010

ACKNOWLEDGEMENTS

We express our sincere gratitude to Dr. Mangala Rai, the-then Secretary, DARE & Director General, ICAR for entrusting this responsibility of conducting the nation-wide study of post harvest losses to AICRP on PHT and also for providing the necessary budgetary grants and institutional support at every stage.

We express our indebtedness to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR whose catalytic role and encouragement has led to the completion of this report.

We are grateful to Dr M. M. Pandey, Deputy Director General (Engg) and Dr. Nawab Ali, ex-DDG (Engg) for providing the leadership and support for bringing this study to its logical conclusion.

Thanks are due to Dr. Anwar Alam, ex-Vice Chancellor, SKUAST, Srinagar and Chairman of the Expert Committee on Post Harvest Losses and all its esteemed members who critically examined the results and provided vital guidance in methodology and interpretation of the results. In this regard, Dr S.M. Ilyas, Ex-Director, NAARM, Hyderabad, who initiated this study during his tenure as PC (PHT), and Dr R.T. Patil, ex-Director, CIPHET, Ludhiana deserve our special thanks for their keen interest, involvement and contributions to this study. Suggestions received from Dr. N.P.S. Sirohi, ADG (Engg) and Dr. K. K. Singh, ADG (Process Engg), ICAR during the finishing stages of this report are gratefully acknowledged. Thanks are also due to Dr. Satish Bal, Professor Emeritus, IIT, Kharagpur & Chairman, QRT during the study period and its members for reviewing the progress of the study at different centres and providing valuable guidance. Assistance and encouragement received from Prof. U.S. Shivhare, Director, CIPHET, Ludhiana during the printing and publishing phase of this study is gratefully acknowledged.

Thanks are also due to all the Vice-Chancellors and Directors of the cooperating centres of AICRP on PHT for their inspiring support. Our sincere appreciations are due to all the Research Engineers/PIs and the Field Investigators who toiled hard to collect the data at field level as well as to the Director and staff of Indian Agricultural Statistics Research, New Delhi who helped in analyzing the data and making this study successful.

Authors wish to place on record their gratitude and thankfulness to the Hon'ble Speaker, Lok Sabha (India) for granting permission to use the data contained in the report *Estimation of harvest and post harvest losses of major crops and livestock produce in India* originally submitted to the Parliamentary Standing Committee on Agriculture (PSCA) in September 2010 by the Council.

S.K. Nanda
R.K. Vishwakarma
H.V.L. Bathla
Anil Rai
Pitam Chandra

September 2012

LIST OF CONTRIBUTORS

Dr. P.A. Borkar
Research Engineer, AICRP on PHT
PDKV Akola

Dr. B. Ranganna
Ex-Research Engineer, AICRP on PHT
UAS Bangalore

Dr. Sivala Kumar
Ex -Research Engineer, AICRP on PHT
ANGRAU Bapatla

Dr. Ch.V. V. Satyanarayanana
Ex -Research Engineer, AICRP on PHT
ANGRAU Bapatla

Dr. K. K. Singh
Ex-Research Engineer, AICRP on PHT
CIAE Bhopal

Dr. Nachiket Kotwaliwale
Research Engineer, AICRP on PHT
CIAE Bhopal

Dr. Md. Khalid Khan
Ex-Research Engineer, AICRP on PHT
OUAT Bhubaneshwar

Dr. R. Viswanathan
Research Engineer, AICRP on PHT
TNAU Coimbatore

Dr. Kaushal Kumar
Ex-Research Engineer, AICRP on PHT
NDUAT Faizabad

Dr. P.K.Malviya
Research Engineer, AICRP on PHT
CAZRI Jodhpur

Dr. S. Patel
Research Engineer, AICRP on PHT
IGKVV Raipur

Dr. Ajay Verma
Ex-Research Engineer, AICRP on PHT
IGKVV Raipur

Dr. M. A. Mir
Ex-PI, AICRP on PHT
SKUAST Srinagar

Dr. K. P. Singh
Ex-Research Engineer, AICRP on PHT
VPKAS Almora

Dr. M. K. Garg
Ex-Research Engineer, AICRP on PHT
HAU Hisar

Dr. (Mrs.) S. M. Mathew
Research Engineer, AICRP on PHT
KAU Tavanur

Dr. P. C. Sharma,
Research Engineer, AICRP on PHT
YSPUH&F Nauni, Solan

Dr. Robinson J. J. Abraham
PI, AICRP on PHT
TANVASU Chennai

Dr. Karan Singh
Ex-Research Engineer, AICRP on PHT
RAU Jaipur

Dr. Abhijit Borah
Research Engineer, AICRP on PHT
AAU Jorhat

Dr. R. N. Borpuzari
PI, AICRP on PHT
AAU Khanapara

Dr. K. K. Jain
Ex -Research Engineer, AICRP on PHT
JAU Junagadh

Er. K. Madhavan
Ex -Research Engineer, AICRP on PHT
CPCRI Kasargod

Dr. S. L. Srivastava
Research Engineer, AICRP on PHT
IIT Kharagpur

Prof. V. K. Sehgal
Rtd. Sr. Research Engineer, AICRP on PHT
PAU Ludhiana

Dr. (Mrs.) Anupama Singh
Ex -PI, AICRP on PHT
GBPUAT Pantnagar

Dr. P.K. Omre
Research Engineer, AICRP on PHT
GBPUAT Pantnagar

Dr. Mukesh Shrivastava
Research Engineer, AICRP on PHT
RAU Pusa

Dr. M. S. Sajeev
Research Engineer, AICRP on PHT
CTCRI Trivandrum

Dr. N. K. Jain
Research Engineer, AICRP on PHT
MPUAT Udaipur

Dr. D. P. Darmora
Ex -Research Engineer, AICRP on PHT
RAU Jaipur

Dr. K. C. Dora
Ex-PI, AICRP on PHT
WBUA&FS Kolkata

Dr. Udaya Kumar Nidoni
Research Engineer, AICRP on PHT
UAS Raichur

Dr. Sharan Kumar Hiregaudar
Research Engineer, AICRP on PHT
UAS Raichur

Dr. D. S. Patil
Ex -PI, AICRP on PHT
RS&JRS Kolhapur

Dr. Jaswant Singh
Research Engineer, AICRP on PHT
IISR Lucknow

Dr. D. D. Singha
Research Engineer, AICRP on PHT
SRS Buralikson

Dr. S. Ramakrishna Rao
Ex -PI, AICRP on PHT
RARS Anakapalle

Dr. Tauqueer Ahmad
Sr. Scientist
IASRI New Delhi

Dr. K. K. Chaturvedi
Scientist
IASRI New Delhi

Dr. Man Singh
Technical Officer
IASRI New Delhi

Sh. G. M. Pathak
Technical Officer
IASRI New Delhi

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1

INTRODUCTION

Food security has been the fundamental concern of the mankind over the millennia. Agriculture, including animal husbandry and fisheries, is the predominant provider of food, feed and fibre. Under the constraint of growing population and nearly constant net sown area, the need for increasing food production has to be met through increasing productivity and more intensive cropping in order to attain food security. In this context, reducing production and post-production losses, or preserving what has been produced, has become inevitable.

During production, agricultural crops require protection in the field from pests, diseases and natural calamities. After production, the agricultural crops and commodities undergo a series of operations (such as harvesting, sorting/grading, processing, packaging, transportation, and storage) before reaching the consumer or the end user. Loss of agricultural produce at these stages of harvesting, post harvest handling, processing and storage has been a matter of great concern. Minimization of these losses could be a significant means to increase the food availability.

Information on the extent of losses during the post harvest operations is important to the scientists and policymakers to work out research programmes and strategies to curtail these losses and to help ensuring food security.

A large number of studies on the extent of harvest and post harvest losses have appeared in literature. Many of these studies are limited to either laboratory-scale, one group of crops, or limited geographical area. These studies adopted diverse procedures and, therefore are not comparable. However, some of the studies on estimation of post harvest losses conducted in the past could serve, at best, as indicators of post harvest losses at national level, especially for food grains.

In early sixties, Government of India appointed a committee under the chairmanship of Dr. V.G. Panse, the-then Director of Indian Agricultural Statistics Research Institute, New Delhi, to assess the post harvest losses of food grains. This was the first study of its kind at the national level in India. The committee collected considerable information on the magnitude of losses from various government agencies, research institutions, etc.

The importance of a uniform and systematic methodology for generating reliable data had prompted the FAO to come out with a manual on 'Assessment and Collection of Data on Post Harvest Food Grain Losses' in 1980 for the benefit of developing countries. The manual provided detailed methodology for data collection on the extent of post harvest losses of cereals based on actual observations in the field.

Directorate of Marketing and Inspections (DMI), Ministry of Agriculture, Government of India, had conducted a large-scale sample survey for estimation of marketable surplus and post harvest losses of food grains in 1996-97. The study covered 25 states, 100 selected districts and 15,000 cultivator households in the country in respect of paddy, wheat, sorghum, bajra, maize, barley, ragi, pigeon pea, chickpea, black gram, green gram and lentil. Stratified multi stage random sampling design was adopted for estimating the losses in different farm operations and storage. The study was based on the data collected by enquiry only. Also, some important operations (such as harvest, and market channels, etc.) were not covered in this survey. However, this report provided fairly good estimates of losses in the operations and channels covered for cereals and pulses.

India ranks second in the world in the production of fruits as well as vegetables with 75.8 and 137.7 million tonnes (2010-11), respectively. Horticultural crops are essential for nutritionally balanced diet, being good sources for vitamins, minerals and anti-oxidants. Most of the loss estimation studies have focused mainly on the durable food grains because of their prominence in the daily diet. However, the perishables crops, because of their high moisture content, are inherently more susceptible to deterioration, especially, under hot and humid tropical conditions. Factors affecting post-harvest food losses of perishables vary widely from place to place and become more and more complex as systems of marketing become more multifaceted. A farmer who is growing fruits for consumption by his family probably doesn't mind if his produce has a few blemishes and bruises. If he is producing for a market at any distance from his own locality, however, he must adopt preventive measures to get the best monetary returns for his efforts.

Fishery sector provides significant employment and adds to the national food supply. Inland fish is an important source of affordable and nutritious protein. Inland fish production in India is 3.8 million tonnes (2006-07), making India the second largest producer of inland fish, next only to China. In case of inland fishery sector, harvest and post harvest losses occur mainly due to discards of small fish, improper handling immediately after catch, insufficient icing, inefficient containers used for transportation of fish, delays in transport, physical damage and bio-chemical changes. A good deal of loss occurs in case of live fish transportation. Efficient utilization of fish resources by reducing post-harvest losses has been of prime concern in recent years as global production falls short of growing demand.

Marine fish landings were 3.0 million tonnes during 2006-07. There are appreciable losses at various levels in the production-distribution system. Harvest losses occur onboard the fishing crafts mainly in the form of discards of juveniles and low value fish and post harvest losses occur due to lack of infrastructure at different points, starting from the landing centre to the consumer, and improper handling.

Poultry production in India has emerged from a backyard activity to rapidly expanding commercial agri-business over the last three decades. The annual egg and poultry meat productions have touched about 63 billion no. and 2.2 million tonnes, respectively (2010-11). Despite cyclic boom and bust arising from

uncontrolled production, inadequate processing, lack of cold-chain and disorganized marketing, the layer and broiler sectors of Indian poultry industry have been growing with an average annual growth rate of 5% and 15%, respectively over the last decade. However, despite these spectacular developments, the per-capita annual availability of both egg (50 eggs) and poultry meat (1.5 kg) in India is still very low. Due to regional imbalance in production, both egg and live/dressed chicken are transported from surplus production areas to deficit regions of the country, resulting in appreciable losses due to egg shell damage, live weight shrinkage, mortality, downgrading of chicken carcasses resulting from bruises and injury as well as spoilage. This results not only in huge economic losses but also loss of valuable nutritious food. The magnitude of such losses in egg and poultry meat has been extensively studied in some industrialized countries but no such systematic study has been carried out in India.

Milk production in India is the highest in the world (127 million tonnes in 2011-12). It is a highly perishable commodity produced mostly in small quantities, scattered and dispersed over remote rural areas. It is produced twice a day without chilling facilities at the farmers' gate. A large network of milk marketing agencies is engaged in the organized and unorganized sectors trying to transfer milk without deterioration to the very large number of distant urban consumers.

There are various production and post-production stages of operations through which milk passes to reach the consumers. These are milk production, procurement, processing, and transportation of processed or unprocessed milk to the market, milk distribution/sale and ultimately milk consumption. There are losses at every stage of milk handling. Ascertaining extent of milk losses at every stage of milk handling operations is, therefore, of great importance.

Based on available data from dispersed reports of post harvest losses, the estimated economic value of post harvest losses from all agricultural produce was reported at the national level to be about Rs 51,500 crores per annum in 2005. The estimated value is expected to have escalated since then in proportion to increasing agricultural production and rising prices, causing concern to post harvest technologists and policymakers. However, these estimates may not reflect the correct scenario of extent of losses at the national level.

Nevertheless, due to the enormity of the post harvest losses, the Parliamentary Standing Committee on Agriculture (PSCA) urged the Indian Council of Agricultural Research to take up the task of collecting authentic data on post harvest losses of agrarian and allied sector produces on all India bases (Appendix I). Accordingly, the All India Coordinated Research Project on Post Harvest Technology (AICRP on PHT) carried out the task of assessment of post harvest losses of all major crops and commodities at national level.

The study was undertaken to carry out a systematic quantitative assessment of the extent of harvest and post harvest losses with the following specific objectives:

1. To evolve necessary methodology and measurement techniques for a systematic quantitative assessment of the extent of harvest and post harvest losses (viz. schedules for all crops and livestock produce selected for collection of data by enquiry and by observation, suitable software

for computerized data entry, and statistical procedure to give a single estimate from the two sets of data collected through enquiry and observation).

2. To estimate the losses in harvesting, all post harvest on-farm operations, transportation from farm to the next destination and storage at various points in marketing channels for all major crops (cereals, millets, pulses, oilseeds, fruits, vegetables, plantation crops, and spices and condiments) as well as livestock produce (meat, fish, egg and milk) at the national level covering all agro-climatic zones.

3. To identify the specific crop / commodity as well as the specific unit operations inducing significant losses in order to prioritize the points of remedial intervention.

The data collection was undertaken by different centres of AICRP on PHT in a nation-wide concurrent survey conducted during October 2005 to February 2007. Results of the work carried out towards the estimation of post harvest losses are summarized in this document.

2

OVERVIEW OF POST HARVEST LOSSES AND THEIR ASSESSMENT

Reduction of pre-harvest, harvest and post-harvest losses is indeed a complementary means of increasing the food availability. Minimization of post harvest losses has been a matter of concern to research workers and government agencies alike. Thus, a large number of studies on assessing post harvest losses and identifying farm operations and channels affecting these losses can be found in various journals and reports. Many of these studies deal with laboratory scale experiments and are limited to one or more crops/commodities, or locations. Entomological storage studies are not particularly relevant to estimation of post harvest losses since the sampling and experimental designs are study-specific and do not provide the actual extent of damage done by the insects in the field conditions of storage. The present review is limited to the studies of greater relevance in the context of the national post harvest loss scenario.

2.1 Data Collection Procedures and Methodology for Assessment

It is important that the methods adopted for assessment of loss over a number of operations in a large population should yield standardized results. Appropriate sampling procedure, data collection and loss measurement techniques are prerequisites for reliable results; and their uniformity may help in comparing the results from different studies.

The Indian Agricultural Statistics Research Institute, New Delhi, conducted a pilot methodological survey in 1973-74 (IASRI, 1975) in one district, namely Aligarh (India), to study food grain losses in storage under the farmers' conditions. In this survey 24 clusters of villages were selected from 6 community development blocks and in each cluster the data of food grains stored, losses and causes of losses were collected from 6 randomly selected cultivators during fortnightly visits. The results of this survey provided considerable information of methodological interests for estimating losses in storage through method of random sample surveys.

The report of 'Post-harvest Grain Losses Assessment Methods' published by the American Association of Cereals Chemists (1978) has dealt with assessment problems in detail, touching almost all the aspects of post harvest food grain losses. The statistical approach has been mentioned in brief including the concepts, definitions and measurements for adoption in the studies to be made in different countries in future with necessary modifications according to local conditions.

The seriousness of the diverse procedural problem of measuring post harvest food grain losses prompted the FAO (1980) to come out with a manual on "Assessment and Collection of Data on Post Harvest Food Grain Losses", and published for the benefit of developing and underdeveloped countries. The manual was prepared with an aim to study the extent of post harvest losses of cereals based on actual observations in the field. This manual provides detailed methodology for data collection on losses in different operations and channels. However, the manual is applicable for the estimation of losses of food grains only.

Diwakar et al. (1983) suggested a methodology for the estimation of losses in food grains caused by the rats. Narain and Khosla (1984) discussed the methodological aspects of estimating food grain losses at different post-harvest stages at farm, intermediary and warehouse levels. Ali (1983) proposed a methodology for assessing storage loss of durable commodities based on clearly defined objectives, reproducible methods, and representativeness of sampling.

Bathla et al. (2005) conducted a pilot level sample survey in one district (Karnal) to develop methodology for estimation of harvest and post harvest losses of milk, meat, poultry meat, egg, inland fish and marine fish. Wanjari et al. (2005) conducted a pilot sample survey to develop methodology for data collection by observation for estimating post harvest losses of five oilseeds, namely mustard, soybean, cottonseed, sunflower and groundnut. In a survey conducted during 2003-04 under a NATP project in Junagarh district of Gujarat, the quantitative post harvest loss in different farm operations (harvesting, handling and threshing stages) and channels (storage at household, market, oil mill and godown levels) were recorded by enquiry as well as by actual observations (Vishwakarma et al., 2007).

2.2 Post Harvest Losses of Durables

Panse committee (1968) estimated the losses, averaged over three years (1962-63, 1963-64 and 1964-65) for the food grains (Table 2.1). This was the first effort to ascertain the post harvest losses at national level in India.

Table 2.1 : Estimates of food grain losses at different post harvest stages,%

Stage at which the loss occurred	Wheat	Paddy	Sorghum	Bajra	Maize	Gram	Millet	Pulses (excluding Gram)
Threshing yard	1.0	2.5	2.0	0.5	0.5	0.5	1.0	0.5
Transport	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Processing	-	2.0	-	-	-	-	-	-
Storage	6.5	6.0	7.5	5.0	6.5	8.5	5.5	8.5

Majumdar and Parpia (1967) gave estimates of losses in different countries referring to the Research Industry Conference report held at CFTRI, Mysore, in 1965. In this report the extent of losses in all food grains was estimated to be 50% (comprising 25% field loss, 15% storage loss, 7% handling and processing loss and 3% other losses).

Mookherjee et al. (1968) estimated the losses due to insects during storage of cereals (paddy, wheat, maize, barley, sorghum, and bajra) for different zones of the country. However, the estimates were based on limited data. Krishnamurthy (1968) reported the storage loss of food grains in different organisations. Food Corporation of India estimated a loss of about 0.2% during storage whereas cooperative organisations estimated the loss as 1-3% and warehousing corporations as 1%. In rural level storage, 2.0 to 9.5% loss was estimated due to insects in wheat. These estimates were based on the reports of various organisations.

The Committee on post harvest losses of food grains in India (1971) reported losses during transportation and storage for the period from 1962-63 to 1968-69. The storage loss of wheat varied from 0.26% in 1964-65 to 0.074% in 1968-69; whereas the transportation loss of wheat varied from 0.75% in 1962-63 to 0.17% in 1966-67.

A Seminar on 'Post-harvest Technology of Food Grains', sponsored by the Indian National Science Academy (INSA), Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR) and Food Corporation of India (FCI), held at New Delhi in December 1972 (Pingle et al., 1972), addressed the problems of losses in harvesting, drying, processing, storage, transport, etc., with respect to cereals and pulses. Prof. B.R. Seshachar, President, INSA, stated that about 10 million tonnes of food grains were lost annually during the process of drying, transportation, storage and distribution.

Srivastava et al. (1973) reported weight loss due to damage by insects in villages to the extent of 9.7% and kernel damage to the tune of 30.1%. Girish et al. (1974) observed farm storage loss of wheat in different regions of Uttar Pradesh ranging from 0.6 to 9.7%.

Girish and Krishnamurthy (1974) reviewed the extent of losses owing to different causes such as insect pests, diseases, storage systems, birds and rats for different periods of storage. They indicated that the methods of assessment of losses were not uniform and, hence, these losses were not comparable. They also suggested that the assessment of losses from farm storage, markets, large-scale storage, should be made by random sampling techniques.

Krishnamurthy (1975) reviewed the work done regarding post-harvest losses in food grains in India and abroad. He reported that the Food Corporation of India estimated the losses of food grains in rail transit at about one per cent during 1970-71. These estimates of losses were mainly based on small-scale studies. He also assessed the loss in commercial storage of food grains as 3 to 5% when storage was for 8 months and around one per cent when the storage was up to 4 months. In underground structures the loss was 6 to 10 per cent. He observed that a loss of 3% was due to use of hooks, 0.1 to 0.2% due to spillage, and 0.5% due to loss of moisture in general during storage.

Girish et al. (1975) found the average loss of wheat due to insect damage as 2.90, 0.85 and 0.95% after 7 months of storage in grain markets of western UP, Punjab and Haryana, respectively.

A supporting study on Post-harvest Grains Losses (1976) of the main study "All India Grains Storage and Distribution" prepared by the Administrative Staff College of India presented a review of 170 studies on post-harvest grain losses. Results were obtained from surveys in two regions, Punjab (Ludhiana district) and Andhra Pradesh (West Godavari and Medak districts) on wheat and maize, respectively. The stratified random sampling technique was adopted in these two regions. Stages of losses, measurement of grain losses at farm storage, trade and market level storage, public storage, transportation loss and loss in processing were considered in the supporting study.

FAO (1977) prepared a manual summarizing the reports regarding the post-harvest crop losses in the developing countries. In this manual, losses in cereals, fruits vegetables, animal products and fish products have been covered.

Directorate of Marketing and Inspections (DMI), Department of Agriculture, Government of India in 1972-73, conducted a large-scale sample survey for estimation of marketable surplus and post harvest losses of food grains. Subsequently, a similar study was conducted by DMI in 1997-99 for paddy, wheat, sorghum, bajra, maize, barley, ragi, pigeon pea, chickpea, black gram, green gram and lentil. This study covered 25 States, 100 selected districts and 15,000 cultivator households in the country with adoption of stratified multi stage random sampling design. The estimates of losses in different farm operations and storage are given in Table 2.2.

Table 2.2 : Estimates of food grain losses (%) at different post harvest stages

S. No	Crop	Operation					
		Threshing	Winnowing	Transport (From field to threshing floor)	Transport (From threshing floor to store)	Storage	Total
1	Paddy	0.89	0.48	0.79	0.16	0.40	2.71
2	Wheat	0.73	0.28	0.49	0.13	0.16	1.79
3	Bajra	0.62	0.32	0.54	0.19	0.22	1.89
4	Sorghum	0.65	0.32	0.68	0.21	0.34	2.20
5	Maize	0.80	0.53	0.58	0.19	0.35	2.45
6	Barley	0.70	0.27	0.57	0.28	0.34	2.16
7	Ragi	0.77	0.76	0.62	1.13	0.53	3.81
8	Pigeon pea	0.61	0.43	0.58	0.23	0.35	2.20
9	Chickpea	0.77	0.78	0.81	0.82	0.56	3.74
10	Green gram	0.63	0.61	0.67	0.19	0.29	2.38
11	Black gram	0.65	0.62	0.70	0.19	0.30	2.46
12	Lentil	2.21	1.01	2.20	1.08	0.64	7.14

Source : DMI (2002). Report of the survey of marketable surplus and post harvest losses of paddy in India (1997-99). Department of Agriculture and Cooperation, Government of India, New Delhi

The estimates of post harvest losses of the DMI survey were based on the data collected by enquiry only. Some important operations (such as harvest, market channels, etc.) were not covered in this survey. However, this report provided fairly good estimates of losses in cereals and pulses. Basappa et al (2007) conducted a study during 2003-2004 in Karnataka for estimating post harvest losses in maize in different farm level operations. The post harvest loss at farm level was estimated to be 3.02%. The losses during harvest, threshing, cleaning, drying, packaging, transportation and storage at farm level were 0.46%, 0.18, 0.05, 0.21, 0.08, 0.21 and 0.33%, respectively. Basavaraja et al. (2007) estimated post-harvest losses at different stages of rice and wheat in India based on the data collected from one district for each crop in Karnataka. The data was collected by enquiry from 100 farmers, 20 wholesalers, 20 processors and 20 retailers in each crop for the year 2003-04. The estimated post-harvest losses are as given in Table 2.3.

Table 2.3 : Post harvest losses of rice and wheat

Stages	Loss (%) in rice	Loss (%) in wheat
Harvesting	0.40	0.36
Threshing	0.52	0.44
Cleaning/Winnowing	0.20	0.14
Drying	0.80	0.66
Packaging	0.20	0.22
Transportation	0.50	0.51
Storage	1.20	0.95
Total losses at farm level	3.82	3.28
Total losses at wholesale level	0.29	0.20
Total losses at processor level	0.03	0.03
Total losses at retailer level	1.06	0.82
Total post-harvest losses	5.19	4.32

In a survey conducted during 2003-04 under National Agricultural Technology Project in Junagadh district of Gujarat for groundnut, losses at harvest, handling and threshing stages were estimated to be 3.72, 2.44 and 2.08%, respectively, by enquiry whereas the losses of 1.57, 0.00 and 0.47% were estimated by observation (Vishwakarma et al., 2007). Losses of 0.59 and 0.44% were observed in bulk and bag storage systems at farm level. At intermediary level, loss of 1.86% was estimated by enquiry and the loss was 2.90% by observation. In oil mill storage, loss of 3.93% was found by enquiry whereas the loss was 1.78% by observation.

2.3 Post Harvest Losses in Perishables

The programmes committed towards assessment and prevention of food losses at national as well as international levels have focused mainly on the durables, i.e., food grains because of their prominence in daily diet. However, the perishable crops, because of their high moisture content, are inherently more liable to deterioration, especially, under tropical conditions. Attempts have been made to estimate harvest and post harvest losses of perishables such as fruits, vegetables, sugarcane, etc. at regional levels.

Fruits

Srinivas et al. (1997) conducted a survey in Karnataka to assess post-harvest losses of 'Totapuri' (Bangalora) and 'Alphonso' (Badami) mangoes in Karnataka. Total post-harvest losses of 17.9% (3.5% orchard/field, 4.9% transportation, 4.1% storage and 5.4% retail level) and 14.4% (1.9% orchard/field, 3.7% transportation, 3.5% storage and 5.3% retail level), respectively, were observed. The major causes of losses in the order of their occurrence were mechanical injuries, spoilage, either over mature/shrivelling, or immature/ unmarketable sizes, pilferage, and damage by birds/hailstorms.

Murthy et al. (2002) assessed the post-harvest losses in Banganapalli mango at different stages of marketing. The average post harvest loss at the farm level was 15.6%. The major post harvest loss (about 66% of total loss) at the farm level was due to the harvest of immature and small fruits. Loss at wholesale market level was virtually zero. The post harvest loss of mango during storage and ripening was estimated as 8.8%. The post harvest loss at retail level was found to be 5.25%. The major cause for this loss was pressing injury, which caused about 51% of the fruit damage. The other factors for retail level losses were black spot (31%) and injury due to mechanical and physical causes. The total post harvest loss in Banganapalli mango from production to consumption was estimated to be 29.7% in Andhra Pradesh.

Gajanana et al. (2002) conducted a survey in two districts of Tamil Nadu to estimate the post harvest loss of banana (Poovan) in the local market. They observed a loss of 3.9% at farm level sorting. The loss during transport ranged from 2.19% to 2.52%. The reason for the higher loss in transport was the long distances of transportation. At wholesale and retail market storage, the losses were 2.52% and 7.5%, respectively. The need to improve packaging for long distance transportation through boxes was suggested.

Sreenivasa Murthy et al. (2007) studied the marketing losses and their impact on marketing margins of banana in Karnataka. They identified three stages, viz. field level, transit and wholesale marketing level and retail marketing level. Simple averages and percentages were used for estimation of post-harvest losses at these stages. The study was conducted in one district (Bangalore rural). They observed losses of 5.53% at the field and assembly level, 6.65% at the wholesale level and 16.66% at the retail level in wholesale marketing system whereas in the co-operative marketing system, the losses were 7.82, 1.77 and 8.72%, respectively at the corresponding stages.

Rana et al. (2005) estimated the post harvest losses in kinnow at orchard, commission/forwarding agent, and retailer levels in Punjab, Himachal Pradesh and Haryana. Quantitative losses were computed on number and weight bases while economic losses were worked out in terms of gross and net losses. Combined physical losses for the three stages were 28.5% in Punjab, 30.4% in Haryana and 15.7% in Himachal Pradesh. Economic losses in Punjab (29.3% gross and 19.3% net) and Haryana (29.8% gross and 18.7% net) were higher than in Himachal Pradesh (12.7% gross and 6.23% net). Transport damage followed by rotten fruits, damage during harvesting and other losses were the main reasons for losses in Himachal Pradesh. In Punjab and Haryana, losses due to drop and bird's injury followed by rotten fruits, transport damage, crushing/pressing in packaging and damage during plucking were the main causes.

Gangwar et al. (2007) undertook a study in Punjab on Kinnow mandarin. They advocated the inclusion of marketing loss in the estimation of marketing margins, price spread and efficiency. A majority of kinnow producers were observed to sell their orchards to the pre-harvest contractors /traders at different stages. The aggregate post-harvest loss from orchards to consumers ranged from 14.87% in Delhi market to 21.91% in Bangalore market. The study indicated the necessity of establishing kinnow processing industries for development of value-added products at regional level, minimizing post-harvest losses and providing remunerative price to the producers.

Murthy et al. (2004) conducted a survey in Bijapur district of Karnataka on grapes. They observed that the loss in sorting and grading of grapes was 7.31%. Aggregate loss during transportation to wholesale market was 4.24%. Losses of 2.85% and 3.27%, respectively were observed in local and distant retail markets. The aggregate post harvest loss in grapes ranged from 14.4% in the local retail market to 21.3% in distant market. Several investigators have attempted to estimate post harvest losses of fruits and vegetables in Himachal Pradesh. Out of total production, the post harvest losses in selected fruits in Himachal Pradesh namely apple (Singh, 2002), mango, peach and kinnow/orange (Prasher and Negi, 2000) were found to be 14.48, 24.85, 18.31 and 24.5%, respectively. The losses were more at wholesaler's/ retailer's level in all the selected fruits, except apple.

Vegetables

Misener et al. (1989) studied the effects of mechanical injury on post-storage marketability of potatoes (variety: Russet Burbank) from 10 commercial storage facilities in New Brunswick. Three treatments were used in the sampling procedure: hand dug from the field, randomly picked from the bulk truck as it unloaded at storage (normal), and selected damaged tubers from the base of the pile (harsh). The results of this investigation indicated that the amount of mechanical injury done to potatoes during harvesting and subsequent handling was the most significant factor affecting the percentage of marketable tubers. Mechanical harvesting, as conducted in New Brunswick, resulted in 60.1% more post-storage losses of marketable potatoes than hand harvesting. The damage level does not significantly affect the proportion of the loss due to moisture loss from the potatoes. The extent of ventilation and humidification capabilities of the storages was reflected in both lower storage loss and weight loss of the product. Results suggested that the efforts to minimize the injury imparted to potatoes during harvesting and handling should be stressed in order to reduce loss of marketable product.

Singh and Ezekiel (2003) determined weight loss in potatoes (Kufri Chandramukhi and Kufri Jyoti varieties) stored at three relative humidity (RH) levels (30-35%, 60-65% and 90-95%) and temperature of 28-30°C. In dormant tubers, weight loss was the highest at 30-35% RH but once dormancy was broken and sprout growth had started, higher RH levels favored greater sprout growth leading to higher weight loss. Greater weight loss occurred in tubers with uncured skin. Weight loss showed a non-significant relationship with number of sprouts/tuber, length of the longest sprout, surface area of tubers and periderm thickness.

Kumar et al. (2006) conducted survey in two districts of Karnataka to assess the post-harvest losses in onion and potato. For each crop, one district was taken for data collection by enquiry. The estimated losses at field level were 6.21% and 7.34% for onion and potato, respectively. Losses of 1.85% and 2.22% were observed at the wholesaler level. The losses at the retail level were 2.36% and 3.41% in onion and potato, respectively. The functional analysis showed that inadequate storage and transportation activities coupled with bad weather conditions significantly influenced the post-harvest losses at the farm level.

Suojala (2001) studied the storage stability of onion as affected by timing of harvest. This study was aimed at determining the most suitable harvest time for obtaining a high yield of bulbs with high quality and storability. Storage experiments were conducted on onions produced in field experiments at a research field and on farms over a period of four years. Results indicated that harvesting could be delayed up to 100% onion maturity levels, or even longer, without a marked increase in storage loss. In rainy years, late harvest appeared to impair quality. The incidence of sprouting in shelf life tests varied considerably between years. An early harvest at less than 50% maturity and a delayed harvest increased the risk of sprouting. It is concluded that harvesting of onions for long-term storage can be timed to take place between 50% maturity and some weeks after complete maturity, without loss of storage quality.

Mohammed et al. (1992) examined post-harvest losses and quality changes in fresh yellow and red hot peppers at five stages in the roadside marketing system in Trinidad i.e. at harvest; on arrival at the packinghouse, during storage, at a roadside market display; and at the consumers' table. Nature of the damage and extent of quality changes in the peppers at these different stages were assessed. Total post-harvest losses were 28.6% and 38.7% of initial commodity weight in dry and wet seasons, respectively. Bruising was the major cause of wastage, followed by physiological and pathological damage in the field and packinghouse during storage. Chilling injury induced during storage at 2-4°C and 50-60% RH became increasingly visible at roadside display stalls and accounted for higher levels of physiological and pathological damage during the last 2 stages. Increase in pepper pH at roadside display and consumer stages, compared with earlier stages, was noted but total titratable acidity increased at the last stage. Vitamin C content decreased in both red and yellow fruit under ambient conditions. A progressive increase in percent fresh weight losses followed decrease in firmness as the fruits moved through the system.

Singh et al. (1989) stored tomatoes (Pusa Ruby & Roma varieties) at 20°C and 30°C with and without treatment with the fungicide guazatine and examined for storage losses. Dipping in a 2% guazatine solution for 5 or 20 min was ineffective in preventing natural infections in fruits held at 20°C and 30°C. An increase in solution concentration to 4% (dip time 5 min) extended shelf life by 2-6 days at 30°C and 20°C Pal (2002) conducted experiments in Orissa state to determine the extent of post-harvest losses occurring at different stages of handling and transportation of tomato, cabbage and cauliflower. Total losses of these vegetables during different post-harvest operations were found to be 30.3%-39.6%, 24.9%-30.4% and 28.6%-35.1% respectively. The maximum losses occurred during transportation from rural markets to urban markets.

Post harvest losses in vegetables, viz. tomato, green pea, capsicum, cauliflower and cabbage in Himachal Pradesh were 24.79%, 18.98%, 22.76%, 28.25% and 25.33% of the total production,

respectively (Singh and Vaidhya, 2005). The losses were more at production level in most of the vegetables. Waheed et al. (1986) studied post-harvest losses in leafy vegetables (cabbage, salad, spinach), roots and tubers (beetroot, carrot, onion, radish, potatoes) and others (bitter gourd, okra, cauliflower, peas, tomato, cucumber). Data showed that maximum (52%) quantitative loss was recorded in spinach, of which 25% was at retailer's shop. Proximate analysis of vegetables at different maturity stages indicated that the nutritional composition of vegetables were species specific and maturity dependent. Protein contents of leafy vegetables were high (25%-46%) at immature stage while roots and tubers indicated high (6.9%-13.7%) protein contents at over-mature stage. Leafy vegetables accumulated more Na and K compared with other vegetables. Vitamin contents (A, B1, B2 and C) of all the vegetables were high at mature stage and indicated significant losses during storage, especially ascorbic acid.

Sugarcane

Egan (1971) observed the post harvest deterioration losses of sugarcane over a period of 3 years (1962-66). During storage over weekends, rakes of chopped cane showed average apparent CCS (commercial sugar percentage in cane) losses of 0.64, 0.91 and 1.31 units, compared with whole stalk cane, representing at least 6%, 8.8% and 11.0% of original CCS present. It was concluded that safe storage periods for whole cane were unacceptable for chopper-harvested cane, which should be crushed as soon as possible.

Siddhant et al. (2008) conducted a study with ten sugarcane varieties of early and late maturing types and assessed for post harvest losses due to staling for periods of 0-120 hours and reduction in cane weight from February to June. The results revealed that the fibrous varieties of late maturing group such as CoSe 92423, CoS 97261 and CoS 8432 showed less reduction in cane weight and higher reduction in sucrose or pol percent whereas the less fibrous type of early maturing group like CoS 95255, CoS 96268 and CoS 8436 showed less reduction in pol percent and higher loss in cane weight.

2.4 Post Harvest Losses of Livestock Produce

Livestock produce (fish, meat, egg, milk) are an important source of protein. Their harvest, handling, processing and distribution provide livelihood for millions of people as well as providing valuable foreign exchange earnings to the country. These are highly perishable food, requiring proper handling, processing and distribution. Global demand for livestock produce is growing and reduction in post-harvest losses can make a major contribution to satisfying this demand, improving quality and quantity for consumers and increasing income for producers.

Marine Fish

Disney (1981) discussed the post-harvest aspects of fisheries development in the tropics. Post-harvest losses tend to be higher in small-scale fisheries, particularly in the period between catching and processing or consumption. Also, large wastage occurs due to physical damage or infestation of cured fish. Ways of improving fish utilization in small-scale fisheries are suggested, e.g. increased production and use of ice, smoking, low-cost solar driers, preparation of minced fish and awareness.

FAO (1981) and Wood (1986) have made serious attempts to develop assessment methodologies for accurate information on post harvest fish losses. The International Development Research Centre (IDRC), Canada, sponsored study in Central Institute of Fisheries Technology, Cochin, India in 1985 was aimed at better utilization of trawler by-catches for prevention of such fish losses.

Poulter (1987) described the losses of fish that were cured by salting, drying, smoking or by a combination of these processes. Physical losses are often caused by insects, which can consume large quantities of fish flesh. Pariser et al. (1987) enumerated the causes of post harvest losses in fish as biological and microbiological damage, chemical, biochemical, mechanical, storage, transportation, refrigeration and marketing systems. It was cited that minimal overall losses in developing countries as 20% of total production of non-grain surplus, perishables and fishes. They further emphasized that more systematic approaches to estimate the loss in developing countries for reduction in post harvest losses in fish by suitable improvement in the use of fish in fresh and iced condition, drying, smoking, small pelagic utilization, marketing and distribution.

Morrissery et al. (1988) provides an overview of post harvest losses in fisheries. The term post harvest has been defined as the period of time from when a fish is separated from its growth medium. Clucas et al. (1989) found 20% of post harvest losses of an annual fish production of about 13.5 lakh tonnes by 16 ECOWAS countries of West Africa. Similar, figures were observed in the artisan fisheries sector that contributes about 90% of the total catch. The Meeting for the Strategy for International Fisheries Research in 1991 recommended that post harvest fish losses should be a priority issue for future research ands noted that there was attempted to test the techniques by which losses could be assessed. Shimang (1992) reported in the absence of proper handling, processing and marketing infrastructure, large quantities of fish were lost each year before consumption.

Mengistu (1993) reported that the reduction of post-harvest losses through improved handling and processing, transport and distribution systems in Ethiopia should be given high priority. Post-harvest losses due to spoilage of fresh fish, burning during smoking, insect infestation in dried and smoked fish, breakage and rehumidification have been reported by FAO in 1992. Total losses, which were about 30% up to the 1970s, have been reduced to about 10% through extension of the use of insecticides and improved smoking ovens.

Adams (1995) suggested with the Individual Fishing Quota (IFQ) system, fishermen can be selective about such factors as fishing depth, bottom substrate, or time of day, month or year. These factors are directly related to incidental halibut by catch mortality. Ward (1996) focused on developing methods to quantitatively assess post harvest fish losses and to understand and identify the causes in qualitative sense. The main outputs of the study are (1) manual of field based loss assessment methodology, (2) Fish loss database, (3) Predictive macro model (4) Predictive cost model. The two systematic fish loss assessment methodologies developed were formal recall questionnaire survey method and an informal method based on rapid and participatory rural appraisal. Details are also given on how informal data collection techniques can be used to generate indicative quantitative data on post harvest fish losses. Ward et al. (1996) studied the fresh fish marketing between Visakhapatnam and Madras (now Chennai) based on a

survey programme conducted jointly by Central Institute of Fisheries Technology, Cochin, India and NRI, UK. Mndeme et al. (1996) concluded that the availability of salted fish markets both within and outside the country has a great extend reduced the loss as the fish, which is not accepted by factories due to low quality and size are now salted and exported.

Hodari et al. (1996) observed that insect infestation in shrimp resulted in considerable quantitative and qualitative loss. Improper packing, handling and stacking during transportation lead to fragmentation and spoilage. Ndem and Akande (1996) concluded heavy post-harvest losses reported for cured fish to be a result of inappropriate processing and handling. Eyo (1997) has estimated that 7% of fish in Kanji Lake was either discarded or value reduced due to spoilage during handling by fisher folk. According to Enujingha and Nwanna (1998), more than 20% of the two varieties of fish species harvested are lost as a result of inadequate handling and processing. Cawthorn et al. (2000) estimated post-harvest losses in North America at 10-15%, representing an economic impact of US $50-75 million annually.

Ward and Jeffries (2000) have described three methods for investigating fish losses. The Informal Fish Loss Assessment Method (IFLAM) describes quick way to generate qualitative and quantitative data based on rapid and participatory rural appraisal (RRA & PRA). The Load Tracking (LT) method uses biometric sampling to measure change in fish quantity and quality loss between stages in the distribution chain. The last method, Questionnaire Loss Assessment Method (QLAM) is based on a formal questionnaire survey approach. However these methods have certain disadvantages viz. the IFLAM method does not generate statistically valid data, the LT method is said to be costly and time consuming and by using the QLAM method it is not easy to quantify the loss levels.

In a study by CIFT (2004) conducted during 2001-04 under NATP on assessment of harvest and post harvest losses, it has been observed that marine fisheries losses occurred within craft/gear (3.61% to 14.48%), after unloading from craft/gear (0.81% to 5.16%) in marketing channels (0.14% to 8.28%) and at consumer level (1.93% to 4.95%)

Inland Fish

During the period 1975 to 1980, Central Institute of Fisheries Technology conducted studies on transportation of fresh fish in an All-India Co-ordinated Research Project. In these studies, the physical, chemical and bacteriological changes in some varieties of fishes before and after transportation were estimated.

Ward (1996) reported that the efficient utilization of fish resources by reducing post-harvest losses had been of prime concern in recent years as global production falls short of growing demand for human consumption. In order to properly plan loss reduction strategies, information on the magnitude of losses is important. For this purpose, two systematic fish loss assessment methodologies have been developed in UK, which may be used by fisheries researchers, policy makers and planners:1) a formal recall questionnaire survey method; and, 2) an informal method based on rapid and participatory rural appraisal. The two methods complement each other, as one primarily generates quantitative data and the other qualitative data. Ward (1997) has also given details on how informal data collection techniques can be used to generate indicative quantitative data on post-harvest fish losses. Over the last two decades a number of

systematic yet informal methods of data collection, project identification and evaluation have been developed, and incorporated into approaches such as Rapid Rural Appraisal (RRA). Number of data collection tools are associated with RRA, some of which have been used experimentally by National Resources Institute of England and the Tanzania Fisheries Division for fish loss assessments. Outlined are the data required and a description of the tools used to gather these data. Calculations used to quantify losses over a set period of time in chosen fisheries are presented. The results of this research suggest that the use of informal tools for fish loss assessment should be seen as a valid approach, but further research is required into the way data is gathered and used in the measurement of losses.

Eyo (1997) has given an assessment of the post-harvest losses in the Lake Kainji fisheries of Nigeria. The study focussed on quantifiable information on post-harvest technology and post-harvest losses from fisherfolk, fish processors and fish traders operating within the Kainji Lake basin. The information was obtained from questionnaires sent to a total of 668 respondents, comprising 317 fishermen, 115 fish processors, 125 fish buyers, and 111 fish sellers in 45 fishing villages and collection centres within the lake basin. Considering the total catch from gillnets, long-lines, traps and cast nets estimated at 14,000 t in 1995, about 1,000 t of fish was either discarded or lost value due to spoilage during handling by fisherfolk. Assuming an average price of 80 Naira/kg of fish, the loss to the economy amounted to 80 million Naira annually. Appropriate recommendations are made to significantly reduce post-harvest losses in the Kainji Lake fishery. Pariser et al. (1987) enumerated the causes of post harvest losses in fish as biological, microbiological, chemical, bio-chemical and mechanical in storage, transportation, refrigeration and marketing systems. They cited the minimal overall losses in developing countries as 20% of total production of non-grain surplus, perishables and fishes. They further emphasized that more systematic approaches to loss estimates in developing countries must be undertaken with more information made available.

Ward and Jeffries (2000) reported that the general factors (variables) that can increase the likelihood of post harvest losses were (1) unreliable transportation (2) iInadequate preservatiim techniques (3) adverse weather conditions (4) diligence or skills of workers (5) species of fish (6) fishing gears used (7) type of processing methods (8) fish supply greater than demand and (9) market for fish not developed. Emujiugha and Nwanna (1998) examined the impact of post-harvest handling and processing techniques on the supply and demand for African catfish (Clarias gariepinus) and tilapia (Oreochromis niloticus), two common fish species in Nigeria's aqua-habitat. It is observed that poor handling, inadequate pre-processing, holding conditions and inappropriate processing methods all have serious negative effects on the species conservation due to diminished supply against increasing demand. The resulting conflict between supply and demand is evaluated with regard to the sustainable utilization measures currently implemented in Nigeria as in other developing countries. More than 20% of the harvest of the two fish species is lost as a result of inadequate handling and processing.

Ward et al. (1998), reported that post-harvest fish losses suffered by small scale processors in India were excessive during monsoon. Preliminary results of a series of exploratory studies in assessing the extent and perceptions of these losses at coastal sites in South India are presented in this paper. Small-scale processors incur processing losses during monsoon and are further constrained owing to shortage and high

price of fish. Many processors consider losses to be an unavoidable aspect of their business. Gitonga (1998) reported that Nile perch (*Lates niloticus*) constituted 60% of total landings in the Kenyan waters of lake Victoria. The bulk of Nile perch is harvested from Lake Victoria whose landings contribute 90% of total fish production in Kenya. Post harvest losses of Nile perch are experienced by fishermen, processors and traders. The heaviest losses occur during the rainy season which corresponds to the period of optimum production. The causes of post harvest losses of Nile perch were found to be bacterial deterioration, blowfly larvae infestation, moulds and fragmentation. Salting of fish in brine concentration of 20% (w/v) before smoking, resulted in the smoked product having salt content of at least 10%. (This concentration was found to reduce fragmentation during smoking, inhibit blowfly larvae infestation and delay and reduce beetle larvae infestation. The salting process reduced moisture content, water activity of fish flesh and appeared to retard microbial spoilage. There was a slight reduction in protein and lipid contents on a dry weight basis after the smoking process. The smoked product with salt content of 10% was readily accepted by the Kenyan consumers, even though they do not customarily consume salted fish products.

Cheke (1997) presented a prototype model for evaluating the economic effects of different interventions to minimize post-harvest losses to fish. The compartmentalized model follows the fate of fish entering and leaving discrete stages between capture and sale at retail markets. The model is described using an example comparing the results of transporting Nile perch (Lates niloticus) caught in three different ways at Lake Victoria, Tanzania, and transported either by rail or by air to markets in Dar-es-Salaam, in a sequential chain with the highest losses occurring at the processing stage. It is concluded that the most cost-effective method, amongst the six comparisons made, is to catch fish in beach seine nets and to transport them by air. The model was designed to be adapted to other fishery systems and so be a useful tool for policy-makers and fisheries officers.

Ngoan (1997) has given a brief account of the current status of post-harvest fisheries technology in Vietnam, detailing the various infrastructures available for fish processing and storage for export. Only about 30% of catches are industrially processed and the remaining is consumed fresh. It is recommended that, for improvement of the fisheries industries, Vietnamese fisheries sector should concentrate on the following areas: (1) reducing post-harvest losses; (2) utilizing low-cost fish and fish waste; (3) strengthening infrastructure and fish quality and safety; and, (4) diversifying fish products.

In fact up to date data on harvest and post-harvest losses in inland fisheries from different resources and at different channels are not available in Indian context. Day (1980) reported briefly on FAO efforts to boost the yield from small-scale fishing activities by reducing post-harvest losses, which in many cases approached 50%. The main concerns are dried fish, where infestation by insects is the major cause of losses. The use of solar driers was recommended to reduce drying periods in the open air, improved smoking ovens, storage in insect-proof containers and insect-free surroundings and better protection of the product during transport and distribution (e.g. packaging in double kraft paper with bitumen between the layers, and with a polyethylene liner).

Bathla et al. (2004) conducted a pilot sample survey in East Godavari, West Godavari, Khammam district of Andhra Pradesh and Hirakund reservoir of Orissa to estimate harvest and post harvest losses of

inland fisheries at different channels. It has been reported that losses at producers level is maximum for reverine fisheries (8.56% to 13.94%) followed by reservoirs (6.52% to 8.89%), estuarine fisheries (6.3%), lake fisheries (3.69% to 4.48%), freshwater aquaculture (2.40%) and brackish water aquaculture (1.86%). Similarly, at market level maximum losses of inland fisheries was reported in wholesale market (up to 10.98%) followed by vendor level (4.10% to 5.52%), retail markets (2.96%), live fish transportation (2.22%) and packaging (0.29%). Further, urban household consumers were reported to be responsible for 4.41% to 4.52% losses of inland fisheries whereas losses of inland fisheries at rural household were 3.96%.

Poultry Meat

As far as poultry meat is concerned, except some information on the processing losses arising due to offals like blood, feathers, head, feet and visceral organs, no information seems to be available on the magnitude of losses occurring during movement of live/ dressed poultry and further-processed products from the producers/ processors to the consumers via different marketing channels in the country. Pandey et al. (1991) studied the effects of repeated interruptions in electricity supply to frozen chickens (-18°C) on physicochemical (drip loss, storage loss, cooking loss, pH, water holding capacity, TBA value, and sarcoplasmic and myofibrillar proteins), microbiological (total plate and psychrotroph counts) and sensory (appearance, flavour, juiciness, texture and overall appearance) quality, and shelf life. Broilers were packaged individually in polyethylene bags and frozen for 48 hours, following which daily electricity cuts for 6 or 9 h were evaluated until several samples were spoiled (28 days). Results indicated that chicken was acceptable for 28 days on exposure to 6 h daily power cuts, vs. 21 days on exposure to 9 h daily power cuts.

However, some pertinent information is available on the processing losses of inedible poultry byproducts during dressing of chicken. Uijttenboogaart (1981) reported 25.9% and 27.3% total offals losses in chicken broilers and spent hens, respectively. Panda and Singh (1980) and Shrivastava and Singh (1985) reported that poultry processing wastes viz. head, feet and shank, feathers, blood and viscera together constituted around 26 to 29% of live weight of chicken. They also reported that every kilo live weight of birds processed yielded 35 g blood, 80.7 g feathers, 30 g head, 39 g feet, 9 g lungs and 80 g viscera, making a total loss of 273.7 g which worked out to be 27.4% total offal. Sharma and Rao (1996) found about 26% total losses in broiler chicken. In general, processing losses were much higher in spent laying hens/culled breeding hens due to reproductive organs than in broiler or culled breeding cocks.

Egg

The incidence of broken and cracked eggs has been extensively studied in some industrialized countries. Hamilton et al. (1979) reviewed data from different countries and reported that approximately 5 to 18% of eggs produced were lost between laying house and retailing to consumers with an average annual losses of 6.4, 6.7 and 8% in the USA, UK and Germany, respectively. These losses were then estimated to cost the American egg producers $ 60 million annually. Detailed study revealed a higher incidence of breakage (3.5%) at the point of lay in cages, 2.2 to 3.6% during mechanical/ manual egg

collection, about 3.6% during transportation to packing and grading station, an additional 3.7% during washing, grading and packing at the egg grading station and about 1% during subsequent transport to retail outlets. In an earlier report (Roland, 1977), losses of eggs in the layer's house due to poor shell quality was found to be 7.8% which went up to a total loss of 14.2% during movement of eggs from the farm to the consumers.

Berry (1976) studied egg shell damage through retail channels and found 3.4% egg breakage at the processing plant, 1.9% during transport to warehouse and only 0.3% in retail store. A lower incidence of egg shell crack upto 1.7% occurred during laying, gathering and packing at the farm whereas the same increased to 14.5% during transport, washing, grading and re-packing at the egg processing plants (Orr et al., 1977). The incidence of body-checked eggs was only 0.3% for eggs from hens under 40 weeks of age as against 2.0% for eggs from birds over 60 weeks of age. Eggs produced and transported during summer exhibited higher (2.2%) shell damage than winter produced eggs (0.8%) (Lederer, 1978). Furthermore, Bains (1997) found 5 to 7% loss of eggs at the farm and an additional 10% loss during transport and handling in the marketing channels in Australia.

In a simulated drop test, Denton et al. (1981) found that 30 dozen cardboard case afforded greater protection against shell damage (7.9%) due to its better cushioning effect than 24 dozen wire case (20.7% damage). Nethercote et al. (1974) found that cross tiers of egg cartons protected eggs better than those stacked in one direction in the egg cases. Carton design appeared more important than the material (pulp/polystyrene) in determining the relative protection against shell damage.

Meagre information is available on the incidence of egg breakage in India. Panda (1973) found higher incidence of egg shell damage in bamboo baskets (15.3%) than in improved egg transport boxes (2.3%) during a long distance (2000 km) transport by rail. Subsequently, Brah et al. (1991) reported 5% mean egg shell breakage at poultry breeding farms in Ludhiana in pure and crossbred White Leghorn hens between 38 and 40 weeks of age. The incidence of hairline crack was maximum (57.6%) followed by star cracks (37.6%) and holes (4.8%) in these genetic groups. The occurrence of soft-shelled or shell less eggs varied between 2.4 to 16.1 and the incidence of egg shell defects and cracked eggs further increased to 21% under hot tropical environment (Rao and Nagalakshmi, 1998).

Milk

Giesecke et al. (1971) studied Bovine mastitis in the Republic of South Africa and found that total value of annual milk losses due to mastitis was Rs 29.68 million (a third of the total annual milk production), or Rs. 24 per cow per year. Grajewski (1974) attempted to assess milk yield losses caused by bovine mastitis. A total of 124 cows with a healthy quarter and a mastitic opposite quarter were selected by clinical examination and bacteriological and mastitis reagent (TOK) tests from 824 polish black and white lowland cow in 9 large herds in Bydgoszcz province. Data for 136 quarter pairs in 107 cows were analysed and it was found that average daily milk losses / quarter due to mastitis depended on the degree of the TOK reaction being 0.8 l. for + reaction (36 quarters), 1.22 l for 2 + (37 quarters) and 2.20 l for 3+ (63 quarters). On the basis of these figures it was estimated that daily milk losses (herd ranged from a minimum of 46.41

(in a 90 cow herd producing 1603 per day, with 8 quarters giving 3+ reactions) to a maximum of 676.41 (in a 190 cow herd producing 2100 l per day, with 188 quarters giving 3+reactions).

Sergeeva and Nezhdanov (1982) studied milk losses due to infertility of cows by comparing two matched groups of 142 Russian Simmental cows in 2nd – 6th lactation. In the test group annual milk yield decreased by 598 kg. As a result of an increase of 62 days in the calving interval, which meant that 0.3% of the potential annual yield was lost with each day of infertility.

Coulon et al. (1989) studied the effects of health problems on lactation in Friesian and Montbeliarde cows during a long term feeding trial. On a short-term basis (5 weeks), greatest milk losses were due to lameness at turnout (56 kg) followed by winter mastitis (24 kg). Over the complete lactation cycle, highest milk losses resulted from recurrent lameness (640 kg loss for cows presenting lameness at least 3 times, compared to 20 kg from those presenting once). Recurrent lameness occurred 3 times more frequently in Friesian than Montbelirade cows and 4 times more frequently in cows fed a grass silage based diet, compared to a hay based diet. Four main types of lactation were characterized on the basis of the level of production, health status, reproductive performance and culling rate of cows. Cumulative differences in these characteristics could account for up to 1800 kg difference in milk production.

Lescourret and Coulon (1994) studied impact of mastitis on milk production by dairy cows. They compared individual milk production curves of 542 cows with 722 cases of mastitis and control curves drawn from healthy lactating cows. First, differences were classified into patterns of milk loss, and their distribution was analyzed with regard to breed, season, lactation number, stage of lactation and milk production. Then individual milk losses were estimated and analysed according to the same factors. In early lactation, almost 7% of mastitis cases necessitated culling or drying off. For 36% of the cases of mastitis occurring in early lactation, milk production was offer for an extended period and the milk loss induced was 911 kg on average over the entire lactation, 52% of the mastitis cases occurring often lactation peat were not accompanied by marked modifications of the lactation curves. For 38% of the cases of mastitis occurring from mid to late lactation, milk production was affected for an extended period. The average loss was 850 kg over the entire lactation. For cases in early or mid to late lactation, the production at mastitis on set was a determining factor of the amount and pattern of milk production loss induced.

Sharma and Srinivasan (1973) conducted a study to estimate the handling losses in milk and milk solids of experimental dairy at National Dairy Research Institute, Karnal. In that they revealed that average liquid milk loss / day was estimated to be 0.67% of the total milk handled and it decreased with the increase in milk handled, on an average at a rate of 0.05% for every 500 kg increase in milk handled. Average fat loss was estimated to be 0.79% of fat handled and SNF loss 0.73% of SNF handled. These losses decreased with the increase in the level of handling, rate of decrease on average, for every 100 kg handled was 0.45% fat and 0.23% for SNF.

A study was conducted by Singh and Kalra (1976) regarding milk losses for a dairy plant. It showed that the losses during separation were 1.27% and 1.18% in the quantitative and monetary terms, respectively. For toned milk bottle the losses were 1.9% and 1.44% in quantitative and monetary terms and for toned milk in sachets the losses were 1.90% and 1.55%, respectively. The losses for other product

were also given, as shown in Table 2.4. Baltjes (1978), reported that from cleaning milking equipment, milk losses from equipment were 0.25 – 1.8 kg / day and from storage tanks 0.15 – 0.64 kg / day.

Table 2.4 : Milk losses in quantitative and monetary terms in a dairy plant

Sl. No	Name of product	Losses	
		Quantity, %	Cost of production
1	(a) Separation cost	1.27	1.18
	(b) Toned milk (component wire) bottle	1.83	1.44
2	Toned milk (bottles)	1.90	1.44
3	Toned milk (sachets)	1.90	1.24
4	Toned milk (Aluminum can)	1.90	1.55
5	Component wise-casein production	1.28	1.16
6	Component wise - paneer	0.74	0.64
7	Component wise - dahi	6.13	3.30
8	Component wise – fermented milk	1.34	7.41
9	Process wise – fermented milk	2.34	3.46
10	Component wise – cooking butter	0.29	0.27
11	Component wise – table butter	0.27	0.23
12	Component wise – sweetened condensed milk	0.60	0.26
13	Component wise – SMP (roller)	1.28	0.60
14	Component wise – SMP (spray)	1.28	0.60
15	Component wise – icecream mixed powder	16.60	9.43
16	Component wise - icecream	0.22	0.11
17	Component wise - flavored milk	1.23	5.95
18	Process wise – flavored milk	1.95	5.95

Marshall (1978) determined the product losses in different dairy processing factories. According to this study losses at different operations such as from whole milk reception and separation is <1.5% of milk purchased; milk losses during evaporation and spray drying in 3 factories are between 2% to 6%. Casein losses in 3 casein factories are 5.9% of the casein in the skim milk, losses being made up of fines in the whey (1.1-3.3%), fines in the wash water (0.4-2.7%), low moisture value (0.2-2.1%) and spills of milk and curd (0.8-1.8%). Salplachta (1979) conducted a study on milk losses and effluent contamination resulting from milk tanker washing. In that, it is concluded from tabulated milk losses and BOD data that mean milk losses were approximately 0.4 l / m^3 of tanker capacity, for a dairy factory with daily deliveries of 200,000 litres milk, the daily milk losses in washing would amount to 40-50 litres.

Rawat and Verma (1985), determined milk fat and SNF losses over a 12-month period at a small dairy plant during 4 stages of toned milk production, namely at Milk reception, Separation, Skim milk handling

for standardization and in toned milk processing and packaging. Annual loss of fat and SNF during toned milk production was 1.30 and 1.38%, respectively, the mean quantity of toned milk processed monthly being about 71,000 kg the proportion of fat and SNF loss, respectively that occurred at each of the 4 production stages were (a) 37.72% and 27.86%. (b) 0.39 and 5.99%. (c) 0.12 and 7.15%. (d) 61.77 and 59.0%. Bouman (1985) in a study on product losses in the evaporation of milk estimated that after 20 hours of operation, whole milk losses/ m^2 heat exchange surface reached 1.3 kg in a 4 - effect evaporator and 1.5 kg in a 7- effect evaporator (both of the falling film types.

Dyurich and Gertsen (1986), studied ways of reducing milk losses on farms. Their studies on experimental and state farms in Ukraine showed that when cows were milked twice daily in ADM-8, UDE-8 and UDT-8 parlors, respectively, 0.63%, 0.38% and 0.32% of the milk was lost for technological reasons, notably design factors that prevented complete removal of milk from the equipment at the end of each working cycle. In farm dairies these technological losses decreased from 0.48 to 0.36 and 0.25% as daily through put of milk increased from 5% to 10% and 15%, with the biggest losses occurring in plate coolers.

Arora, Rajorhia and Jain (1988), in their study in losses of milk solids in a small sized multi product plant reported that for a total of 6 million litres of milk processed during the 3 year, total loss of fat and TS due to excess supply was 647 Kg. and 5353 kg, respectively. Average fat and TS losses ranged from 0.24% to 2.71% and 0.58% to 8.04%, respectively, with corresponding overall average of 1.06% and 2.65%, respectively. They also pointed out that throughout three year period the factory operated as <50% of its total capacity and the reasons for losses were casual approach to standardization and lack of mechanical facilities for processing.

Rao (1990), in his study on reduction of losses in dairy industry, identified the major sources of losses as spoilages, wastage of surplus materials, spills cod leaks, inadequate drainage of milk from plant processing losses, packaging losses, losses due to analytical variations and storage losses. He also calculated the processing losses for three product combinations and they are in the order of dried skim milk + ghee > toned milk + surplus fat converted to ghee > standardized milk + surplus fat converted to ghee.

Saxena (1994) reviewed economic value of milk loss caused by foot and mouth disease (FMD) in India. Three types of milk losses are taken into account for cows and buffaloes are i) direct reduction in milk yields of milch animals. ii) reduction in milk output due to conception delay in breeding animals. iii) Reduction due to abortions in pregnant animals. However, in terms of total annual losses, indigenous cows rank first followed by buffaloes and cross-bred cows, respectively. As a whole, the disease causes a milk loss of about 3508 million liters which is about 6.5% of total annual milk output at the national level. In terms of value at 1990 prices, the annual loss of milk accounts to about Rs 12,520 million in terms of foreign exchange lost, and from Rs. 16500 million to Rs. 18730 million in terms of domestic economic surplus cost.

Khatri et al. (1998) conducted a study on post-production losses of milk in rural areas of Rohtak district of Haryana state. The results show that loss of milk was of the order of 3.0%, 1.1% and 2.8% at household, cycle vendor and halwai levels, respectively. This prosperous region has fairly good production and marketing infrastructures where the people are reasonably educated and more business

minded. In other less prosperous area having poor market infrastructure, the milk losses at different stages are expected to be higher.

Shakeel and Khan (1999), in their study on milk packing film and milk handling losses in Gulbarga Co-operative milk union estimated that the total losses of milk fat and milk solids not fat were 0.73%, total losses of milk were 6.8%. Keeping in view, the information scanned from the literature, it was found that their findings were not in consonance with the present research requirements of the researchers for category-wise and season-wise in-depth estimation of milk losses with standard errors at every stage of milk handling during production, market and consumption levels.

It is observed that the assessment of losses for food grains exceed other crops and commodities and studies have been conducted in a more systematic manner with procedural development over time. This is expected as food grains dominate in our daily diet. Attention to study the losses in perishables of plant origin, such as fruits and vegetables, have picked up of late as their contribution of nutritionally important vitamins and trace elements is being increasingly realised. Similarly, the literature on estimation of post harvest losses in perishable livestock produce is somewhat scant, except for fish. There is a need to assess the post harvest losses of these crops and commodities at national level. Research workers have dealt with the problem of assessment according to their needs and situations. A comparison of the results of their study may not be fair on account of diverse techniques of loss measurement adopted. The information generated, however, underlines the gravity of the situation. Their experience is also useful in evolving a uniform standard approach to assessment of post harvest losses.

3

SAMPLING DESIGN OF THE SURVEY

The study was undertaken with an aim to provide estimates of harvest and post harvest losses of different crops and commodities at the national level. Keeping the practical utility and limitations in view and based on the deliberations during a Coordination Committee Meeting of AICRP on PHT (2005), the following criteria were adopted for the assessment of post harvest losses of crops/ commodities.

1. Only the quantitative post harvest losses would be assessed.
2. The data for harvest and post harvest losses would be collected for one full cycle of the selected commodities.
3. While the data for losses would be collected (i) through enquiry with the respondents and also (ii) by recording onsite observations, these two sets of data would be suitably combined to eventually report a single figure for the loss in each operation and channel.

3.1 Concepts and Definitions of Loss

There is a good deal of variation in the concepts and definitions of loss adopted by various research workers. This is not surprising, since numerous post harvest operations are associated with food grains, horticultural crops and livestock produce and multiple channels are involved in the flow of crop/ commodity from the producers to the consumers making the scenario complex and varied. In developing a methodology for the assessment of losses it is, therefore, necessary to simplify the problem as far as possible to achieve feasibility in the intended task of data collection and analysis.

A definition of loss, favoured by a number of research workers, is "reduction in weight of edible produce available for consumption". Though adequate for practical purposes and convenient because of its simplicity, it does not address the reduction in weight due to drying operations. Though drying may involve considerable reduction in weight, there is no loss of food value and therefore such reduction should not be counted as loss. The quantitative loss is caused by reduction in weight due to factors such as incidence of pests (viz. insects, mites, fungi and bacteria, rodents and birds), and also due to physico-chemical changes. The present study was, therefore, limited to only the assessment of quantitative losses (discounting the weight loss due to drying operation) as the material rendered 'unfit for consumption'.

The losses in quality, food value, goodwill or reputation, seed vigour, etc are difficult to quantify and hence have not been considered in the present study. However, when qualitative deterioration takes place to such an extent that the food material is rendered unfit for consumption and is rejected, it would amount to a quantitative loss.

Further, it was decided to estimate the post harvest losses through (1) verbal enquiry and also by (2) actual measurements in the field. Previous studies arrived at estimates based on either enquiry only or reported the estimates based on enquiry and observation separately. The present study aimed to evolve suitable statistical methodology to combine both the data obtained through enquiry and observation.

3.2 Selection of Crops/Livestock Produce, Operations and Channels

The major crops and commodities as well as operations to be covered for each crop/commodity were identified collectively in a meeting of post harvest engineers and scientists such that various food categories were well represented. The crops/commodities were classified as cereals, pulses, oilseeds, fruits, vegetables, plantation crops, spices, livestock and fisheries produce and then major crops/ commodities of each group were selected for the study on the basis of national production. Altogether 46 major crops/commodities were selected for the study. The farm operations and channels to be covered for different crops/commodities during the survey and extent of coverage of each operation are summarized in Table 3.1.

Table 3.1 : Farm operations / channels and extent of coverage for crops /livestock produce

S. No.	Operation/ Channel	Extent of coverage of the operation	Crops covered
1.	**Harvesting**	Cutting of the standing crop	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Arecanut, Black gram, Mustard, Sunflower, Safflower, Soybean, Coriander, Chickpea, Green pea, Sugarcane, Mushroom
		Plucking of fruits / bolls / bunch from tree/ plant / vines	Cottonseed, Apple, Banana, Mango, Papaya, Sapota, Grapes, Black pepper, Citrus, Guava, Coconut, Cashew, Tomato, Chilli, Cauliflower, Cabbage
		Digging/ uprooting of the tubers from soil	Onion, Potato, Tapioca, Turmeric
		Digging / uprooting of pods from soil and collection of leftover pods after ploughing	Groundnut
		Catch	Inland fish
		During milking	Milk
		Slaughter of the animal/ bird and removal of offal	Meat, Poultry meat
		Not covered	Egg, Marine fish, Jaggery & khandsari
2.	**Collection**	Stacking, bundling and transportation up to threshing floor	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Coriander, Groundnut, Black pepper

Table 3.1 (Continued)

S. No.	Operation/ Channel	Extent of coverage of the operation	Crops covered
		Stacking, filling in baskets/bags, transportation to sorting/ grading area	Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Arecanut, Coconut, Cashew, Chilli, Cauliflower, Cabbage, Onion, Potato, Tapioca, Green pea, Turmeric, Tomato, Cottonseed, Mushroom
		Removal of dry and green leaves, stacking, bundling	Sugarcane
		Removal of Jaggery from pans, block making	Jaggery & khandsari
		Separation from net, filling in baskets/ transportation tanks	Inland fish
		Filling in cans, unloading at collection center	Milk
		Collection of eggs from cages, transportation up to packaging yard	Egg
		Unloading the fish from boat at landing centre	Marine fish
		Not covered	Meat, Poultry meat
3.	**Threshing**	Separation of grain from crop manually or using thresher and collection of straw and grain	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Chickpea, Green gram, Black gram, Mustard, Soybean, Sunflower, Safflower, Groundnut, Arecanut, Black pepper, Coriander
		Operation not performed	Apple, Banana, Citrus, Grapes, Guava, Mango, Papaya, Sapota, Chilli, Onion, Cauliflower, Cabbage, Potato, Green pea, Turmeric, Tomato, Mushroom, Tapioca, Sugarcane, Egg, Inland, Fish, Marine fish, meat, Poultry meat, Milk, Jaggery & khandsari
		Not covered	Cashew, Coconut
4.	**Sorting/ grading**	Separation of material not fit for human consumption due to damages, injuries, unripe harvest, removal of first layer of cabbage leaves	Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Coconut, Chilli, Cauliflower, Cabbage, Onion, Potato, Green pea, Turmeric, Tomato, Mushroom
		Separation of uneconomical, small fish	Inland fish, Marine fish

Table 3.1 (Continued)

S. No.	Operation/ Channel	Extent of coverage of the operation	Crops covered
		Trimming	Tapioca, Sugarcane
		Not covered	Milk, Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Coriander, Groundnut, Black pepper, Cottonseed, Cashew, Egg, Meat,Poultry meat, Jaggery & khandsari
5.	**Winnowing/ cleaning**	Collection of threshed material, winnowing to remove chaff, dust etc	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Coriander, Groundnut, Black pepper, Arecanut, Chilli, Turmeric
		During ginning	Cottonseed
		Not covered	Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Coconut, Cashew, Cauliflower, Cabbage, Onion, Potato, Tapioca, Green pea, Tomato, Mushroom, Sugarcane, Inland fish, Milk, Egg, Marine fish, Meat, Poultry meat, Jaggery & khandsari
6.	**Drying**	Collection of material after cleaning, spreading for drying, heaping after drying	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon Pea, Green Gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Coriander, Groundnut, Black Pepper, Arecanut, Coconut, Cashew, Cottonseed, Turmeric, Chilli
		Collection of material after sorting/grading, spreading for drying, heaping after drying	Coconut, Marine fish
		Transportation from field to crushing unit, before crushing starts (Staling)	Sugarcane
		Not covered	Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Cauliflower, Cabbage, Onion, Potato, Tapioca, Green pea, Tomato, Mushroom, Inland fish, Milk, Egg, Meat, Poultry meat, Jaggery & khandsari

Table 3.1 (Continued)

S. No.	Operation/ Channel	Extent of coverage of the operation	Crops covered
7.	**Packaging**	Collection after winnowing/ cleaning/ drying/ sorting/ grading/ threshing (by thresher having blower), filling in the bags/ baskets/ other packaging material	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Chilli, Safflower, Soybean, Coriander, Tomato, Groundnut, Black pepper, Arecanut, Turmeric, Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Coconut, Cashew, Cauliflower, Cabbage, Onion, Potato Tapioca, Green pea, Mushroom.
		Packaging in filler flats, stacking filler flats	Egg
		Packaging of seed into bags after ginning	Cottonseed
		Application of ice, packaging for transportation	Inland fish
		Collection from block making units, filling in bags/ packaging material	Jaggery & khandsari
		Not covered	Milk, Marine fish, Meat, Poultry meat
8.	**Transportation**	Loading of packed material in threshing yard, transportation to store of farmer, unloading for storage, transportation from threshing yard/store to market yard, unloading at market yard	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Groundnut, Cottonseed, Sugarcane, Jaggery & khandsari
		Loading of packed material in sorting/ grading place, transportation to store of farmer, unloading for storage, transportation from sorting/ grading place/ store to market yard, unloading at market yard	Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Cauliflower, Cabbage, Onion, Potato, Tapioca, Green pea, Tomato, Mushroom
		Loading of packed material in drying yard, transportation to store of farmer, unloading for storage, transportation from drying yard/ store to market yard, unloading at market yard	Black pepper, Chilli, Coriander, Turmeric, Arecanut, Coconut
		Loading of material collected after harvesting, transportation to prosseing unit, unloading for storage	Sugarcane

Table 3.1 (Continued)

S. No.	Operation/ Channel	Extent of coverage of the operation	Crops covered
		Loading of material after collection (from mould), transportation to store of farmer, unloading for storage, transportation from collection point/ store to market yard, unloading at market yard	Jaggery and khandsari
		Loading of material after sorting / grading, transportation, unloading at market yard	Inland Fish Marine Fish
		Loading of packed material, transportation to market yard, unloading	Egg
		Loading from collection point, transportation to market yard/consumer	Milk
9.	**Storage at farm/ household level**	During storage, cleaning/ grading, before sending to market for sale or own consumption	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Coriander, Groundnut, Black pepper, Arecanut, Coconut, Cashew, Cottonseed, Turmeric, Chili, Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Cauliflower, Cabbage, Onion, Potato, Tapioca, Green pea, Tomato, Inland fish, Milk, Egg, Sugarcane, Jaggery & khandsari
		Storage at farm level not done	Marine fish, Mushroom, Meat, Poultry meat
10.	**Storage at godown/ warehouse/ cold stores**	Unloading, during storage, loading for further sale/ disposal	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Onion, Soybean, Coriander, Groundnut, Black pepper, Arecanut, Coconut, Cashew, Jaggery & khandsari
		Unloading, during storage, loading for further sale/ disposal (in cold stores)	Chilli, Apple, Banana, Papaya, Citrus, Cauliflower, Cabbage, Potato, Green pea, Tomato
		Units not available in selected districts/ storage not done in this channel	Cottonseed, Sapota, Grapes, Mango, Guava, Tapioca, Mushroom, Sugarcane, Turmeric, Egg, Inland fish, Milk, Marine Fish, Meat, Poultry meat

11.	**Storage at wholesale level**	Unloading, during storage, loading for further sale/ disposal	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Safflower, Soybean, Coriander, Groundnut, Black pepper, Arecanut, Coconut, Cashew, Cottonseed, Turmeric, Chilli, Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus,Guava, Cauliflower, Cabbage, Onion, Potato, Tapioca, Green pea, Tomato, Inland fish, Egg, Marine fish, Meat, Poultry meat, Jaggery & khandsari
		Storage not done in this channel	Sugarcane, Mushroom, Milk
12.	**Storage at retailer level**	Unloading and loading, during storage, sorting/ grading for sale	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Soybean, Coriander, Groundnut, Black pepper, Arecanut, Coconut, Cashew, Turmeric, Chilli, Apple, Banana, Mango, Papaya, Sapota, Grapes, Citrus, Guava, Cauliflower, Cabbage, Onion, potato, Tapioca, Green pea, Tomato, Inland fish, Egg, Marinefish, Meat, Poultry meat, Sugarcane,Mushroom, Milk, Jaggery & khandsari,
		Retailing not done	Safflower, Cottonseed
12	Storage at processing units	Unloading material for storage during storage	Paddy, Wheat, Maize, Bajra, Sorghum, Pigeon pea, Green gram, Black gram, Chickpea, Mustard, Sunflower, Soybean, Coriander, Groundnut, Black pepper, Arecanut, Coconut, Cashew, Chilli, Apple, Banana, Mango, Papaya, Grapes, Citrus, Guava, Cabbage, Onion, Potato, Tapioca, Tomato, Jaggery & khandsari, Egg, Marine fish, Poultry meat, Sugarcane, Milk
		Units not available in the selected districts/ storage not done in this channel	Sapota, Cauliflower, Green pea, Mushroom,

3.3 Sampling Design and Selection of Districts

For selection of respondents to collect the data for assessment of harvest and post harvest losses, stratified multistage random sampling method was used. The agro-climatic zones were taken as strata. Districts in each stratum were taken as first stage, blocks as second stage, villages as third stage, and farmers as fourth stage units. Fourteen out of 15 agro–climatic zones of the country were considered for selection of representative districts (Fig 3.1). The zone pertaining to the island region was not included in the survey as the total contribution to Indian agricultural production from this zone is quite low.

To estimate post harvest losses accurately using sample survey, it was considered necessary to cover maximum number of units at the first stage of sampling. Hence, a total of 120 districts were selected from 14 agro-climatic zones (20% of the total districts in each agro-climatic zone, excluding the urban districts where cultivation is not done). The allocation of 120 districts in different agro climatic zones was done according to proportion of area cultivated in year 2003-2004 under major crops. The number of districts to be selected in each agro-climatic zone was taken proportionately, rounded off to the nearest integer.

The districts in each of the agro-climatic zones were then selected randomly. These districts were allotted to different centres of the AICRP on PHT for data collection. The list of districts selected and allocated to PHT centres is shown in the Fig. 3.2. The agro-climatic zone-wise list of districts surveyed is provided in Appendix III.

3.4 Allocation of Crops/Commodities

The crops/commodities for different agro-climatic zones were allotted according to the intensity of production of crops/commodities in the selected zone. Major crops of the region were first allotted to the agro-climatic zones. The mandated crops of the PHT centres (falling in that agro-climatic zone), which were selected for the survey, were added to the list. Thereafter, selected crops having smaller area in the zone were added so that the effect of socio-economic and technological factors could be minimized and complete representative coverage of the country could be obtained. The distribution of crops and districts to different PHT centres is given in Table 3.2.

3.5 Sample Size and Sampling Procedure

3.5.1 Sample size

The survey was conducted in rural areas, markets, private agency godowns, cold storages and processing units. The sample size for data collection was decided on the basis of statistical sampling procedures. Selection of farmers, and respondents in market channels was done using random sampling method. The sample size for each operation and channel and sampling procedure are described below.

Farm operations: Two blocks were selected randomly from each selected district. Five villages were selected randomly from each block. A random sample of ten farmers was drawn form each village for data collection by enquiry. For data collection by observation, two farmers from the list of already selected 10 farmers of each village were selected randomly. The sample sizes (actual number of respondents) for estimation of loss for each crop/commodity and for each of the farm operations in the present study at the national level have been shown in Appendix IV.

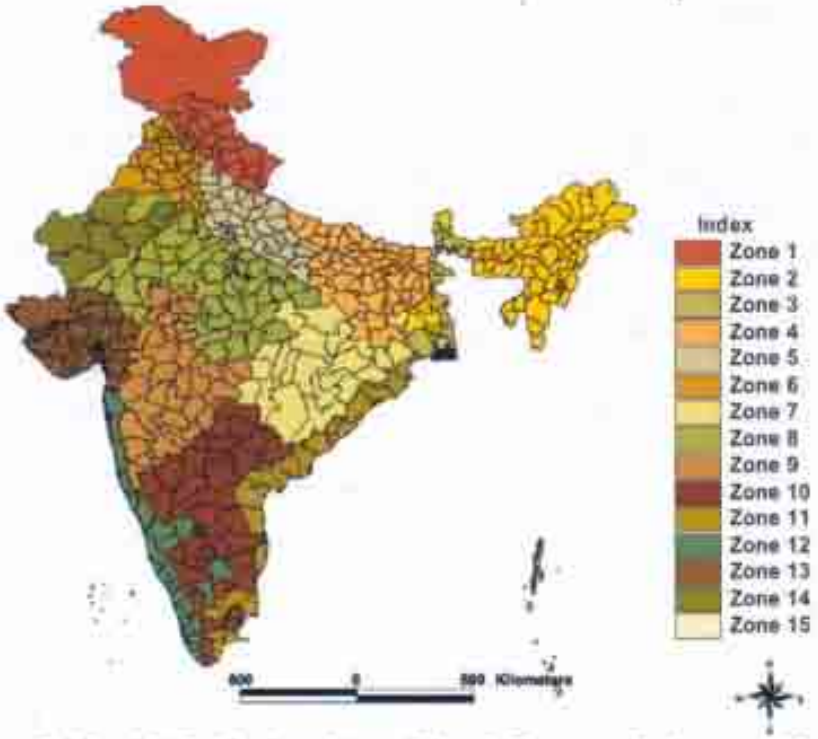

Figure 3.1 Spatial distribution of Agro-Climatic Zones on district map of India

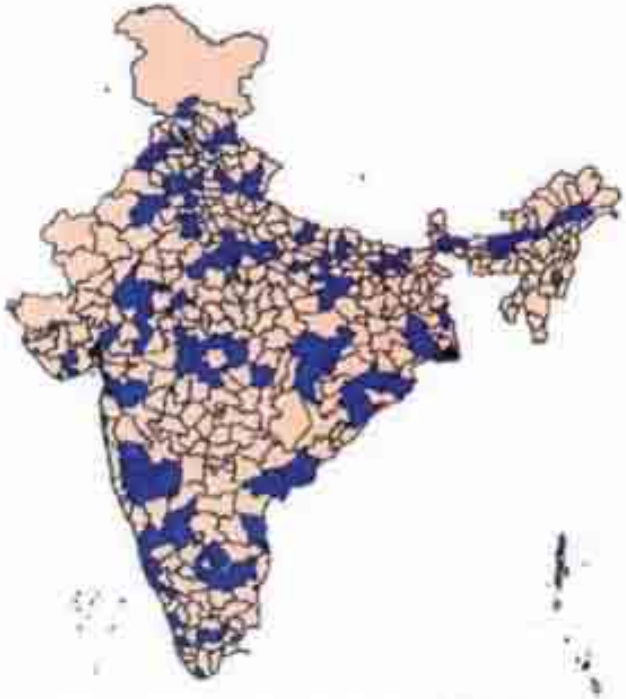

Figure 3.2 Location of all selected districts

Table 3.2 : List of districts and crops/commodities allotted to the cooperating centres of AICRP on PHT

S. No.	Name of Centre	State	Identified districts	Crop/commodity
1.	PDKV, Akola	Maharashtra	Amaravati, Bhandara, Nasik	Paddy, Sorghum, Bajra, Pigeon pea, Chickpea, Black gram, Green gram, Mango, Groundnut, Sunflower, Soybean, Safflower, Citrus, Banana, Grapes, Onion, Sapota, Papaya, Cabbage, Tomato, Mushroom, Cashew, Sugarcane
2.	AMU, Aligarh	Uttar Pradesh	Hathras, Orriya, Meerut, Bijnor, Hamirpur, Ferozabad	Meat, Wheat, Paddy, Bajra, Pigeon pea, Mustard, Mango, Guava, Potato, Green pea, Sugarcane
3.	VPKAS, Almora	Uttaranchal	Almora, Bageshwar	Citrus, Apple, Green pea, Milk, Mushroom
4.	RARS, Anakapalle	Andhra Pradesh	East Godavari, West Godavari	Paddy, Sorghum, Pigeon pea, Chickpea, Black gram, Cashew, Green gram, Onion, Groundnut, Sunflower, Cottonseed, Mango, Citrus, Banana, Guava, Papaya, Tomato, Tapioca, Chilli, Coconut, Coriander, Turmeric, Sugarcane, Egg, Poultry, Inland fish
5.	UAS, Bangalore	Karnataka	Bangalore (rural), Kolar, Shimoga, Chitradurga	Maize, Sorghum, Bajra, Milk, Groundnut, Sunflower, Safflower Mango, Grapes, Guava, Sapota, Papaya, Tomato, Onion, Chilli, Coconut, Arecanut, Marine fish
6.	ANGRAU Bapatla	Andhra Pradesh	Krishna, Nellore, Guntur	Paddy, Sorghum, Pigeon pea, Chickpea, Black gram, Cashew, Green gram, Groundnut, Onion, Sunflower, Coconut, Cottonseed, Mango, Citrus, Banana, Guava, Papaya, Tomato, Tapioca, Chilli, Coriander, Turmeric, Sugarcane, Egg, Poultry meat, Inland fish
7.	OUAT, Bhubaneswar	Orissa	Ganjam, Sonapur, Dhenkanal, Phoolbani, Cuttack, Jagatsinghpur	Paddy, Chickpea, Black gram, Onion, Green gram, Groundnut, Banana, Chilli, Turmeric, Arecanut, Cashew, Inland fish
8.	SRS, AAU Buralikson	Assam	Barpeta, Darrang, Kamrup	Citrus, Papaya, Cauliflower, Cabbage, Tapioca, Green pea, Sugarcane, Meat, Egg, Poultry meat, Jaggery & khandsari

Table 3.2 (Continued)

S. No.	Name of Centre	State	Identified districts	Crop/commodity
9.	CIAE, Bhopal	Madhya Pradesh	Hosangabad, Dewas, Jhabua, Neemuch	Wheat, Maize, Sorghum, Chickpea, Black gram, Mustard, Soybean, Banana, Coriander
10.	TANUVAS, Chennai	Tamil Nadu	Thiruvallur	Sorghum, Bajra, Green gram, Mango, Banana, Grapes, Tapioca, Groundnut, Cottonseed, Mushroom, Turmeric, Coconut, Sugarcane, Poultry meat, Marine fish, Meat
11.	TNAU, Coimbatore	Tamil Nadu	Kanyakumari, Karur, North Arcot, Dharmapuri, Dindigul	Sorghum, Bajra, Green gram, Mango, Banana, Grapes, Tapioca, Groundnut, Cottonseed, Mushroom, Turmeric, Coconut, Sugarcane, Poultry meat, Marine fish, Meat
12.	NDUAT, Faizabad	Uttar Pradesh	Azamgarh, Pratapgarh Balrampur, Varanasi, Ambedkarnagar, Sonbhadra	Wheat, Paddy, Bajra, Pigeon pea, Mango, Mustard, Guava, Potato, Green pea, Sugarcane
13.	CCSHAU, Hisar	Haryana	Fatehabad, Hisar, Jind, Karnal, Rohatak	Sorghum, Chickpea, Cottonseed, Cabbage, Cauliflower, Sugarcane, Milk
14.	JNKVV, Jabalpur	Madhya Pradesh	Bhind, Shadol Gwalior, Chindwara, Morena, Khandawa	Wheat, Maize, Sorghum, Banana, Mustard, Chickpea, Black gram, Soybean, Coriander
15.	RAU, ARS, Jaipur	Rajasthan	Karauli, Churu	Maize, Bajra, Chickpea, Mustard, Soybean, Cottonseed, Coriander
16.	CAZRI, Jodhpur	Rajasthan	Alwar	Maize, Bajra, Chickpea, Mustard, Soybean, Cottonseed, Coriander
17.	AAU, Jorhat	Assam	Nalbari, Naugaon, Tinsukia, Lakhimpur	Citrus, Cauliflower, Sugarcane, Cabbage, Papaya, Tapioca, Green pea, Meat, Egg, Poultry meat
18.	JAU, Junagarh	Gujarat	Mehasana, Kheda, Valsad, Porbandar, Navsari, Amareli	Wheat, Bajra, Pigeon pea, Black gram, Groundnut, Mustard, Papaya, Cottonseed, Mango, Banana, Sapota, Potato, Onion, Cauliflower, Milk
19.	IIT, Kharagpur	West Bengal	Bankura, Purulia, Medinipur (West)	Wheat, Paddy, Black gram, Mustard, Guava, Papaya, Potato, Tomato, Cabbage, Cauliflower, Green pea, Coconut, Arecanut, Chilli, Marine fish, Inland fish
20.	CPCRI, Kasaragod	Kerala	Kasaragod, Kannur	Black pepper, Coconut, Arecanut, Tapioca, Cashew, Marine fish

Table 3.2 (Continued)

S. No.	Name of Centre	State	Identified districts	Crop/commodity
21.	RS&JRS, Kolhapur	Maharashtra	Kolhapur, Satara, Sangli	Paddy, Sorghum, Bajra, Pigeon pea, Chickpea, Black gram, Green gram, Citrus, Groundnut, Onion, Sunflower, Soybean, Safflower, Cottonseed, Mango, Banana, Grapes, Sapota, Papaya, Cabbage, Tomato, Cashew, Mushroom, Sugarcane, Jaggery
22.	WBUAFS, Kolkata	West Bengal	Jalpaiguri, Medinipur (East), Nadia	Wheat, Paddy, Black gram, Mustard, Guava, Papaya, Potato, Tomato, Cabbage, Cauliflower, Green pea, Chilli, Coconut, Arecanut, Marine fish, Inland fish
23.	PAU, Ludhiana	Punjab	Jalandhar, Moga, Ferozepor	Wheat, Paddy, Mustard, Citrus, Poultry meat, Inland fish
24.	IISR, Lucknow	Uttar Pradesh	Chandauli, Deoria, Kanpur (Dehat), Etawah, Unnao	Wheat, Paddy, Bajra, Pigeon pea, Potato, Mustard, Mango, Guava, Green pea, Sugarcane
25.	GBPUA&T Pantnagar	Uttaranchal	Nainital, Haridwar	Citrus, Apple, Green pea, Milk, Mushroom,
26.	RAU, Pusa	Bihar	Bhabhua, Supal, Darbhanga, Samastipur, Vaishali	Maize, Pigeon pea, Green gram, Guava, Potato, Tomato, Onion, Cauliflower, Cabbage, Inland fish
27.	UAS, Raichur	Karnataka	Belgaum, Bijapur, Bellary, Dakshin Kannada	Maize, Sorghum, Bajra, Milk, Grapes, Groundnut, Sunflower, Safflower, Onion, Tomato, Chili, Arecanut, Mango, Guava, Sapota, Papaya, Coconut, Marine fish
28.	IGKVV, Raipur	Chattisgarh	Bilaspur, Raipur, Kawardha, Jashpur, Raigarh	Wheat, Tomato, Guava
29.	YSPUH&F, Solan	Himachal Pradesh	Una, Chamba, Kinnore, Shimla	Apple, Potato, Green pea, Mushroom
30.	SKUAS&T, Srinagar	Jammu & Kashmir	Jammu, Pulwama, Baramula	Apple, Meat
31.	KAU, Tavanur	Kerala	Wayanad, Kottayam	Black pepper, Coconut, Arecanut, Cashew, Marine Fish, Tapioca
32.	CTCRI, Trivandrum	Kerala	Palakkad	Black pepper, Coconut, Arecanut, Cashew, Marine Fish, Tapioca
33.	MPUAT, Udaipur	Rajasthan	Baran, Rajsmand, Udaipur, Banawara, Chittorgarh	Maize, Bajra, Chickpea, Mustard, Soybean, Cottonseed, Coriander

Storage at producer level: Same samples of farmers (as taken for data collection at farm level) were taken for data collection on storage losses at farm level by enquiry and observation.

Storage at market level: Two units of each channel such as wholesaler, retailer, godown, and processing unit for each crop/livestock produce were selected randomly from the list of the respondents prepared after complete enumeration of units for each channel of each selected district. In case a particular channel was not available in the selected district then nearby districts were considered for data collection by enquiry/actual observation. The data by enquiry as well as by observation was collected from all selected respondents. The sample size (actual number of respondents) for estimation of loss for each crop/commodity during storage in different channels in the present study at the national level has been shown in Appendix V.

3.5.2 Sampling procedure

The selection of sampling units was done on the basis of simple random sampling technique without replacement for each crops/commodities. The sampling procedure for each stage is described below.

Selection of blocks in the district: A list of all blocks of the district was prepared. Two blocks were selected randomly with equal probability for sampling of villages.

Selection of villages: List of villages in the selected block was prepared and five villages were selected randomly from the list. In some of the cases where villages were big with more than 1500 households, one segment of the village was enumerated and selection of farmers was made from that list only.

Selection of farmers: After complete enumeration of each village, the households not related to the identified commodities of the district were discarded and a list of farmers growing or expected to grow the identified crops/commodities in the current survey period for the districts was prepared. The farmers were sub-stratified into two categories i.e. those growing more than or equal to 70% of the selected commodities (nearest integer number) and those growing less than 70% of selected commodities. Six farmers were selected from the first list randomly and remaining 4 farmers were randomly selected from the second list. In case the number of farmers in the first list was less than 6, all these farmers were selected and rest of the farmers were selected from the second list.

Selection of field and plot: This selection was done to record the losses during farm operations by observation. For field crops (cereals, pulses, oilseeds, spices, sugarcane, vegetables), the selection of plot was done for each crop. A list of all the fields of selected farmers for each crop grown was prepared. One field for a particular crop was selected randomly. After selecting the field, a plot of 5m×5m (for plains) or 2m×10m (for hilly regions having contour or terrace farming) was identified to assess the losses by actual observation.

For horticultural crops, the orchard (A cluster of minimum 12 fruit bearing trees of particular crop on a single piece of land) was identified for assessment of losses. Four fruit bearing trees were selected randomly.

For fishponds, all the fishponds of the village were completely enumerated and two ponds were selected randomly from this list.

For livestock, information on all the milch and meat animals of the selected households in the selected village was recorded. In case of egg and poultry birds, all the egg and poultry units in the village were completely enumerated and two units were selected randomly for data collection.

Selection of wholesalers: A list of market yards/mandies at the district headquarter was prepared and one mandi was selected randomly. All the wholesalers in a market yard/mandi were enumerated and two wholesalers for each commodity were selected randomly from the list. Priority was given to the wholesalers handling more than one crop/commodity.

Selection of retailers: A list of main retail markets at district headquarters including the retail fruit and vegetable markets was prepared. One market was randomly selected and enumerated. Two retailers were selected randomly giving priority to the retailer handling more than one crop.

Selection of processing units: A list of processing units related to identified crops/livestock produce was prepared for each district headquarter and two units were selected randomly for each crop/commodity. In case the processing unit was not available in the identified districts, units located in neighbouring district were taken.

The sample size (number of respondents) for estimation of loss in different farm operations at the national level has been provided in the Appendix IV. Similarly, the sample size (no. of respondents) for estimation of loss during storage in different channels at the national level has been provided in the Appendix V.

The intent of the study has been to represent as much of production bases of the selected commodities as possible. However, the sampling has been such that in case of sapota, the study represented as high as 71% of the production base, while the representation was as low as 0.35% in case of poultry meat. This was partly owing to the limited number of the centres specializing in livestock produce. The range for food grains and oilseeds was 22.75% – 4.01%. The actual commodity-wise coverage of production base at the completion of the study has been presented in Appendix VI.

4

DATA COLLECTION PROCEDURE

Collection of requisite information from respondents in a systematic manner is the most important task for success of any survey work. Therefore, it is essential to develop appropriate questionnaire, or schedules, to systematically collect all requisite data. Different schedules were developed based on detailed group discussion with experts to collect the data through enquiry and actual observations. These schedules were evaluated in the field before making them available to all PHT centres for data collection. Field investigators were employed to collect the data for subsequent scrutiny and analysis.

4.1 Data Collection by Enquiry

Five survey schedules for collection of data on assessment of post harvest losses of crops/commodities "by enquiry" were formulated (Appendix II). Schedule 1 was for complete enumeration of the selected villages and schedule 3 was for complete enumeration of selected market channels. Based on the enumerations, the farmers and respondents from marketing channels were selected. Schedule 2A was for data collection of losses in farm operations including harvesting, collection, threshing, sorting/grading, winnowing/cleaning, drying, packaging and transportation. Data on losses during storage at farm/household level was collected in Schedule 2B. Data of losses during storage in market channels was collected in Schedule 4. A brief description of procedure and type of data collected is described below.

4.1.1 Complete enumeration of households of the selected village

Each of the selected villages was completely enumerated at the beginning of survey. The information collected was identification particulars of agro climatic zone, state, district, Tehsil, block, name of village and details of farmers including operational holding, crops/commodities grown or expected to be grown in current year and area under crop. The selection of farmers was done on the basis of these informations.

4.1.2 Losses during farm operations by inquiry

It covers the data collected by enquiry for losses during harvesting and other operations prior to storage. The data was collected at the time of harvest or within one week after harvest. Subsequent visits were made to record the loss in other operations. In the case of fruits, plantation crops, meat, fish, egg and poultry meat, harvesting/production is done two to three times. Hence, the field investigators visited every

time and at the end of operation or within 7 days from completion of operation. The data for operation, method of operation, equipment used, quantity handled and quantity lost etc were recorded. The farmers were interviewed for their assessment of the quantitative loss in each of the farm operations.

4.1.3 Losses at producer level during storage

The data on losses during storage at farmers' level was collected periodically. The periodicity of data collection was once in every month for a period of one year. Previous balance of crop, addition during enquiry period, withdrawal, total quantity stored, loss during the enquiry period, and causes of loss were recorded. In case of fruits, vegetables and plantation crops, more visits within a month were made, as storage time at farmers' fields is usually less than one month. Design of the schedule for this purpose automatically checks the validity of data on the basis of material balance. In case of any difference, correction in the data was possible and correct data could be recorded.

4.1.4 Complete enumeration of market channels

All selected market channels such as mandi, retail market, processing units etc were completely enumerated. Name of stockist/retailer/processing unit/godown and its address, crop/commodity handled, and types of storage structures used were recorded. Wholesalers, retailers, processing units and godowns were segregated and lists prepared.

4.1.5 Losses during storage at market level

This procedure was for recording the losses by enquiry during storage at market level. The frequency of data collection was once in every month and continued for one year. Type of storage, quantity stored, withdrawal, addition, losses during storage, total quantity stored and causes of loss etc were recorded. In the case of processing units, loss was recorded till the crop/commodity was in store and not processed. Design of schedule for this purpose automatically provides a check for the validity of data. In case of fruits, vegetables and plantation crops, frequent visits within a month were made, as the storage time for this commodity is quite less.

The survey was planned for one-year crop cycle for all the selected crops and livestock produce. The enumeration of villages as well as of market channels began on October 01, 2005. The data collection by enquiry and observation began in December 2005 and was completed by 28 February 2007.

4.2 Data Collection by Observation

Survey schedules for collection of data by observation on assessment of losses were developed through intensive dialogue in multiple group meetings among all the research investigators and subject matter specialists from State Agricultural Universities and ICAR institutes. The schedules thus prepared and used for data collection by observation are given in Appendix II.

Altogether 18 schedules were developed for data collection by observation. These schedules can be grouped into two categories namely data collection by observation in farm operations (group of schedule number 5, total 12 schedules) and data collection by observation during storage at farm and market

channels (group of schedule 6, total 6 schedules). Details of data collection procedure by observation for different schedule are given below.

4.2.1 Harvesting losses at farm level in cereals and coriander

Data collection protocols for losses during harvesting, threshing and cleaning/winnowing of wheat, paddy, sorghum, bajra, maize and coriander were similar. Particulars of the selected field, variety, soil condition, date of sowing, harvesting date, method of harvesting, equipment used, etc were recorded. In case of traditional harvesting, manual harvesting or harvesting with reaper, a plot of 5m×5m / 2m×10m was selected and harvested with the method followed by the farmer. Harvested crop of the selected plot was collected separately. Then, the fallen grains on the selected plots were collected and weighed or number of fallen grains was counted. Yield of the selected plot was recorded after threshing it separately with usual practice of the farmer. In case of combine harvesting, the yield of selected field was recorded after harvesting. After measuring actual area of the selected field in which harvesting was done by combine harvester, the yield from 5m×5m plot was estimated. Then a plot of 5m×5m was selected in the harvested field. The weight/number of fallen grains from the 5m×5m plot was recorded.

For estimating the loss during threshing/shelling, the harvested crop of 5m×5m was threshed with the usual practice followed by the farmer. The produce and straw were weighed separately. Then a sample of 250g straw was drawn and grains recovered from straw were separated and weighed or number of grains was recorded.

To estimate the losses during cleaning/winnowing, a sample of 10 kg unclean grains-straw mixture was drawn and cleaned using the method followed by the farmer. Grain and straw were collected separately. A sample of 250g was drawn following quadruple technique from the straw. Grains recovered from the straw sample were separated and counted/weighed.

4.2.2 Losses at farm level in oilseeds and pulses

In order to collect the loss data by actual observation during harvesting, threshing and winnowing stages of oilseeds and pulses (mustard, soybean, groundnut, sunflower, safflower, cottonseed, pigeon pea, chickpea, green gram and black gram) different procedures were followed. For estimating losses during harvesting for pulses, and safflower, a plot of 5m×5m was selected and loss was estimated by the method followed for cereals. In the case of groundnut, the plants of 5m×5m plot were uprooted through usual practice and then pods left in the soil of selected plot were collected and weighed. Sum of yields from threshing the crop of selected plot and pods collected from the soil gave the production from 5m×5m plot. Again a separate plot of 5m×5m was selected when farmer stopped ploughing and picking left-over pods. The weight/number of remaining pods in the soil was recorded.

For mustard and soybean, 10 plants were randomly selected from the selected plot of 5m×5m. Number of siliques/ pods present in each plant including shattered siliques/ pods, if any, were counted. Then, the farmer harvested the whole field including the selected plot as usual. When all harvested crop of the field reached the threshing floor, ten plants were randomly selected once again after ensuring that the selected

plants contained all branches and had been harvested from main stem. Number of shattered siliques/pods of each selected plant was counted.

For sunflower, plot of 5m×5m and ten plants were selected as done in mustard crop. Number of seeds present in each plant prior to harvest was counted and flowers were marked Then the farmer harvested the crop. After harvesting, the same flowers were taken once again and numbers of seeds shattered were counted.

In case of cottonseed, the farmer was allowed to pick the cotton bolls with usual practice. After last picking, a plot of 5m×5m was selected from which 10 plants were selected randomly. Numbers of bolls already plucked and opened balls remaining un-plucked were counted for each plant.

For estimating the loss during threshing for pulses, safflower and groundnut, harvested crop of 5m×5m or 2m×10m plot was taken and threshed with the method followed by the farmer. The grain/pod and straw obtained after threshing were weighed separately. A sample of 250g from straw was drawn and analyzed. The number/weight of seeds in the straw was counted/ weighed. In case of sunflower, mustard and soybean, a sample of three bundles of harvested crop of same field was drawn, threshed and analyzed with the method similar to cereals.

To estimate losses during cleaning/ winnowing; the methodology was the same as that followed for cereals. In cottonseed, losses during threshing and cleaning/ winnowing were not estimated.

4.2.3 Losses at farm level in fruits and plantation crops

In the estimation of losses during harvesting of the fruits, the selected trees were harvested using the method followed by the farmer. Production from all selected trees was recorded and harvested produce was analyzed for damages during harvesting. The fruits not suitable for human consumption were taken as loss in this case. Causes of loss were also recorded. For estimating the losses during grading/sorting a sample of 10kg or 50 fruits was drawn and graded or sorted following the method of farmer. Damaged fruits during this operation were recorded. To estimate the loading, transportation and unloading loss (farm to market), a sample of 10 kg or 50 number or 5 boxes (if packed in boxes) was drawn after unloading in the market. The undamaged and spoiled pieces were separated and their weight/number was recorded. For Cashew, the sample size for loss estimation during grading/sorting and transport was 5 kg and methodology similar to the fruits was used.

4.2.4 Losses at farm level in vegetable crops

Data on loss during farm operations in case of vegetable crops was collected in separate schedules following different procedures. For estimating losses during harvesting a plot of 5m×5m was selected and harvested with the method followed by the farmer to get the production of plot.

For onion, potato and turmeric, in case of manual harvesting, the left-over produce in the soil in the selected plot was collected after completion of harvesting. In case of mechanical harvesting, the production of 5m×5m plot was recorded as usual and then again a plot of 5m×5m was selected and the left-over produce in the soil was collected and weighted.

In chilli and tomato, the crop was harvested from selected plot with usual method. Then the harvested produce of selected plot was analysed for damage. Weight of damaged produce gave the loss of selected plot during harvesting. For cabbage, mushroom, cauliflower and green pea, the loss during harvest was not estimated.

For Tapioca, 10 plants in a row (continuous) in place of 5m×5m plot were taken to estimate the loss during harvest. The left-over produce in the soil of the area of 10 selected plants was collected and taken as loss. To estimate the loss during cleaning/grading and sorting, the operation actually performed for tapioca is trimming. Sample of 50 kg tapioca was drawn in place of 10 kg / 50 numbers. Then weight of produce/part of produce rejected during trimming was considered as loss and recorded. For estimating the loss during grading/sorting and transportation of vegetables, the methodologies of fruits were followed.

4.2.5 Losses at farm level in black pepper

To estimate the losses during harvest of black pepper, four vines of black pepper were selected as done for fruits/ plantation crops and same methodology for the loss estimation was followed. To estimate the loss during threshing, 5 kg of unthreshed produce was taken and threshing was done with the method followed by the farmer. Rest of the methodology was similar to that followed for cereals. For loss during cleaning/ grading and sorting, a sample of 5 kg unclean pepper was taken and cleaned with the method followed by farmer. Rest of the methodology was similar to that of cereals.

4.2.6 Post harvest losses in milk

Estimation of loss in milk was very difficult to record by observation. The loss at each stage was assessed by the Research Engineer /Associates of the project. The loss in different operations was based on their personal assessment and observation.

4.2.7 Losses at farm level in sugarcane

In the estimation of the loss during harvest of sugarcane, a plot of 5m×5m was selected and the farmer was allowed to harvest the plot with usual practice. The produce of the selected plot was weighed to get the production. After harvesting, the stubbles left in the selected plot were separated. Weight of stubbles and unpicked sugarcane pieces in selected plot gave the loss during harvest.

To estimate the loss during staling of sugarcane, three bundles of sugarcane were prepared in the field. Weight of these bundles was recorded. Then the bundles were transported to the crushing unit with the usual practice followed by the farmer and kept in the crushing yard till the farmer went for crushing. The period of staling was the time between weighing bundles in the field and immediately before crushing and this duration was recorded. The bundles were weighed again before crushing. The difference in the weight gave loss during staling.

4.2.8 Losses of egg at producer level

Data on losses during collection and packaging of eggs at poultry farm was collected in a separate schedule. The worker was allowed to collect all the eggs laid in the selected shed. Total number of eggs collected and damaged ones were counted separately. To estimate the loss during packaging, the worker

was allowed to pack the collected eggs of one shed and numbers of eggs packed and damaged were counted.

4.2.9 Losses of meat at producer level

In order to estimate losses of meat at producer level, two butcher's shop and two slaughterhouses (organized) were selected in a district. The data on losses during slaughter were collected once in every month for one year. To determine the loss during slaughter, the data of 5 animals slaughtered continuously were recorded. After slaughter, weight of fresh carcass was taken. The parts of carcass removed by the butcher which were not fit for human consumption due to damages, injury, diseased parts etc were weighed and recorded.

4.2.10 Losses of poultry meat at producer level

The data on loss of poultry meat during slaughter and storage at poultry meat producer level was collected in this schedule. Two slaughterhouses and two butcher's shop, where poultry birds were slaughtered, were taken in each district for data collection. The frequency of data collection was once in every month for one year. To estimate the loss during slaughter, the methodology was similar to that of meat.

To estimate the loss during storage, the type of storage, capacity etc used for storing dressed chicken was recorded. Five chickens (carcasses) were randomly selected from the store and checked for their condition. Spoiled portion of the carcass was considered as loss.

4.2.11 Losses of inland fish at fisherman level

To record the losses during catch of inland fish, weight of total catch on the date of visit was recorded and then the fisherman was asked to sort the fish (fishes not fit for human consumption) after that the weight of discarded fishes was taken.

4.2.12 Losses of marine fish at landing centre

Losses during catch of marine fish was not recorded due to practical difficulty. Estimation of loss were recorded after boat landed on designated landing center. After unloading of fish from boat and weighing the total fish landed, the boat was checked for any fish left in the boat. Some fish (uneconomical/small fish, damaged or spoiled one) remain indisposed were usually thrown. Weight of these fish before throwing them was taken.

4.3 Data Collection through Observation in Storage Channels

4.3.1 Losses during storage in different channels for cereals, pulses, oilseeds and coriander

Samples of 100-150 g of commodity were taken every month subject to the availability with the respondent. Addition in the stock, consumption, sale or processed stock in the previous month and remaining stock was recorded for the enquiry period. The samples were packed into polythene pouches

with the identity slips. These samples were sent to concerned PHT center for further analysis soon after collecting them. The samples collected for different crops were analyzed for moisture content, 1000 grains weight, number of undamaged grains, and infested/damaged grains and their weight were recorded.

4.3.2 Losses during storage in different channels in fruits, vegetables and plantation crops

A separate schedule was designed to collect the data on loses during storage of fruits, vegetables and plantation crops in different channels. In some of the fruits and vegetables, the storage period was less than one month in all channels. In those cases, the field investigator visited the respondent at the time of disposal even before one month. To estimate loss during storage, the data about addition, sale/consumption/ quantity processed was recorded. Then a sample of 10 kg/50 numbers/3 packs of produce was drawn (when respondent allowed drawing the sample). The damaged produce was separated and weighed/counted. For Cashew, a sample of 5 kg was drawn for loss estimation. Methodology for sample analysis remained similar to those of cereals. Loss during storage was not estimated for pepper and tapioca by observation (as decided in group meeting).

4.3.3 Losses of egg during transportation and storage in different channels

In order to collect the data on losses of eggs by observation during transportation and storage at wholesaler and retailer levels, mode of transport, total distance of transportation and time taken for transportation (days) were recorded. Then, at the time of unloading, 5 packages of filler flats were selected randomly. Total numbers of eggs present in the selected filler flats and damaged eggs were counted. For estimating loss during storage five packages of filler flats were selected randomly from the store and numbers of eggs present and damaged were counted.

4.3.4 Losses at market level storage and transportation of inland fish

The loss during transport at the time of unloading at market/processing unit and storage at market/processing unit were recorded in a well-designed schedule. To record the loss during transportation, a sample of 10 kg fish or complete pack (whichever was allowed by respondent) was drawn and weighed. Then the fish spoiled during transport was sorted and weighed. Similar method was followed to record the loss during storage.

4.3.5 Losses at market level storage, drying and transportation of marine fish

Data on loss during transportation, drying and storage of marine fish were collected. The methodology for transportation and storage was similar to that followed for inland fish. To estimate the loss during drying, the details of drying method and particulars were collected. Then a sample of 5 kg from the fish kept for drying was drawn. The sample was analyzed and the fish spoiled during drying was separated and weighed. Loss during this operation was estimated only when the respondent performed it.

(a) Manual harvesting of wheat

(b) Combine harvesting of safflower

(c) Traditional threshing of paddy

(d) Threshing of wheat

(e) Drying of wheat

(f) Packaging of wheat

Figure 4.1 Assessment of losses in grains

(a) Assessment of loss during harvesting of banana (by observation)

(b) Apples collected after harvesting (by observation)

(c) Sorting and grading of apples before packaging

(d) Packaging of apples

(e) Storage of banana by wholesaler

Figure 4.2 Assessment of losses in fruits

(a) Transportation of banana and tomato in the same truck

(b) Transportation of tomato by retailer

(c) Storage of onion at farm level

(d) Storage of onion in godown

Figure 4.3 Assessment of losses in vegetables

(a) Loss during collection of Eggs (by observation)

(b) Loss after slaughtering (by observation)

(c) Marine fish at landing centre

(d) Loss during drying of marine fish (by observation)

(e) Transportation of fish to processing industry

(f) Retail marketing of inland fish

Figure 4.4 Assessment of losses in livestock produce

5

ANALYTICAL TOOLS AND PROCEDURES

The data collected by the PHT centres were scrutinized for functionality through internal consistency checks at the time of data entry. The digital data from different centres were pooled appropriately for further analysis.

Data collected through enquiry were analysed using Statistical Analysis Software (SAS) whereas data by observation were analysed using Microsoft Excel. Data for each selected district were analysed separately and then the results were pooled by assigning appropriate weights at higher levels (i.e agro-climatic zones, states etc.). Sampling weights were obtained for each record according to sampling design implemented for data collection at district level (i.e. weightage of sample numbers of farmers, villages and blocks to their actual number).

For estimating the losses at agro-climatic zone level, weightage were assigned based on the production of the specific crop/commodity in all the sample districts. Similarly, post harvest losses at the national level were estimated by assigning weightage on the basis of the production of a specific crop/commodity in the agro-climatic zones. The procedure for analysis of data is described below.

All notations used in the following equations have been explained at the end of this chapter.

5.1 Analysis of Data of Farm Operations

The data obtained though enquiry and observation for each district were analyzed separately.

5.1.1 Data collected by enquiry

Total quantity handled of a crop/commodity for a particular farm operation in a district was obtained as

$$\bar{Y}_i = \frac{R_i}{h_i} \sum_{h=1}^{h_i} \frac{V_{ih}}{v_{ih}} \sum_{v=1}^{v_{ih}} \frac{F_{ihv}}{f_{ihv}} \sum_{f=1}^{f_{ihv}} y_{ihvf} \qquad (1)$$

Total quantity of the crop/commodity lost in the same farm operation in a particular district is given by:

$$\bar{\delta}_i = \frac{R_i}{h_i} \sum_{h=1}^{h_i} \frac{V_{ih}}{v_{ih}} \sum_{v=1}^{v_{ih}} \frac{F_{ihv}}{f_{ihv}} \sum_{f=1}^{f_{ihv}} \delta_{ihvf} \qquad (2)$$

The loss (%) obtained by enquiry for the crop/commodity in i[th] district was estimated using following formula:

$$\hat{L}_i = \frac{\hat{\delta}_i}{\hat{Y}_i} X\ 100 \tag{3}$$

Estimate of variance of $\hat{L}_i$ was obtained as follows:

$$\hat{V}\left(\hat{L}_i\right) = \left(\frac{\hat{\delta}_i}{\hat{Y}_i} \times 100\right)^2 \left(\frac{\hat{V}\left(\hat{\delta}_i\right)}{\left(\hat{\delta}_i\right)^2} + \frac{\hat{V}\left(\hat{Y}_i\right)}{\left(\hat{Y}_i\right)^2}\right) \tag{4}$$

Where the estimates of variance of $\hat{\delta}_i$ and $\hat{Y}_i$ were obtained by

$$\hat{v}\left(\hat{\bar{X}}_i\right) = \frac{1}{b_i(b_i - 1)} \sum_{k=1}^{b_i} \left(\hat{X}_{ik} - \hat{\bar{X}}_i\right)^2 \tag{5}$$

$$\hat{X}_{ik} = \frac{V_{ik}}{v_{ik}} \sum_{r=1}^{r_{ik}} \frac{F_{ikr}}{f_{ikr}} \sum_{f=1}^{f_{ikr}} x_{ikrf}$$

$$\hat{\bar{X}}_i = \frac{1}{b_i} \sum_{k=1}^{b_i} \hat{X}_{ik}$$

where $\hat{\bar{X}}_i$ is the mean of variable (quantity handled or quantity lost) for i[th] district, and X_{ik} is estimate of quantity handled/lost for b[th] block in i[th] district.

5.1.2 Data collected by actual observation

The estimate of quantity handled for an operation of a crop/commodity in the district was obtained as:

$$\hat{\bar{Y}}_i' = \frac{B_i}{b_i} \sum_{k=1}^{b_i} \frac{V_{ik}}{v_{ik}} \sum_{r=1}^{r_{ik}} \frac{F_{ikr}}{f_{ikr}} \sum_{f=1}^{f_{ikr}} y'_{ikrf} \tag{6}$$

Similarly, an estimate of quantity lost was obtained as:

$$\hat{\bar{\delta}}_i' = \frac{B_i}{b_i} \sum_{k=1}^{b_i} \frac{V_{ik}}{v_{ik}} \sum_{r=1}^{r_{ik}} \frac{F_{ikr}}{f_{ikr}} \sum_{f=1}^{f_{ikr}} \delta'_{ikrf} \tag{7}$$

The percentage loss for the district could then be represented as:

$$\hat{L}'_i = \frac{\hat{\bar{\delta}}_i'}{\hat{\bar{Y}}_i'} \times 100 \tag{8}$$

Estimate of variance of $\left(\hat{L}_i\right)$ was obtained as:

$$\hat{V}\left(\hat{L}'_i\right) = \left(\frac{\hat{\bar{\delta}}_i'}{\hat{\bar{Y}}_i'} \times 100\right)^2 \left(\frac{\hat{V}\left(\hat{\bar{\delta}}_i'\right)}{\left(\hat{\bar{\delta}}_i'\right)^2} + \frac{\hat{V}\left(\hat{\bar{Y}}_i'\right)}{\left(\hat{\bar{Y}}_i'\right)^2}\right) \tag{9}$$

where, the estimates of variances of δ_i' and $\bar{\bar{y}}^{*}$ were obtained as

$$\hat{V}\left(\bar{X}_i'\right)=\frac{1}{b_i(b_i-1)}\sum_{k=1}^{b_i}\left(\hat{X}_{ik}'-\bar{\hat{X}}_i'\right)^2 \qquad (10)$$

where X' is a variable for quantity handled / quantity lost in ith district and

$$\hat{X}_{ik}'=\sum_{j=1}^{s_{ik}}\sum_{j=1}^{f_{ikj}}x_{ikjq}'$$

$$\bar{\hat{X}}_i'=\frac{1}{b_i}\sum_{k=1}^{b_i}\hat{X}_{ik}$$

5.1.3 Pooling of data obtained through enquiry and observation

In order to estimate the loss during farm operations at district level for different crops/commodities, the estimates obtained for loss (%) through enquiry and observation were pooled using following weighted estimator.

$$\bar{\bar{L}}_i^{(c)}=\frac{\bar{\bar{s}}_i^{*2}\hat{\bar{L}}_i+\bar{\bar{s}}_i^{2}\bar{\bar{L}}_i^{*}}{\left(\bar{\bar{s}}_i^{*2}+\bar{\bar{s}}_i^{2}\right)} \qquad (11)$$

The standard error of estimate of loss (%) for the pooled estimator was obtained by

$$\hat{\bar{S}}_i=\sqrt{\frac{\bar{\bar{s}}_i^{*2}\bar{\bar{s}}_i^{2}}{\bar{\bar{s}}_i^{2}+\bar{\bar{s}}_i^{*2}}} \qquad (12)$$

5.1.4 Estimation of loss at agro-climatic zone level

Data collected through enquiry

The estimate of loss of a crop/commodity in a farm operation at agro-climatic zone level through enquiry was obtained using the following estimator.

$$\bar{\bar{L}}_z=\frac{\sum_{i=1}^{d}\hat{\bar{P}}_{iz}\times\hat{\bar{L}}_{iz}}{\sum_{i=1}^{d}\bar{\bar{P}}_{iz}} \qquad (13)$$

Data collected through observation

The estimate of loss of a crop/commodity in a farm operation at agro-climatic zone level through observation was obtained as follows.

$$\hat{\bar{L}}_z'=\frac{\sum_{i=1}^{d}\hat{\bar{P}}_{iz}\times\overline{\hat{L}}_{iz}'}{\sum_{i=1}^{d}\bar{\bar{P}}_{iz}} \qquad (14)$$

The standard error of estimate of loss for data colleted through enquiry / observation was obtained by

$$\hat{\bar{S}}_z = \sqrt{\frac{\sum_{i=1}^{d} P_{iz}^2 \hat{V}(\hat{\bar{L}}_{iz}^*)}{\left(\sum_{i=1}^{d} P_{iz}\right)^2}} \qquad (15)$$

where,

$\hat{\bar{S}}_{iz}$: standard error of estimate of enquiry/observation in the i^{th} district of z^{th} agro-climatic zone as estimated using equations 4 and 9

$\hat{\bar{L}}_{iz}^*$: loss (%) obtained by collecting data through enquiry/observations in the i^{th} district falling in z^{th} agro-climatic zone

The estimates of loss (%) and their standard errors from pooled data collected through enquiry and observation at agro-climatic zone level were obtained using estimators similar to the Equations 11 and 12, respectively. Again, using production data of crops/commodities at agro-climatic zones, weighted estimators of loss (%) and their standard errors were obtained as above for estimating national level loss (%) and its standard errors.

5.2 Estimation of Loss during Storage at Farm level

District-wise estimates of loss (%) from the data collected through enquiry and observation were obtained separately and then pooled through optimum pooling technique.

5.2.1 Data collected through enquiry

Total quantity of a crop/ commodity withdrawn in a district was obtained by

$$\hat{\bar{P}}_i = \frac{B_i}{h_i} \sum_{h=1}^{h_i} \frac{V_{ih}}{v_{ih}} \sum_{v=1}^{v_{ih}} \frac{F_{ihv}}{f_{ihv}} \sum_{f=1}^{f_{ihv}} \left(\sum_{k=1}^{T} p_{ihvfk} \right) \qquad (16)$$

Estimated total quantity lost in the i^{th} district was obtained by

$$\hat{\bar{\zeta}}_i = \frac{B_i}{h_i} \sum_{h=1}^{h_i} \frac{V_{ih}}{v_{ih}} \sum_{v=1}^{v_{ih}} \frac{F_{ihv}}{f_{ihv}} \sum_{f=1}^{f_{ihv}} \left(\sum_{k=1}^{T} \zeta_{ihvfk} \right) \qquad (17)$$

The loss (%) through enquiry in i^{th} district was estimated as:

$$\hat{\bar{L}}_i = \frac{\hat{\bar{\zeta}}_i}{\hat{\bar{P}}_i} \times 100 \qquad (18)$$

Variance of $\hat{\bar{L}}_i$ was estimated in the same way as in Equation (4).

5.2.2 Data collected through observation

Loss (%) for data collected through observation may be represented as

$$\hat{\bar{L}}_i' = \frac{\frac{B_j}{b_j}\sum_{h=1}^{b_j}\sum_{s=1}^{s_h}\sum_{f=1}^{f_{hs}}\left(\sum_{t=1}^{T} d_{ihsft}\right)}{\frac{B_j}{b_j}\sum_{h=1}^{b_j}\sum_{s=1}^{s_h}\sum_{f=1}^{f_{hs}}\left(\sum_{t=1}^{T} d_{ihsft} + \sum_{t=1}^{T} u_{ihsft}\right)} \times 100 \qquad (19)$$

An estimate of variance of loss (%) may be obtained as

$$\hat{V}\left(\hat{\bar{L}}_i'\right) = \left(\hat{\bar{L}}_i'\right)^2 \left\{ \frac{\left(\hat{S}_i'(d_i)\right)^2}{\left(\frac{B_j}{b_j}\sum_{h=1}^{b_j}\sum_{s=1}^{s_h}\sum_{f=1}^{f_{hs}}\left(\sum_{t=1}^{T} d_{ihsft}\right)\right)^2} + \frac{\left(\hat{S}_i'(TG_i)\right)^2}{\left(\frac{B_j}{b_j}\sum_{h=1}^{b_j}\sum_{s=1}^{s_h}\sum_{f=1}^{f_{hs}}\left(\sum_{t=1}^{T} TG_{ihsft}\right)\right)^2} \right\} \qquad (20)$$

The estimate of variance of d_i (numerator part - I of estimator (12)) and TG_i (numerator part –II of estimator (12) was obtained as

$$\hat{V}\left(\bar{\bar{X}}_i\right) = \frac{1}{b_j(b_j-1)}\sum_{h=1}^{b_j}\left(\hat{\bar{X}}_{ih} - \hat{\bar{X}}_i\right)^2 \qquad (21)$$

where, X in the above equation is the variable d_i or TG_i merger of the estimates of loss (%) through enquiry and observation is achieved by using Equations (11) and (12).

5.3 Estimation of Loss during Storage in Marketing Channels (Wholesaler, Retailer, Godown, and Processing Unit) at District Level

5.3.1 Data collected by enquiry

The estimates of loss (%) for different crops /commodities and their estimates of variance for data collected through enquiry were obtained using equations (16), (17) and (18).

5.3.2 Data collected by actual observation

Estimate of loss (%) for data collected through actual observation was obtained as

$$\hat{\bar{L}}_i' = \frac{\sum_{h=1}^{b_j}\sum_{t=1}^{T} d_{ihs}}{\left(\sum_{h=1}^{b_j}\sum_{t=1}^{T} d_{ihs} + \sum_{m=1}^{m}\sum_{t=1}^{t} u_{ihs}\right)} \times 100 \qquad (22)$$

where, $\hat{\bar{L}}_i'$ denotes loss (%) during storage in ith district.

An estimate of variance was obtained as

$$\hat{V}\left(\hat{L}_i'\right)=\left(\hat{L}_i'\right)^2\left\{\frac{\left(\hat{S}_i^2(d_i)\right)^2}{\left(\sum_{h=1}^{h_i}\sum_{t=1}^{T} d_{iht}\right)^2}+\frac{\left(\hat{S}_i^2(TG_i)\right)^2}{\left(\sum_{h=1}^{h_i}\sum_{t=1}^{T} TG_{iht}\right)^2}\right\} \qquad (23)$$

The estimates of variance of d and TG_i were obtained in the same way as in Equation 21. The estimates of loss (%) through enquiry and observation were combined using Equations (11) and (12).

5.4 Estimation of Total Loss of Crop/ Livestock Produce at National Level

To estimate the total loss in a crop/commodity, it is essential to know the quantity of crop/ commodity retention/handling in each operation and channels during storage. Since, the total produce is handled in each of the farm operations, the total loss of a crop/ commodity in all farm operations is taken as arithmetic sum of losses in individual operations.

However, to estimate the total loss during storage in different marketing channels, data of percent retention in each market channel was required. To obtain this information, a Schedule was developed (Appendix II). The percent retention in each channel were collected from 62 respondents. These respondents were Heads of ICAR Institutes and Project Directorates dealing in research and development of specific crop/livestock produce as well as all Research Engineers of AICRP on PHT centres. The respondents provided estimates of percent retention in each channel based on their experience and judgment, availability of previous data, survey of small group of stakeholders of channels and experience in the field during data collection. The data received from them was compiled, scrutinized and analyzed after discarding the extreme values (beyond average ± 2×SE) to obtain the average percent retention in each channel. The estimated values of percent retention in different channels are presented in Table 5.1

Total percent loss of a crop/ commodity during storage in different channels was estimated as follows.

$$\bar{L}_{T\%}=\frac{\bar{L}_1\times\bar{R}_1+\bar{L}_2\times\bar{R}_2+\bar{L}_3\times\bar{R}_3+\bar{L}_4\times\bar{R}_4+\bar{L}_5\times\bar{R}_5}{100} \qquad (24)$$

Total loss in a crop/commodity at national level was calculated by adding the total loss in farm operations and total loss during storage in different channels.

Table 5.1 Estimates of percent storage of major crops and livestock produce in different channels at national level

S. No.	Crop/ commodity	Retained by farmer	Stored in godowns	Retained by wholesaler	Retailer level storage	Stored in processing unit
	Grains (Cereals, Pulses, Oilseeds)					
1.	Paddy	33.2	6.6	15.5	2.7	42.0
2.	Wheat	37.8	11.8	17.8	4.9	27.7
3.	Maize	23.4	8.7	38.2	14.4	15.3
4.	Bajra	39.2	4.5	36.6	10.6	9.1
5.	Sorghum	22.7	4.9	59.8	10.9	1.7
6.	Pigeon pea	57.7	4.5	9.7	10.0	18.1
7.	Chick pea	23.5	8.1	37.2	13.5	17.7
8.	Black gram	50.8	6.6	17.4	12.6	12.6
9.	Green gram	33.2	0.5	30.0	27.2	9.1
10.	Mustard	28.9	5.4	24.8	8.5	32.4
11.	Cottonseed	8.3	4.2	56.4	10.5	20.6
12.	Soybean	12.2	12.6	50.7	9.2	15.3
13.	Safflower	5.6	4.0	28.0	5.0	57.4
14.	Sunflower	1.7	2.5	22.3	4.2	69.3
15.	Groundnut	9.4	6.7	40.2	10.1	33.6
	Fruits					
16.	Apple	1.9	8.2	51.3	21.3	17.3
17.	Banana	2.6	5.0	77.2	14.9	0.3
18.	Citrus	2.2	1.8	54.8	34.2	7.0
19.	Grapes	0.3	14.6	33.7	39.7	11.7
20.	Guava	20.2	0.0	31.0	47.6	1.2
21.	Mango	4.4	1.9	36.8	34.7	22.2
22.	Papaya	3.6	0.4	44.2	49.8	2.0
23.	Sapota	1.1	9.6	42.7	41.8	4.8
	Vegetables					
24.	Cabbage	7.2	5.2	40.4	46.1	1.1
25.	Cauliflower	5.5	7.6	46.0	39.6	1.3
26.	Green pea	5.2	0.1	54.4	37.9	2.4

Table 5.1 (Continued)

S. No.	Crop/ commodity	Retained by farmer	Stored in godowns	Retained by wholesaler	Retailer level storage	Stored in processing unit
27.	Mushroom	12.5	0.0	0.0	87.5	0.0
28.	Onion	20.3	18.1	38.0	22.3	1.3
29.	Potato	9.0	55.6	24.7	7.8	2.9
30.	Tomato	26.3	0.0	39.7	25.7	8.3
31.	Tapioca	4.0	0.0	46.6	43.7	5.7
	Plantation crops and spices					
32.	Arecanut	1.0	0.0	70.3	14.0	14.7
33.	Black pepper	4.2	28.8	28.7	17.0	21.3
34.	Cashew	1.9	0.9	31.6	5.8	59.8
35.	Chilli	3.3	5.6	65.7	17.3	8.1
36.	Coconut	7.1	11.4	41.5	14.8	25.2
37.	Coriander	4.7	0.6	61.4	25.7	7.6
38.	Sugarcane	8.9	0.0	19.4	5.0	66.7
39.	Turmeric	12.0	23.0	45.5	9.1	10.4
	Livestock produce					
40.	Egg	5.2	0.4	56.2	37.5	0.7
41.	Inland fish	4.4	1.0	34.5	60.0	0.1
42.	Marine fish	0.1	15.1	43.7	15.6	25.5
43.	Meat	1.0	1.1	47.3	50.5	0.1
44.	Poultry meat	1.1	0.2	52.6	45.2	0.9
45.	Milk	20.6	0.0	30.7	16.4	32.3

The data analyzed by application of the tools and procedures described above were critically examined by an Experts Committee (Appendix VII) constituted by ICAR. This was followed by presentations of the results of this study to high officials from ICAR and other related important organizations such as Department of Agriculture and Cooperation (DoAC), Food Corporation of India (FCI), Central Warehousing Corporation (CWC), National Horticulture Board (NHB), etc., prior to its presentation before the Parliamentary Standing Committee on Agriculture (PSCA) of India in June 2010. After incorporating the valuable suggestions of this august body, the final report was submitted in September 2010 to PSCA for perusal and approval. The approval of Parliament of India for using the data came from the Hon'ble Speaker, Loksabha in August 2012 to help research workers, policy makers and other stake holders for adapting suitable remedial interventions towards reduction of post harvest losses.

Notations

$\hat{\bar{Y}}_i$: Estimate of quantity handled for a particular farm operation of the crop/commodity in i^{th} district (by enquiry)

B_i : Total number of blocks in i^{th} district

b_i : Number of selected blocks in i^{th} district

V_{ib} : Total number of villages in b^{th} selected block of i^{th} district

v_{ib} : Number of selected villages in b^{th} selected block of i^{th} district for a farm operation

F_{ibv} : Total number of farmers growing a particular crop/commodity in v^{th} selected village of b^{th} selected block from i^{th} district

f_{ibv} : Number of selected farmers growing a crop/commodity in v^{th} selected villages of b^{th} selected block of i^{th} district for a farm operation

y_{ibvf} : Quantity handled for a farm operation of a crop/commodity by the f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by enquiry)

$\hat{\bar{\delta}}_i$: Estimate of quantity lost for a farm operation of a crop/commodity in i^{th} district (by enquiry)

δ_{ibvf} : Quantity of crop/commodity lost at a particular farm operation by the f^{th} selected farmer in v^{th} selected village of b^{th} selected block for i^{th} district (by enquiry)

$\hat{\bar{L}}_i$: Estimate of percent loss by enquiry for i^{th} district

$\hat{V}(\bar{L}_i)$: Estimate of variance of percent loss by enquiry for i^{th} district

$\hat{V}(\hat{\bar{\delta}}_i)$: Estimate of variance of quantity lost (by enquiry) for an operation in the crop for i^{th} district

$\hat{V}(\hat{\bar{Y}}_i)$: Estimate of variance of quantity handled (by enquiry) for an operation in the crop for i^{th} district

$\hat{\bar{Y}}'_i$: Estimates of quantity handled at a particular farm operation of the crop/commodity in i^{th} district (by observation)

y'_{ibvf} : Quantity handled at a particular farm operation of the crop/ commodity of the f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by observation)

$\hat{\bar{\delta}}'_i$: Estimates of quantity lost for a particular farm operation of the crop/ commodity in i^{th} district (by observation)

δ'_{ibvf} : Quantity lost at particular farm operation of the crop/ commodity by the f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by observation)

$\hat{\bar{L}}'_i$: Estimate of percent loss by observation for i^{th} district

$\hat{V}(\hat{\bar{L}}'_i)$: Estimate of variance of percent loss by observation for i^{th} district

$\hat{V}(\hat{\bar{\delta}}'_i)$: Estimate of variance of quantity lost (by observation) for an operation in a crop / commodity of i^{th} district

$\hat{V}\left(\bar{\hat{Y}}_i\right)$: Estimate of variance of quantity handled (by observation) for an operation in a crop/commodity for i^{th} district

$\hat{\bar{L}}_i^{(c)}$: Estimate of combined percent loss in a farm operation of i^{th} district for c^{th} crop

$\hat{s}_i$: Standard error estimate of loss (%) in a farm operation of i^{th} district obtained by observation

$\hat{s}_i'$: Standard error estimate of loss (%) in a farm operation of i^{th} district obtained by enquiry

n_i : Number of data points obtained through method of actual observation in a particular farm operation for a particular crop/commodity in i^{th} district

n_i' : Number of data points obtained through method of enquiry in a particular farm operation for a particular crop/commodity in i^{th} district

$\hat{\bar{S}}_i$: Estimate of standard error of combined loss (%) in a farm operation of i^{th} district

P_{iz} : Production of crop/commodity for the i^{th} district falling in z^{th} zone (in year 2005-06)

$\hat{\bar{L}}_{iz}$: Estimate of percent loss (by enquiry) of the crop/commodity in a farm operation for the i^{th} district falling in z^{th} agro climatic zone

$\hat{\bar{L}}_z$: Estimated percent loss of the crop/commodity in a operation for z^{th} agro-climatic zone (by enquiry)

$\hat{\bar{L}}_{iz}'$: Estimate of percent loss (by observation) of the crop/commodity in the operation for the i^{th} district falling in z^{th} agro climatic zone

$\hat{\bar{L}}_z'$: Estimated percent loss of the crop/commodity in an operation for z^{th} Agro-climatic zone (by observation)

$\hat{s}_{iz}$: Standard error estimate of loss (%) in a farm operation of i^{th} district in z^{th} agro-climatic zone by enquiry / observation

$\hat{\bar{S}}_z$: Estimate of standard error of estimated loss (%) in a farm operation of z^{th} agro-climatic zone by enquiry/observation

$\hat{\bar{L}}_z$: Combined estimated percent loss of a crop/commodity in the operation of z^{th} agro-climatic zone

$\hat{\bar{S}}_z$: Combined standard error estimate of percent loss of a crop/commodity in a farm operation for z^{th} agro-climatic zone

P_z : Production of crop/commodity for the z^{th} zone (in year 2005-06)

$\hat{\bar{L}}_N$: Estimated percent loss of the crop in an operation at National level

$\hat{\bar{S}}_N$: Standard error estimate of percent loss of the crop in a farm operation at National level

$\hat{\bar{P}}_i$: Total quantity withdrawal from the store of crop/commodity from selected farmers of the i^{th} district during total enquiry period

P_{ijvtf} : Quantity withdrawal from the storage of crop/commodity between previous and t^{th} visit to f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by enquiry)

$\hat{\xi}_{ti}$: Estimate of total quantity lost of crop/commodity of selected farmers of the i^{th} district during total enquiry period

ξ_{ibvfl} : Quantity lost of crop/commodity between previous and t^{th} visit to f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by enquiry)

d_{ibvfl} : Weight/number of crop/commodity damaged in the sample drawn at the time of t^{th} visit to f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by observation)

u_{ibvfl} : Weight/number of crop/commodity undamaged in the sample drawn at the time of t^{th} visit to f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by observation)

TG_{ibvfl} : Total weight/number of crop/commodity of the sample drawn at the time of t^{th} visit to f^{th} selected farmer in v^{th} selected village of b^{th} selected block of i^{th} district (by observation)

$\hat{\bar{S}}_i^2(d_i)$: Estimate of standard error of weight/number of crop/commodity damaged in stores of farmers of i^{th} district (by observation)

$\hat{\bar{S}}_i^2(TG_i)$: Estimate of standard error of total weight/number of crop/ commodity drawn from stores of farmers of i^{th} district (by observation)

d_{ibr} : Weight/number of crop/commodity damaged in the sample drawn at the time of t^{th} visit to b^{th} respondent (godown/wholesaler/retailer/ processing unit) of i^{th} district (by observation)

u_{ibr} : Weight/number of crop/commodity undamaged in the sample drawn at the time of t^{th} visit to b^{th} respondent (Godown/ wholesaler/ retailer/ processing unit) of i^{th} district (by observation)

SE : Standard error of estimates

$\hat{L}_{TS}$: Total loss (%) during storage in different marketing channels

$\hat{L}_F$: Estimated loss (%) of crops / commodity during storage at farm

$\hat{R}_F$: Estimated % retention of crops / commodity in storage at farm

$\hat{L}_G$: Estimated loss (%) of crops / commodity during storage at godown

$\hat{R}_G$: Estimated % retention of crops / commodity in storage at godown

$\hat{L}_W$: Estimated loss (%) of crops / commodity during storage at wholesaler

$\hat{R}_W$: Estimated % retention of crops / commodity in storage at wholesaler

$\hat{L}_R$: Estimated loss (%) of crops / commodity during storage at retailer

$\hat{R}_R$: Estimated % retention of crops / commodity for storage at retailer

$\hat{L}_P$: Estimated loss (%) of crops / commodity during storage at processing unit

$\hat{R}_P$: Estimated % retention of crops / commodity for storage at processing unit

6

ESTIMATES OF POST HARVEST LOSS FOR DIFFERENT CROPS AND COMMODITIES

The study for which the results are being presented herein consisted of three specific objectives: (1) to develop the necessary methodology and analytical tools, (2) to estimate the post harvest losses for major crops and livestock produce, and (3) to identify those operations and commodities where the magnitude of post harvest losses is high.

The study encompassed 46 crops and allied commodities constituting the major portion of food produced in the country. Fourteen out of 15 agro-climatic zones, except the island region, were covered under the study. The island region contributes little to the food production in the country and therefore was not included. Stratified multistage random sampling technique was employed for data acquisition from 10600 farmers of 106 districts of the country making up about 20% of the rural districts. Besides, two each of wholesaler, retailer, processing industry, fish pond, slaughterhouse, dairy plant, and poultry unit from each district were selected for the survey. Twenty three separate schedules were developed for complete enumeration of villages in the study, data collection by enquiry, and data collection through observations. Data collection continued over the whole cropping cycle. Data were collected by enquiry as well as actual observation and the results were suitably combined to arrive at overall loss estimates.

Methods of data scrutiny, pooling from different regions, and their analysis were developed. Data collected by enquiry were analysed using Statistical Analysis Software (SAS) whereas the data by observation were analysed by using MS Excel. The estimated losses at national level in each of the farm operations and storage channels as well as overall total loss for each of the 46 commodities have been summarized in Tables (6.1) to (6.7). The category-wise estimated losses for the selected commodities have been presented and discussed below.

6.1 Cereals

Paddy, wheat, maize, bajra (pearl millet) and sorghum that constitute about 94% of the total cereal production in the country were selected for the study. Storage losses for cereals at different levels have been found to be in the range of 1.0 to 1.3%. However, the major losses occur at farm level during

harvesting, threshing, collection, cleaning, drying, packaging and transport amounting to 2.8 to 4.7% depending upon the cereal (Fig. 6.1).

It can be observed from Table 6.1 that there is considerable reduction of storage losses estimated in the present study in comparison to those reported by FAO (1980). On the other hand, the total losses (%) of different food grains in this study are higher than those reported by DMI (2002). Difference in estimates of losses in different studies is mainly due to variations in concept, procedure of data collection, geographical coverage, coverage of stages and channels, and finally the technological changes. There are a number of other regional/local studies and results of these studies may not be comparable with the results of the present study. Results of the present study and those of DMI (2002) in general indicate that there has been a reduction in storage loss over the past years. This may reflect some absorption of improved post harvest technologies at the stakeholders' level. However, the magnitude of losses is still very high due to enhanced production and partial adoption of improved technologies.

6.2 Pulses

The selected pulses for the study were pigeon pea, chick pea, black gram and green gram. Post harvest losses in different farm operations were in the range of 3.4 to 5.0% depending upon the pulse crop (Table 6.2). However, storage losses for different pulses were in the range of 0.9 to 2.0% (Fig. 6.2). Pulses exhibited slightly higher storage losses (up to 2.0%). The losses reported by DMI (2002) were quite low in comparison to those reported in the present study. The reasons might be the same as stated in the case of cereals, especially the difference in procedures and concept adopted.

6.3 Oilseeds

The oilseeds selected for the study were mustard, cottonseed, soybean, safflower, sunflower and groundnut that constituted about 95% of the total oilseeds produced in the country. It can be observed from the Table 6.3 that losses in different farm level operations were in the range of 2.2 to 9.1% for different oilseeds. The storage losses for different oilseeds were in the range of 0.4 to 1.0% (Fig. 6.3). The data of losses for mustard, soybean and groundnut indicated very high harvesting and threshing losses (Table 6.3). The losses in these two operations accounted for almost two-thirds of total losses. While losses in mustard were higher on account of high shattering in harvesting operation whereas in case of groundnut, losses were higher due to high percentage of leftover pods under the ground in harvesting operation.

6.4 Fruits

The selected fruits for the study were apple, banana, citrus, grapes, guava, mango, papaya and sapota that constituted about 84% of the total fruits produced in the country. The losses of different fruits in farm level operations were observed to be in the range of 4.2 to 13.9% (Table 6.4). The losses of different fruits in storage at various levels were observed to be in the range of 1.2 to 4.1% (Figs. 6.4 a and 6.4 b). It was also observed that on-farm losses of different fruits were not uniform in different operations. Total losses in farm operations were the highest in case of guava (13.9%) followed by those in apple (11.1%) and mango (10.6%). However, the losses in farm operations for other fruits were in the relatively lower range of 4.0 to 7.0%. Guava also exhibited the highest storage loss (4.1%) whereas the storage losses for other fruits were

in the range of 1.5% to 2.4%. Transportation losses were observed to be generally high for all the selected fruits, but were more pronounced in case of guava, mango and grapes. The overall total losses were the highest (18%) for guava and the lowest (5.8%) for sapota.

6.5 Vegetables

The selected vegetables for the study were potato, tomato, onion, green pea, cauliflower, cabbage, mushroom and tapioca that constituted about 65% of the total vegetables produced in the country. The losses for different vegetables in farm operations were observed in the range of 4.6 to 11.0% (Table 6.5). The losses of different vegetables in storage were observed to be in the range of 1.5 to 2.5% (Fig. 6.5 a and Fig. 6.5 b). It was also observed that the overall losses were the highest in case of tomato (12.98%) followed by those in mushroom (12.5%), green pea (10.3%), tapioca (9.2%), potato (9%), onion (7.5%), etc. The minimum loss was observed in case of cauliflower (6.8%). The losses in harvesting and sorting/grading operations were higher than those in other operations. The losses in sorting/grading operations (4.3%) were considerably high in crops like, onion, potato and tapioca (Table 6.5).

6.6 Plantation Crops, Sugarcane, Spices and Condiments

The selected commodities for the study under this category were cashew, arecanut, coconut, black pepper, chilli, coriander and turmeric. The losses of different commodities in farm operations were observed in the range of 0.9 to 7.8% (Table 6.6). It can be observed that harvesting losses were high in case of turmeric (3.7%) and coriander (2.8%). The storage losses for these commodities were observed in the range of 0.2% to 1.7% (Fig. 6.6), the lowest for cashew (0.2%) and the highest for chilli (1.7%). The relative losses in case of important spices in different channels can be seen from Fig. 6.7. Also, it is seen that packaging and transportation losses for these commodities were very low. However, major losses could be attributed to farm operations such as harvesting, collection, and sorting/grading. Therefore, there is a need to reduce the losses in farm operations by adopting appropriate post harvest technology to perform these operations. The overall losses in arecanut, coriander and turmeric are about 8% that need greater attention to minimize the losses.

6.7 Livestock Produce

The estimated losses in livestock produce including milk, egg, meat and fish were in the range of 0.8% to 6.9% (Table 6.7). The contribution of operations following catch/slaughter for these losses is considerably higher than storage losses. The losses in collection, packaging and transportation of eggs were the highest at 4.9% (Fig. 6.8) that need immediate attention for intervention of appropriate technology. In the case of inland fish, harvest losses were found to be the highest at 2.6% that could be attributed to discarding of immature finger-lings. In the present study, assessment of losses in case of marine fish did not take into account the on-board discards harvesting losses. The highest loss in inland fisheries was observed at wholesaler level storage (2.4%), quite probably due to inadequate storage facilities with respect to the volume of product handled.

Table 6.1: Harvest and Post Harvest Losses (%) of Cereals at National Level in India

S. No.	Crop	Harvesting	Collection	Threshing	Winnowing/ cleaning	Drying	Transportation	Total loss in farm operations	Farm level storage	Godown/ warehouse storage	Wholesaler level storage	Retailer-level storage	Processing unit level storage	*Total loss in storage	Overall Total Loss
1.	Paddy	1.2 ±1.1	0.74 ±0.53	1.15 ±0.44	0.36 ±0.48	0.23 ±0.23	0.13 ±0.16	**3.91** ±0.58	1.93 ±0.88 (0.64 ±0.29)	0.52 ±0.26 (0.03 ±0.02)	1.34 ±0.25 (0.22 ±0.04)	0.67 ±0.70 (0.02 ±0.02)	0.89 ±0.25 (0.39 ±0.11)	**1.28** ±0.31	**5.19** ±0.49
2.	Wheat	1.69 ±0.7	0.56 ±0.43	1.62 ±0.48	0.48 ±0.59	0.04 ±0.11	0.16 ±0.13	**4.67** ±0.47	1.53 ±0.63 (0.59 ±0.24)	0.47 ±0.54 (0.06 ±0.06)	0.72 ±0.69 (0.13 ±0.12)	0.77 ±0.70 (0.04 ±0.03)	1.72 ±0.49 (0.48 ±0.14)	**1.28** ±0.31	**5.96** ±0.38
3.	Maize	0.5 ±0.42	0.19 ±0.17	1.57 ±0.36	0.21 ±0.30	0.17 ±0.09	0.07 ±0.08	**2.81** ±0.26	1.74 ±0.62 (0.41 ±0.15)	0.16 ±0.26 (0.01 ±0.02)	1.73 ±0.67 (0.66 ±0.26)	0.75 ±0.60 (0.11 ±0.09)	0.68 ±0.44 (0.11 ±0.07)	**1.29** ±0.31	**4.10** ±0.29
4.	Bajra	0.8 ±0.64	0.56 ±0.41	1.30 ±0.60	0.33 ±0.72	0.30 ±0.25	0.17 ±0.16	**3.82** ±0.52	1.40 ±0.99 (0.56 ±0.39)	0.29 ±0.17 (0.01 ±0.01)	0.65 ±0.34 (0.24 ±0.12)	1.13 ±0.81 (0.12 ±0.09)	0.67 ±0.36 (0.07 ±0.03)	**0.98** ±0.42	**4.80** ±0.47
5.	Sorghum	0.6 ±0.78	0.38 ±0.39	0.67 ±0.82	0.39 ±0.49	0.34 ±0.20	0.13 ±0.09	**2.76** ±0.52	1.65 ±0.49 (0.36 ±0.11)	0.63 ±0.15 (0.03 ±0.01)	1.11 ±0.20 (0.66 ±0.12)	0.37 ±0.27 (0.04 ±0.03)	0.58 ±0.12 (0.01 ±0.01)	**1.12** ±0.17	**3.87** ±0.38

Figures in parentheses show contribution of storage % in relation to total production

* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)

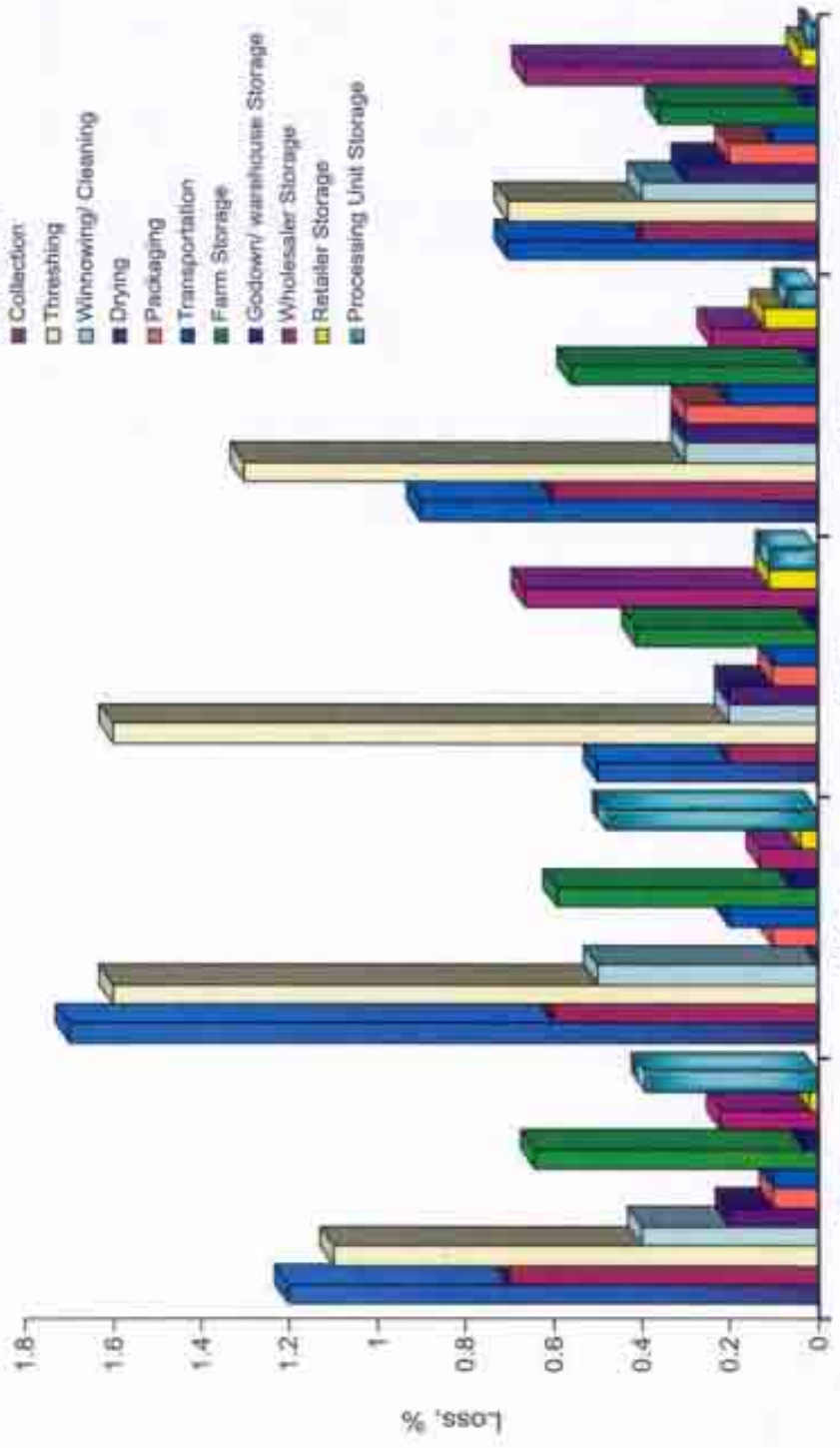

Figure 6.1: Harvest and post harvest losses of cereals at national level

Table 6.2: Harvest and Post Harvest Losses (%) of Pulses at National Level in India

S. No.	Crop	Harve-sting	Colle-ction	Thres-hing	Winn-owing/ Clea-ning	Drying	Packa-ging	Tran-sport-ation	Total loss in farm opera-tions	Farm level storage	God-own/ ware-house	Whol-esaler level storage	Retailer level storage	Process-ing unit level storage	Total loss in storage*	Overall Total Loss
1.	Pigeon Pea	0.48 ±1.58	0.44 ±1.24	0.69 ±0.63	1.04 ±1.23	0.47 ±0.54	0.19 ±0.52	0.11 ±0.33	**3.43** ±1.03	2.35 ±1.03 (1.36 ±0.59)	0.20 ±0.09 (0.01 ±0.01)	2.23 ±0.40 (0.22 ±0.04)	0.78 ±0.69 (0.08 ±0.07)	1.69 ±0.29 (0.30 ±0.05)	**1.96** ±0.60	**5.39** ±0.78
2.	Chick Pea	0.72 ±1.14	0.56 ±0.83	0.82 ±0.88	0.38 ±0.81	0.56 ±0.83	0.22 ±0.29	0.16 ±0.14	**3.41** ±0.80	1.30 ±1.04 (0.31 ±0.24)	0.21 ±0.08 (0.02 ±0.01)	0.97 ±0.35 (0.37 ±0.13)	0.57 ±0.36 (0.08 ±0.05)	0.60 ±0.09 (0.12 ±0.02)	**0.86** ±0.28	**4.28** ±0.56
3.	Black Gram	1.13 ±1.79	1.04 ±1.22	1.62 ±2.84	0.31 ±0.53	0.50 ±0.99	0.23 ±0.61	0.14 ±0.36	**4.96** ±1.56	1.44 ±1.65 (0.73 ±0.84)	0.11 ±0.07 (0.01 ±0.00)	0.86 ±0.19 (0.16 ±0.03)	0.70 ±1.62 (0.09 ±0.20)	0.77 ±0.33 (0.11 ±0.04)	**1.07** ±0.86	**6.06** ±1.28
4.	Green Gram	0.86 ±1.28	0.62 ±1.12	1.63 ±0.89	0.32 ±1.02	0.31 ±1.09	0.14 ±0.21	0.21 ±0.27	**4.09** ±0.97	2.06 ±2.04 (0.68 ±0.68)	0.21 ±0.11 (0.01 ±0.00)	0.47 ±0.22 (0.47 ±0.06)	1.60 ±0.44 (0.8 ±0.12)	0.43 ±0.12 (0.04 ±0.01)	**1.42** ±0.69	**5.51** ±0.84

Figures in parentheses show contribution of storage % in relation to total production

* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)

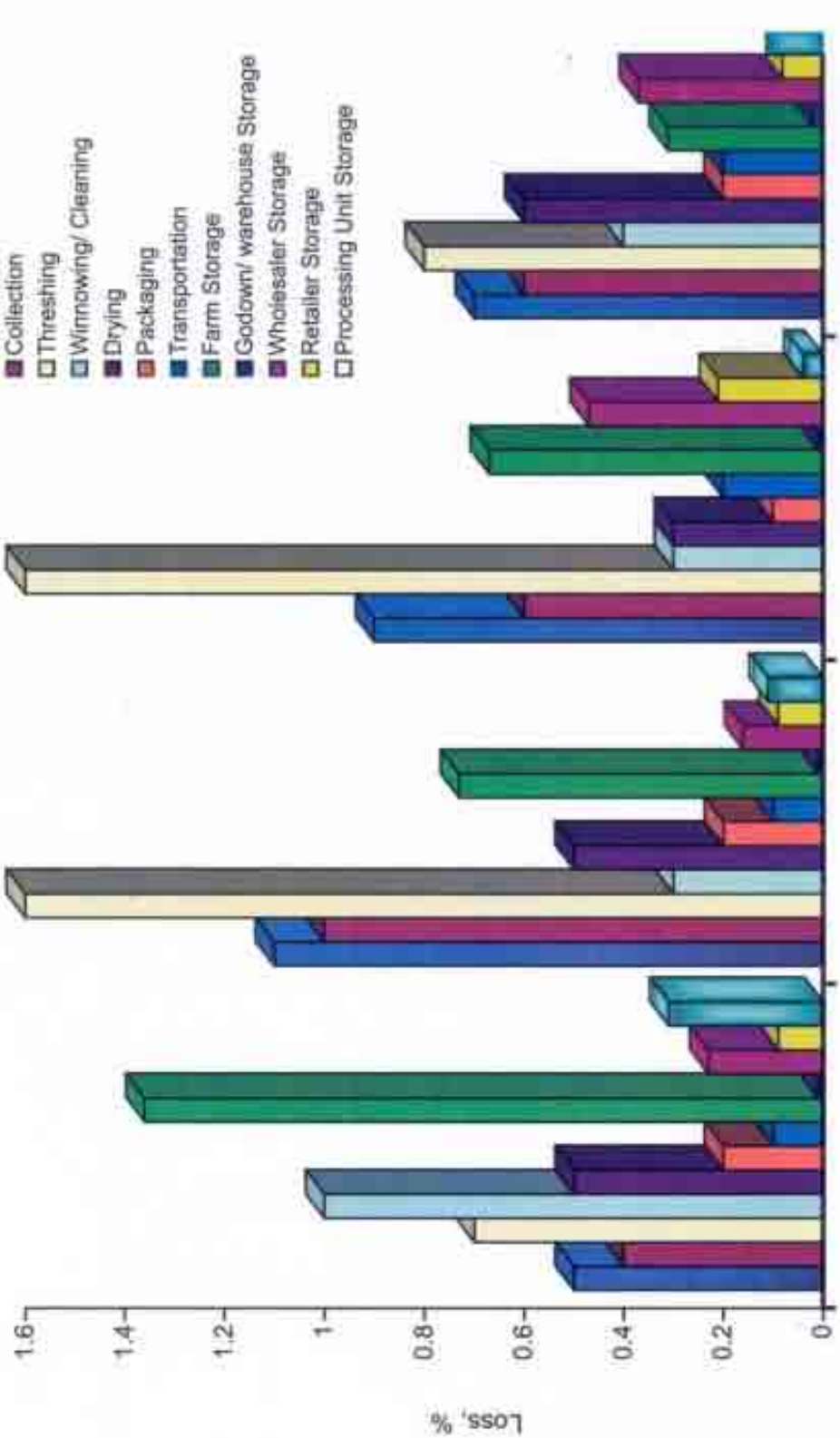

Figure 6.2: Harvest and post harvest losses in pulses at national level in India

Table 6.3: Harvest and Post Harvest Losses (%) of Oilseeds at National Level in India

S. No.	Crop	Harvesting	Collection	Threshing	Winnowing/ Cleaning/ Ginning*	Drying	Packaging	Transportation	Total Loss in Farm Operations	Farm Level Storage	Godown warehouse storage	Wholesaler Level Storage	Retailer Level Storage	Processing Unit Level Storage	*Total Loss in Storage	Overall Total Loss
1.	Mustard	4.54 ±2.11	1.09 ±1.17	1.78 ±0.92	0.33 ±0.98	0.23 ±0.42	0.21 ±0.55	0.24 ±0.45	**8.43** ±1.19	0.78 ± 0.57 (0.24 ±0.16)	0.28 ± 0.09 (0.02 ±0.00)	0.37 ± 0.14 (0.10 ±0.03)	0.42 ± 0.48 (0.04 ±0.03)	0.26 ± 0.31 (0.10 ±0.10)	**0.46** ±0.20	**8.89** ±0.84
2.	Cottonseed*	0.59 ±1.85	0.24 ±1.12	-	0.86 ±1.13*	0.38 ±0.91	0.06 ±0.19	0.06 ±0.14	**2.19** ±1.31	0.11 ± 0.29 (0.01 ±0.02)	-	0.88 ± 0.57 (0.52 ±0.32)	-	0.25 ± 0.04 (0.06 ±0.01)	**0.56** ±0.32	**2.76** ±1.08
3.	Soybean	3.14 ±1.02	0.46 ±0.39	1.24 ±0.67	0.49 ±0.35	0.22 ±0.21	0.14 ±0.10	0.17 ±0.13	**5.84** ±0.57	0.83 ± 0.42 (0.10 ±0.05)	0.10 ± 0.19 (0.01 ±0.02)	0.49 ± 0.09 (0.24 ±0.05)	0.42 ± 0.39 (0.04 ±0.04)	0.08 ± 0.05 (0.01 ±0.01)	**0.41** ±0.08	**6.26** ±0.47
4.	Safflower	0.47 ±0.52	0.73 ±0.69	1.06 ±1.87	0.52 ±0.45	0.33 ±0.31	0.08 ±0.15	0.07 ±0.10	**3.26** ±0.71	0.62 ± 0.79 (0.03 ±0.04)	0.02 ±0.02 (0.00 ±0.00)	0.33 ± 0.33 (0.08 ±0.09)	-	0.52 ± 0.44 (0.29 ±0.25)	**0.43** ±0.27	**3.68** ±0.54
5.	Sunflower	1.08 ±0.36	0.47 ±0.17	1.31 ±0.47	0.52 ±0.21	0.31 ±0.17	0.13 ±0.05	0.11 ±0.06	**3.93** ±0.26	2.22 ± 0.42 (0.04 ±0.01)	0.12 ± 0.29 (0.01 ±0.01)	0.89 ± 0.20 (0.19 ±0.04)	0.24 ± 0.18 (0.01 ±0.01)	0.54 ± 0.18 (0.35 ±0.12)	**0.62** ±0.13	**4.55** ±0.24
6.	Groundnut	4.79 ±3.75	0.68 ±2.26	2.72 ±1.81	0.34 ±0.78	0.28 ±0.54	0.20 ±0.26	0.10 ±0.26	**9.11** ±1.99	1.61 ± 1.22 (0.16 ±0.11)	0.01 ± 0.01 (0.00 ±0.00)	1.22 ± 0.32 (0.50 ±0.13)	0.56 ± 0.42 (0.07 ±0.04)	0.76 ± 0.23 (0.27 ±0.08)	**0.96** ±0.19	**10.07** ±1.41

Figures in parentheses show contribution of storage % in relation to total production
* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)
*In cottonseed the ginning of cotton bolls is done to separate the cotton from the seed

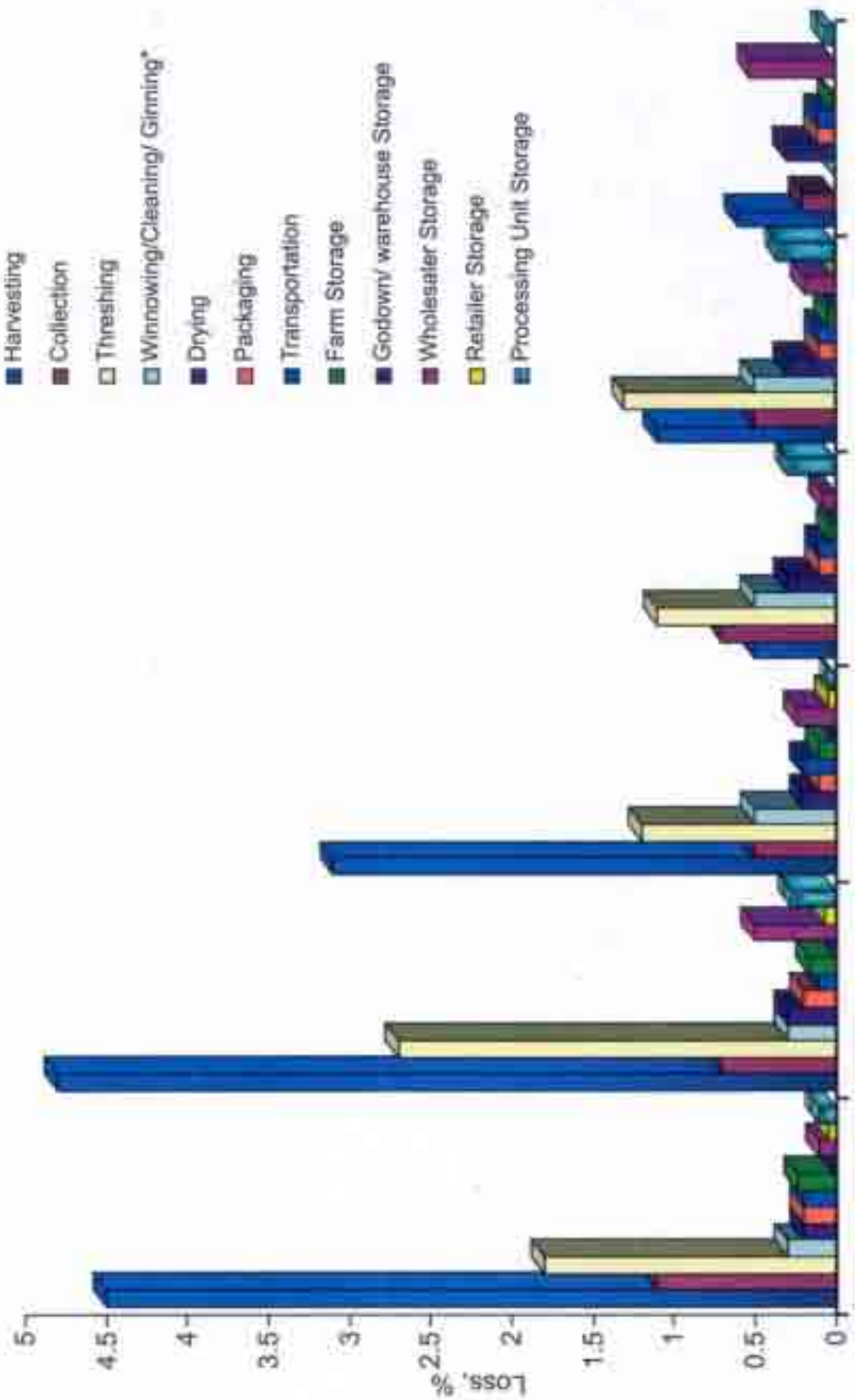

Figure 6.3: Harvest and post harvest losses of oilseeds at national level in India

Table 6.4: Harvest and Post Harvest Losses (%) of Fruits at National Level in India

S. No.	Crop	Harvesting	Collection	Sorting/ grading	Drying	Packaging	Transportation	Total loss in farm operations	Farm level storage	Godown/ cold storage	Wholesaler level storage	Retailer level storage	Processing unit level storage	*Total loss in storage	Overall Total Loss
1.	Apple	4.56 ±1.41	0.42 ±1.03	4.79 ±1.51	-	0.10 ±0.08	1.19 ±0.22	**11.06** ±1.08	2.26 ±0.99 (0.04 ±0.02)	1.47 ± 1.21 (0.12 ±0.10)	0.99 ± 0.63 (0.52 ±0.32)	1.10 ± 0.49 (0.23 ±0.10)	1.70 ± 4.24 (0.29 ±0.73)	**1.20** ±0.81	**12.26** ±1.05
2.	Banana	1.33 ±8.59	0.36 ±0.54	0.93 ±0.35	-	0.44 ±0.46	1.14 ±1.29	**4.18** ±5.08	1.60 ±1.02 (0.04 ±0.03)	3.34 ± 0.11 (0.16 ±0.01)	2.39 ± 1.06 (1.85 ±0.82)	2.44 ± 1.51 (0.36 ±0.23)	0.26 ± 0.16 (0.01 ±0.00)	**2.42** ±0.85	**6.60** ±3.43
3.	Citrus	0.92 ±1.39	0.48 ±1.01	1.79 ±1.16	-	0.35 ±0.94	1.30 ±1.67	**4.84** ±1.30	1.94 ±2.96 (0.03 ±0.07)	0.00 ± 0.00 (0.00 ±0.00)	1.28 ± 0.64 (0.69 ±0.35)	2.29 ± 0.79 (0.77 ±0.27)	0.21 ± 0.26 (0.01 ±0.02)	**1.54** ±0.45	**6.38** ±1.15
4.	Grapes	0.94 ±1.94	0.24 ±1.10	3.21 ±1.26	-	0.26 ±0.98	1.93 ±1.13	**6.57** ±1.39	5.54 ±0.56 (0.02 ±0.00)	-	1.61 ± 0.84 (0.54 ±0.28)	2.17 ± 0.74 (0.84 ±0.29)	2.69 ± 1.03 (0.30 ±0.12)	**1.73** ±0.42	**8.30** ±1.00
5.	Guava	4.36 ±1.53	1.20 ±1.05	4.64 ±1.18	-	0.94 ±0.69	2.77 ±0.73	**13.92** ±1.17	2.10 ±1.27 (0.41 ±0.26)	-	5.91 ± 1.09 (1.83 ±0.34)	3.79 ± 1.57 (1.80 ±0.75)	5.71 ± 0.66 (0.06 ±0.01)	**4.13** ±0.86	**18.05** ±1.12
6.	Mango	4.11 ±2.37	0.68 ±0.71	2.80 ±1.54	-	0.51 ±0.54	2.53 ±2.49	**10.64** ±1.89	1.50 ±0.59 (0.06 ±0.03)	-	2.50 ±1.14 (0.92 ±0.42)	2.67 ±1.70 (0.93 ±0.59)	0.87 ±0.39 (0.19 ±0.09)	**2.11** ±0.73	**12.74** ±1.57
7.	Papaya	1.45 ±1.56	0.28 ±0.26	1.97 ±0.92	-	0.23 ±0.20	1.13 ±1.35	**5.06** ±1.08	2.10 ±3.34 (0.08 ±0.12)	0.00 ±0.00 (0.00 ±0.00)	2.28 ±1.48 (1.02 ±0.66)	2.39 ±1.28 (1.20 ±0.64)	0.03 ±0.03 (0.00 ±0.00)	**2.28** ±0.92	**7.36** ±1.04
8.	Sapota	1.53 ±1.14	0.23 ±0.52	1.43 ±0.83	-	0.08 ±0.51	1.06 ±0.67	**4.31** ±0.89	0.84 ±0.13 (0.02 ±0.00)	-	1.74 ±0.58 (0.75 ±0.25)	1.71 ±0.76 (0.73 ±0.32)	-	**1.46** ±0.40	**5.77** ±0.69

Figures in parentheses show contribution of storage % in relation to total production

* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)

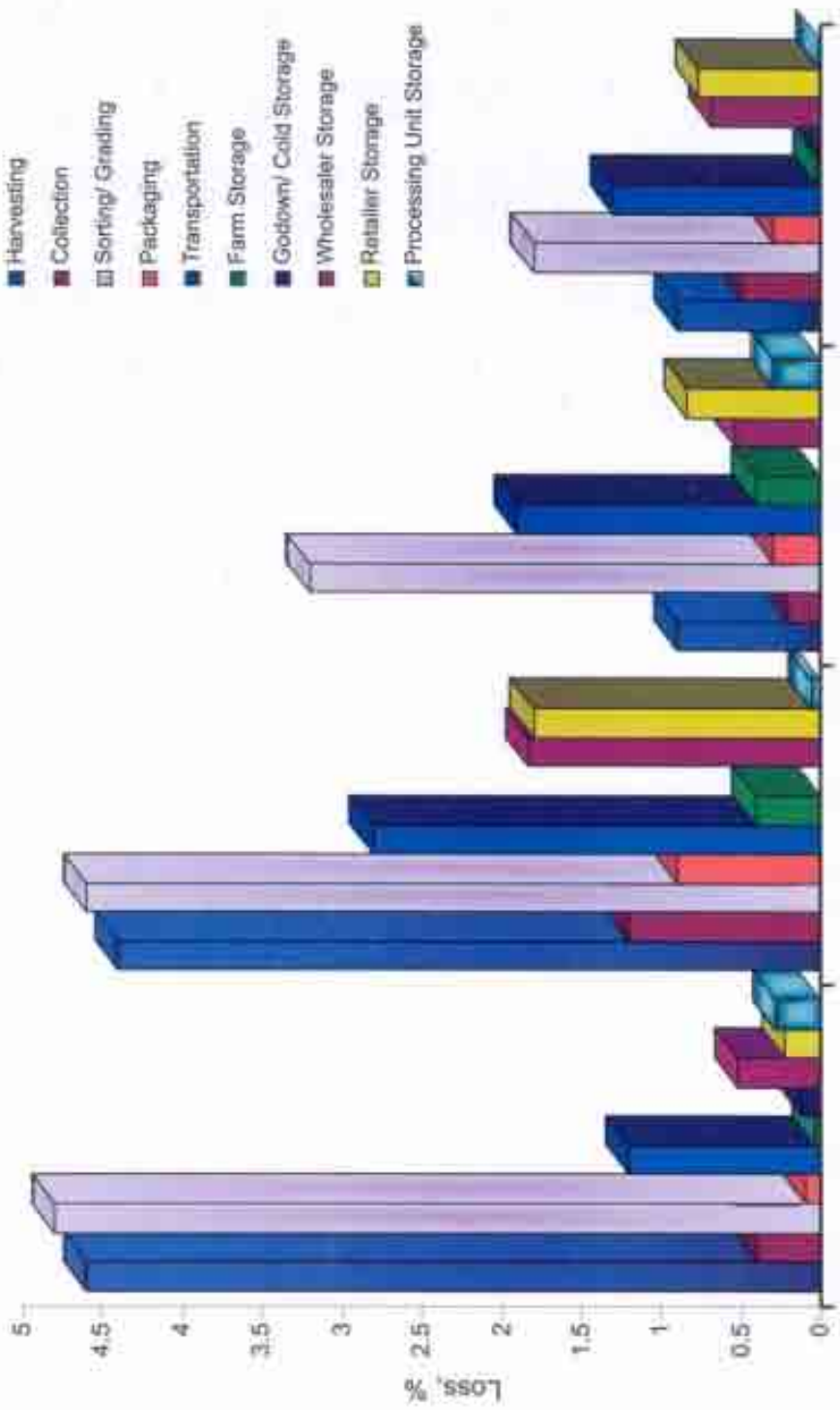

Figure 6.4 (a): Harvest and post harvest losses of fruits at national level in India

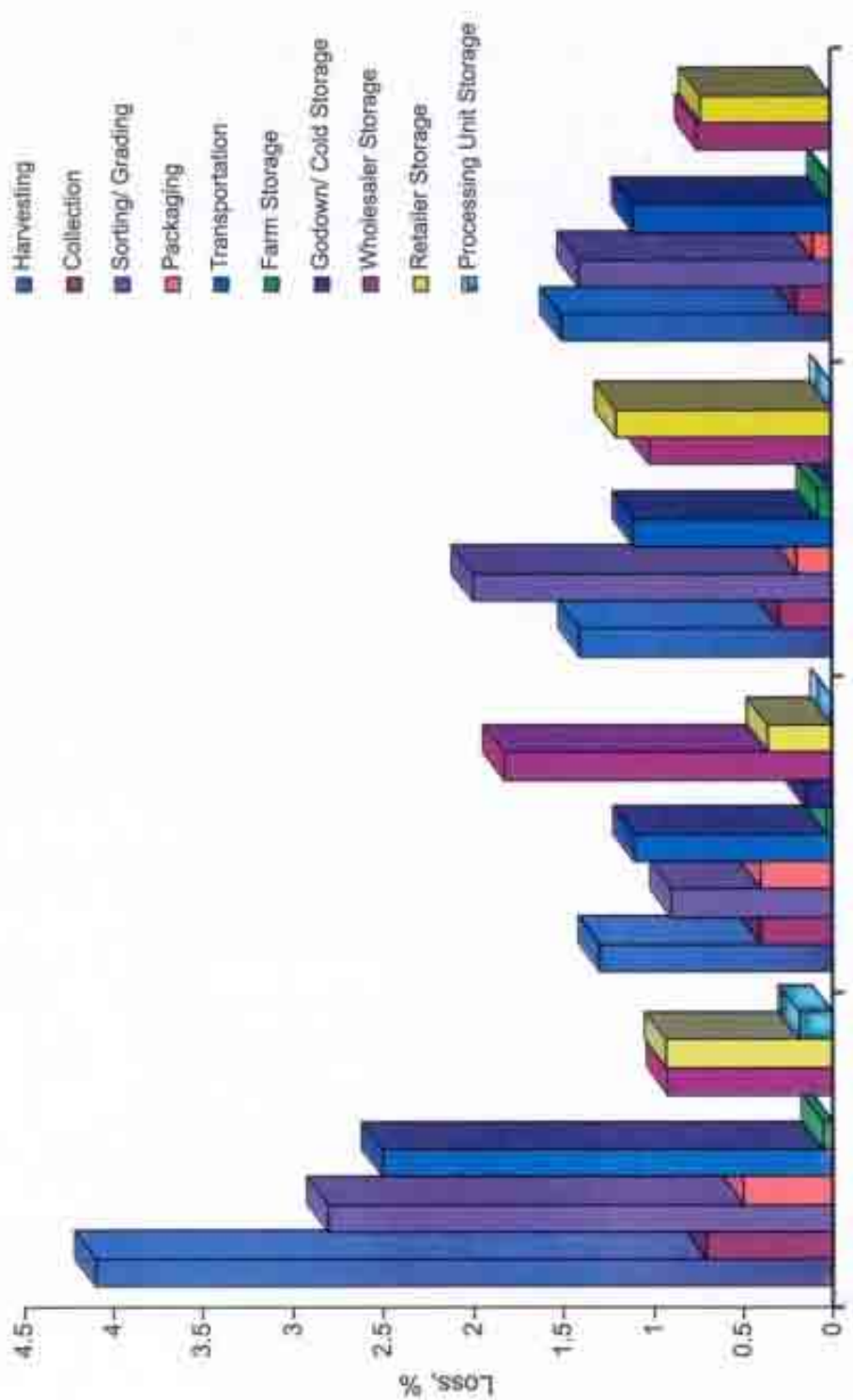

Figure 6.4 (b): Harvest and post harvest losses in fruits at national level in India

Table 6.5: Harvest and Post Harvest Losses (%) of Vegetables at National Level in India

S. No.	Crop	Harve-sting	Collec-tion	Sorting grading	Drying	Packa-ging	Trans-porta-tion	Total loss in farm opera-tions	Farm level storage	Godown cold storage	Whole-saler level storage	Retailer level storage	Process-ing unit level Stor	*Total Loss in storage	Overall Total Loss
1.	Cabbage	1.08 ±2.84	0.30 ±0.39	1.64 ±2.10	-	0.27 ±0.64	1.32 ±0.79	**4.61** ±1.71	2.10 ±2.09 (0.14 ±0.15)	1.11 ±0.83 (0.06 ±0.04)	2.20 ±0.68 (0.88 ±0.27)	2.62 ±0.84 (1.21 ±0.39)	2.31 ±1.68 (0.03 ±0.02)	**2.33** ±0.50	**6.94** ±1.51
2.	Cauliflower	0.84 ±1.78	0.27 ±0.45	1.66 ±2.30	-	0.18 ±0.35	1.91 ±1.13	**4.85** ±1.38	1.52 ±1.30 (0.08 ±0.07)	0.47 ±0.12 (0.04 ±0.01)	2.17 ±1.69 (1.00 ±0.78)	2.31 ±1.60 (0.89 ±0.63)	-	**2.03** ±1.01	**6.88** ±1.32
3.	Green Pea	3.46 ±2.63	1.08 ±1.07	3.30 ±2.22	-	0.23 ±0.50	0.50 ±0.54	**8.58** ±1.78	1.18 ±1.77 (0.06 ±0.09)	0.30 ±0.16 (0.01 ±0.00)	1.32 ±1.93 (0.72 ±1.05)	2.44 ±0.66 (0.92 ±0.25)	-	**1.70** ±1.08	**10.28** ±1.67
4.	Mushroom	1.37 ±2.45	1.77 ±3.08	4.26 ±4.59	-	1.64 ±2.10	2.00 ±0.85	**11.03** ±2.96	-	-	-	1.73 ±0.89 (1.51 ±0.78)	-	**1.51** ±0.78	**12.54** ±1.40
5.	Onion	2.70 ±2.54	0.23 ±0.49	1.64 ±1.37	-	0.14 ±0.56	0.44 ±0.58	**5.17** ±1.47	2.67 ±1.98 (0.54 ±0.40)	2.18 ±0.93 (0.40 ±0.17)	2.19 ±0.53 (0.83 ±0.20)	2.57 ±0.98 (0.57 ±0.22)	0.09 ±0.07 (0.01 ±0.00)	**2.34** ±0.53	**7.51** ±1.09
6.	Potato	3.18 ±4.02	0.69 ±0.23	2.23 ±3.41	-	0.10 ±0.14	0.54 ±0.36	**6.73** ±2.53	3.88 ±2.10 (0.35 ±0.19)	1.36 ±0.64 (0.76 ±0.35)	3.87 ±0.61 (0.96 ±0.15)	2.41 ±0.65 (0.19 ±0.05)	0.43 ±0.11 (0.01 ±0.00)	**2.26** ±0.43	**8.99** ±1.87
7.	Tomato	1.73 ±1.26	1.06 ±0.49	3.24 ±0.98	-	0.77 ±0.53	3.14 ±1.20	**9.94** ±1.03	4.62 ±2.75 (1.22 ±0.72)	1.57 ±0.60 (0.01 ±0.00)	2.66 ±0.72 (1.06 ±0.29)	2.27 ±1.16 (0.58 ±0.30)	2.00 ±1.65 (0.17 ±0.14)	**3.04** ±0.84	**12.98** ±1.00
8.	Tapioca	3.61 ±2.77	0.51 ±0.62	1.54 ±1.52	-	0.53 ±1.08	1.28 ±0.78	**7.47** ±1.79	4.13 ±4.10	- (0.17 ±0.17)	1.47 ±0.75	1.70 ±1.04 (0.68 ±0.35)	2.34 ±0.66 (0.74 ±0.46)	**1.72** ±0.60 (0.13 ±0.04)	**9.19** ±1.52

Figures in parentheses show contribution of storage % in relation to total production

* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)

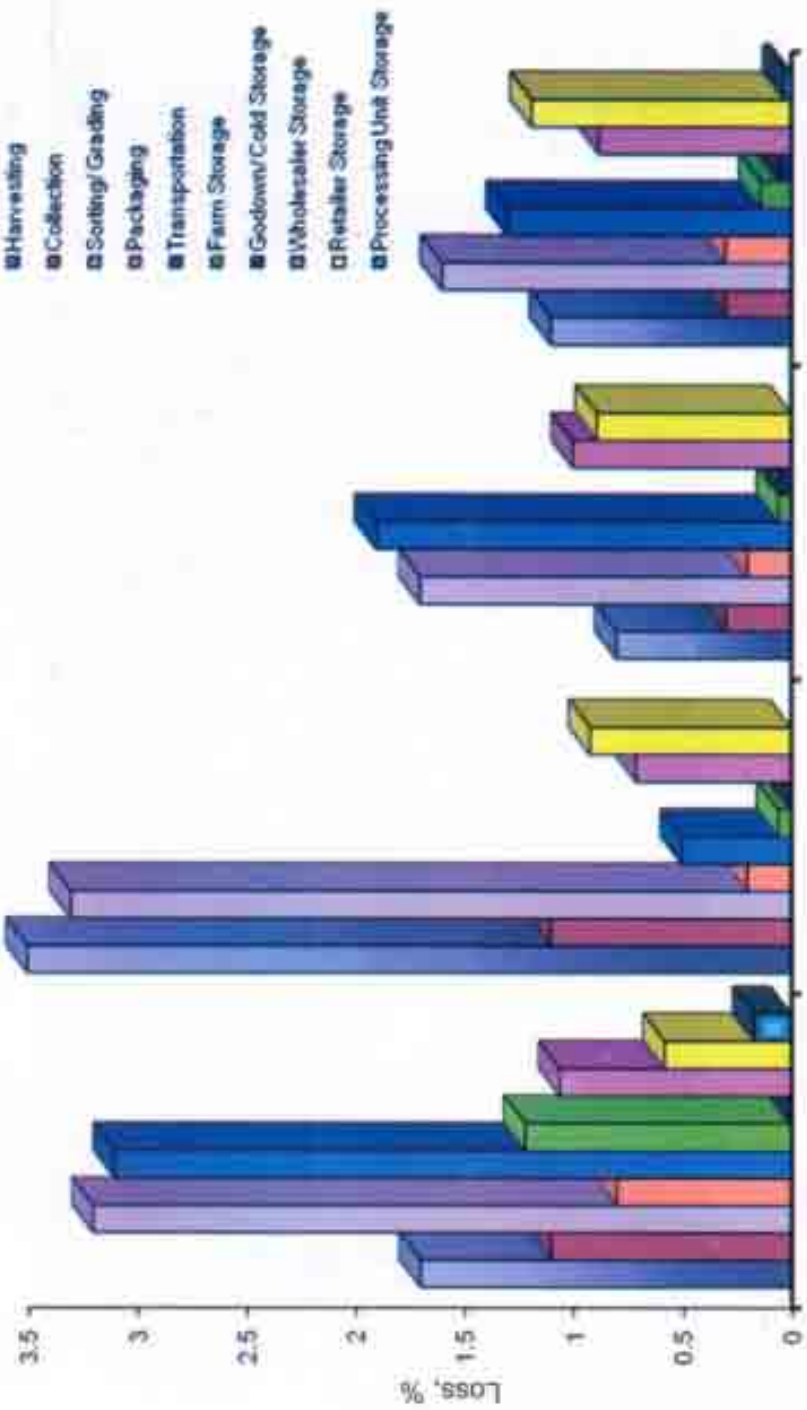

Figure 6.5 (a): Harvest and post harvest losses in vegetables at national level in India

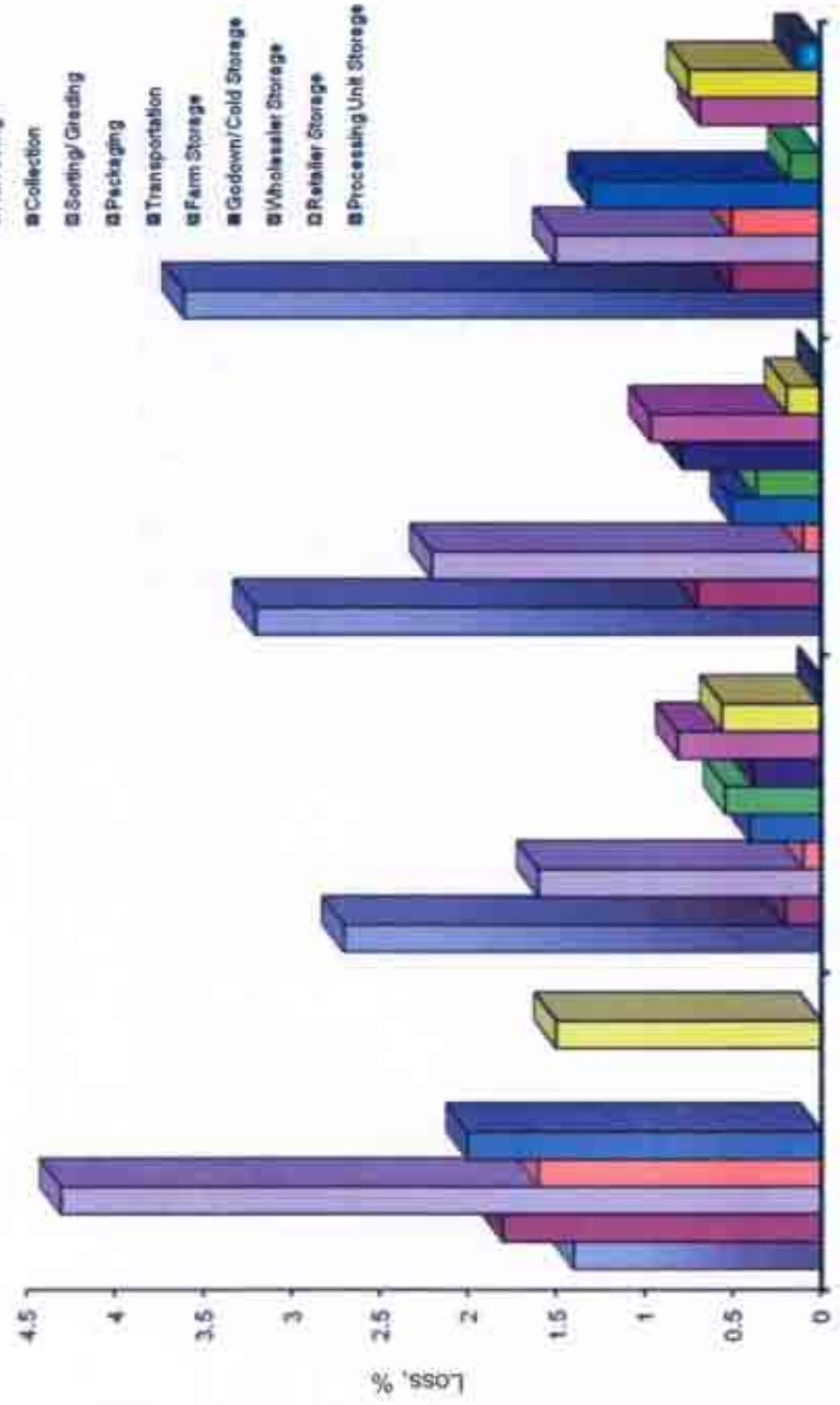

Figure 6.5 (b): Harvest and post harvest losses in vegetables at national level

Table 6.6: Harvest and Post Harvest Losses (%) of Plantation Crops and Spices at National Level in India

S. No	Crop	Harvesting	Collection	Threshing	Sorting/ grading	Winnowing/ cleaning	Drying/ stalingv	Packaging	Transportation	Total loss in farm operations	Farm level storage	Godown/ cold storage	Wholesaler level storage	Retailer Level storage	Processing unit level storage	*Total loss in storage	Overall Total Loss
1	Arecanut	1.90 ±0.37	0.16 ±0.16	3.32 ±0.83	0.39 ±0.59	0.41 ±0.20	0.19 ±0.37	0.06 ±0.04	0.19 ±0.09	**6.62** ±0.32	1.53 ±0.91 (0.03 ±0.01)	0.00 ±0.00 (0.00 ±0.00)	1.24 ±0.18 (0.88 ±0.13)	1.85 ±0.12 (0.27 ±0.02)	0.74 ±0.13 (0.12 ±0.02)	**1.26** ±0.13	**7.87** ±0.34
2	Cashew	0.16 ±0.09	0.14 ±0.45	0.37 ±0.11	-	-	0.21 ±0.95	0.00 ±0.00	0.01 ±0.05	**0.89** ±0.26	0.13 ±0.12 (0.01 ±0.00)	0.00 ±0.00 (0.00 ±0.00)	0.22 ±0.07 (0.06 ±0.02)	0.36 ±0.18 (0.02 ±0.01)	0.24 ±0.11 (0.14 ±0.07)	**0.23** ±0.07	**1.12** ±0.23
3	Coconut	1.57 ±0.47	0.22 ±0.26	-	1.36 ±1.77	-	0.66 ±0.51	0.13 ±0.22	0.17 ±0.16	**4.10** ±0.87	1.94 ±0.76 (0.14 ±0.05)	0.21 ±0.16 (0.02 ±0.02)	1.08 ±0.29 (0.46 ±0.12)	2.09 ±0.79 (0.32 ±0.12)	1.37 ±0.29 (0.36 ±0.07)	**1.27** ±0.19	**5.36** ±0.71
4	Sugarcanev	2.78 ±1.75	0.86 ±0.61	-	0.31 ±6.55	-	3.52v ±0.62	0.09 ±0.29	0.22 ±0.63	**7.79** ±1.85	0.83 ±2.62 (0.08 ±0.23)	-	-	0.14 ±0.15 (0.01 ±0.01)	1.16 ±1.08 (0.81 ±0.72)	**0.90** ±0.76	**8.64** ±1.82
5	Black Pepper	0.71 ±0.33	0.16 ±0.11	0.46 ±0.70	-	0.83 ±0.49	0.92 ±0.58	0.24 ±0.19	0.31 ±0.41	**3.60** ±0.49	0.28 ±0.41 (0.01 ±0.02)	0.00 ±0.00 (0.00 ±0.00)	0.57 ±0.09 (0.19 ±0.02)	0.50 ±0.09 (0.10 ±0.02)	0.03 ±0.02 (0.00 ±0.01)	**0.27** ±0.03	**3.86** ±0.41
6	Chilli	1.64 ±1.05	0.71 ±0.58	-	0.67 ±0.85	0.56 ±0.29	0.12 ±0.49	0.12 ±0.22	0.13 ±0.47	**3.95** ±0.70	0.90 ±1.32 (0.03 ±0.04)	0.61 ±0.26 (0.03 ±0.01)	1.78 ±0.79 (1.19 ±0.52)	1.96 ±0.88 (0.36 ±0.15)	0.99 ±0.79 (0.09 ±0.06)	**1.66** ±0.55	**5.60** ±0.66
7	Coriander	2.19 ±1.36	0.68 ±0.68	3.10 ±1.66	-	0.21 ±0.57	0.37 ±0.30	0.16 ±0.22	0.20 ±0.19	**6.81** ±1.03	1.89 ±0.65 (0.09 ±0.03)	0.00 ±0.00 (0.00 ±0.00)	0.52 ±0.12 (0.31 ±0.08)	0.40 ±0.27 (0.10 ±0.07)	0.00 ±0.00 (0.00 ±0.00)	**0.51** ±0.11	**7.31** ±0.66
8	Turmeric	3.66 ±6.47	0.77 ±0.99	-	0.67 ±1.93	1.14 ±1.46	0.12 ±0.07	0.13 ±0.34	0.22 ±0.59	**6.72** ±3.34	1.32 ±1.08 (0.18 ±0.13)	-	0.95 ±0.29 (0.43 ±0.14)	0.76 ±0.84 (0.08 ±0.08)	-	**0.66** ±0.20	**7.37** ±2.53

Figures in parentheses show contribution of storage % in relation to total production
* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)
vStaling in case of sugarcane

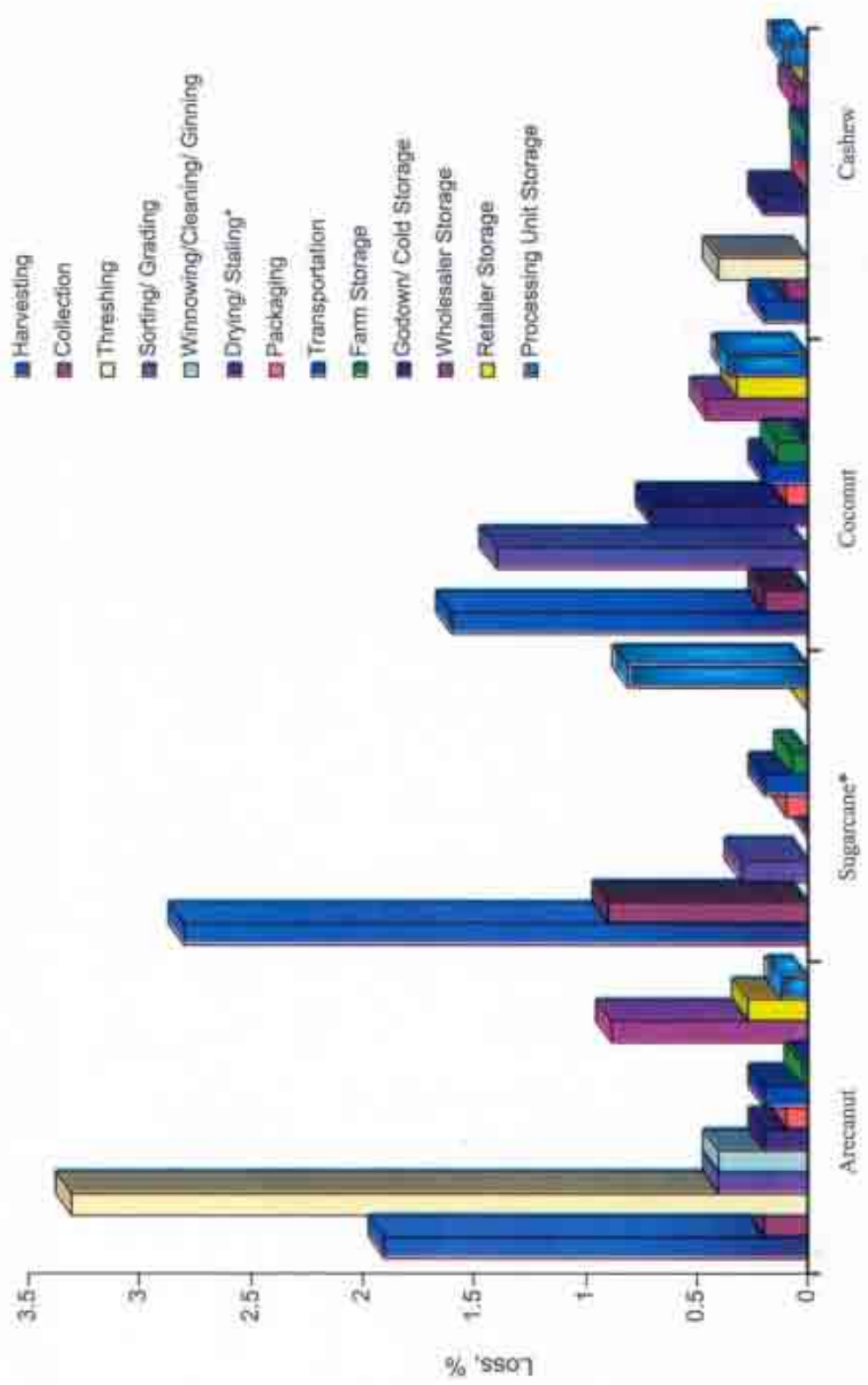

Figure 6.6: Harvest and post harvest losses in plantation/cash crops at national level in India

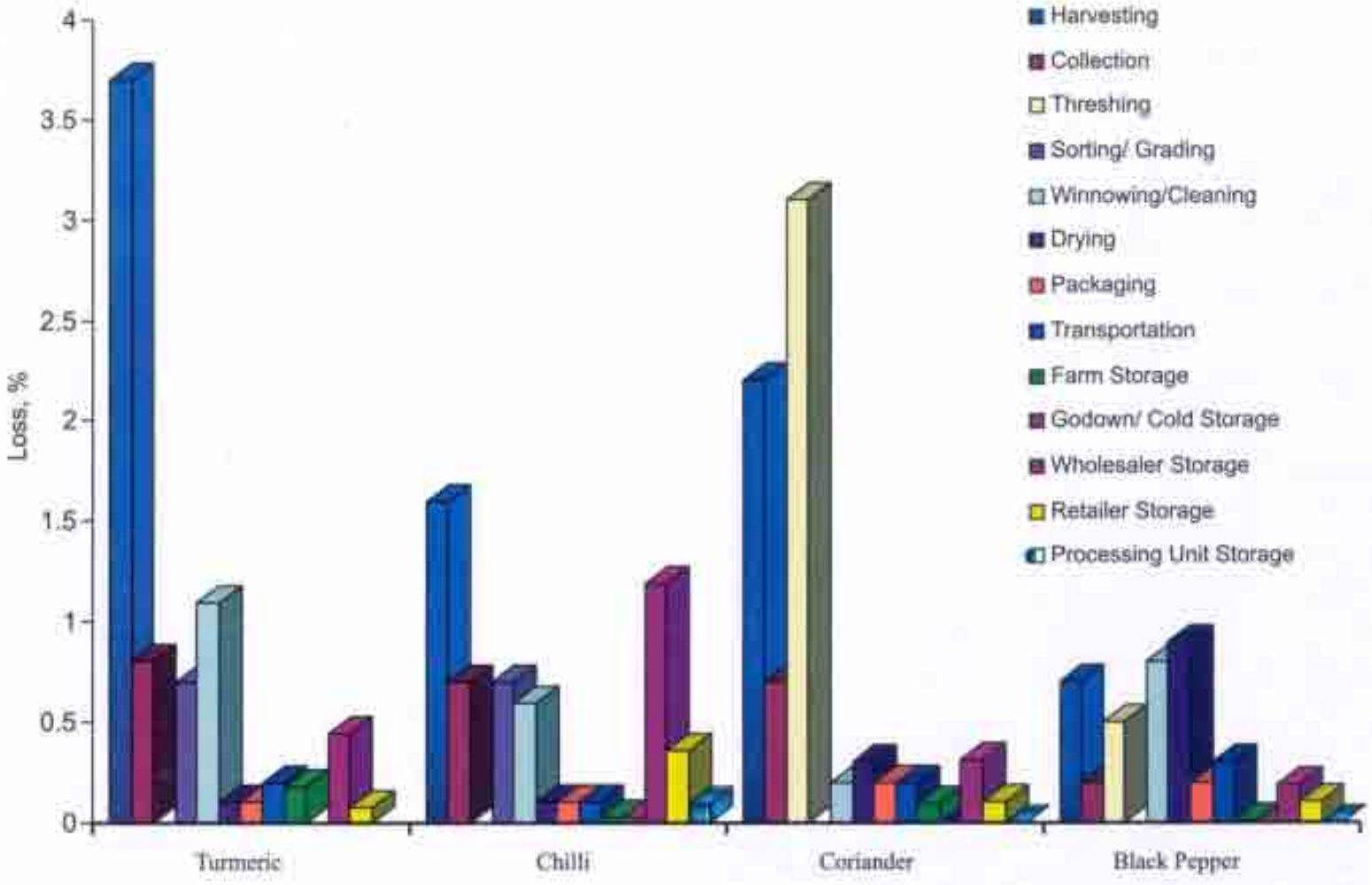

Figure 6.7: Harvest and post harvest losses in spices at national level in India

Table 6.7: Harvest and Post Harvest Losses of Livestock Produce and Jaggery & Khandsari (%) at National Level

S. No.	Crop	Harvesting	Collection	Sorting/ grading	Drying	Packaging	Transportation	Total loss in farm operations	Farm level storage	Godown cold storage	Wholesaler level storage	Retailer level storage	Processing unit level storage	*Total loss in storage	Overall Total Loss
40.	Egg	-	2.08 ±0.58	-	-	0.98 ±0.25	1.83 ±0.90	**4.88** ±0.56	0.76 ±0.77 (0.04 ±0.04)	-	1.72 ±0.49 (0.98 ±0.28)	1.73 ±0.91 (0.66 ±0.34)	2.07 ±1.51 (0.02 ±0.01)	**1.67** ±0.44	**6.55** ±0.52
41.	Inland Fish	2.62 ±2.58	0.14 ±0.25	1.63 ±2.16	-	0.46 ±0.89	0.32 ±0.33	**5.18** ±1.66	1.00 ±1.98 (0.04 ±0.09)	-	2.45 ±0.76 (0.82 ±0.26)	1.43 ±1.22 (0.84 ±0.73)	-	**1.75** ±0.78	**6.92** ±1.49
42.	Marine Fish †	-	0.17 ±0.01	0.09 ±0.01	-	-	1.56 ±0.06	**1.81** ±0.04	-	-	0.64 ±0.05 (0.28 ±0.02)	1.71 ±0.08 (0.28 ±0.01)	1.67 ±0.22 (0.44 ±0.06)	**0.97** ±0.06	**2.78** ±0.04
43.	Meat▲	1.36 ±0.09	-	-	-	-	-	**1.36** ±0.09	-	-	0.98 ±0.86 (0.48 ±0.40)	0.81 ±0.54 (0.42 ±0.27)	-	**0.87** ±0.49	**2.23** ±0.22
44.	Poultry Meat	2.67 ±0.16	-	-	-	-	-	**2.67** ±0.16	-	-	0.57 ±0.64 (0.31 ±0.34)	1.51 ±1.26 (0.68 ±0.57)	0.07 ±0.04 (0.01 ±0.00)	**0.98** ±0.66	**3.65** ±0.36
45.	Milk	0.12 ±0.16	0.49 ±0.09	-	-	-	0.07 ±0.04	**0.67** ±0.13	0.09 ±0.06 (0.02 ±0.01)	-	-	-	0.24 ±0.02 (0.08 ±0.01)	**0.10** ±0.01	**0.77** ±0.12
46.	Jaggery¤	-	0.01 ±0.01	-	-	0.19 ±0.17	0.33 ±0.28	**0.52** ±0.20	1.79 ±2.11 (0.15 ±0.18)	1.96 ±0.12 (0.09 ±0.01)	0.89 ±0.65 (0.46 ±0.35)	2.03 ±1.90 (0.60 ±0.58)	0.00 ±0.00	**1.35** ±0.70	**1.87** ±0.70

Figures in parentheses show contribution of storage % in relation to total production

* Sum of the loss as % of the total produce from all storage channels (i.e. sum of the figures in parentheses)

▲Livestock produce 'meat' includes the meat of Sheep and Goat only. For meat and poultry meat, estimation of loss commenced from slaughtering (analogous to harvest operation).

† In Marine fish, estimation of loss commenced from landing at sea shore (analogous to harvest operation)

¤ In Jaggy, estimation starts from removal of Jaggery from heating pan (analogous to collection operation).

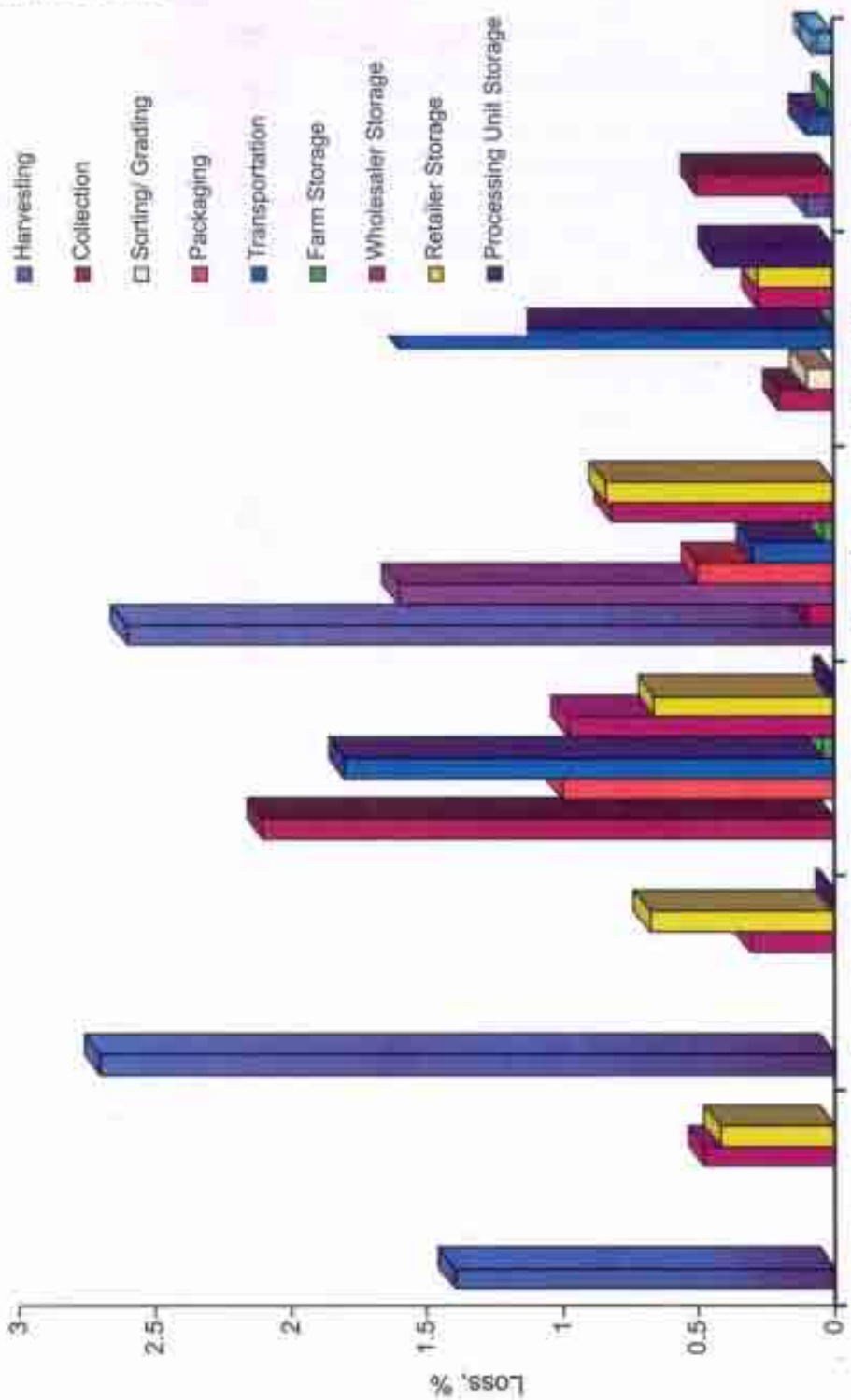

Figure 6.8: Harvest and post harvest losses in livestock produce at national level

6.8 Computation of the Economic Value of Losses

An attempt was made to compute the monitory value of the harvest and post harvest losses estimated in this study at national level, based on the production of various crops and livestock produce in the year 2005 to facilitate comparison to the value of Rs 51,500 crore reported to the Parliamentary Standing Committee on Agriculture (PSCA) in 2005. The computed economic values have been presented in Table 6.8.

Table 6.8 : Estimate of the monitory value of harvest and post harvest losses in India at price and production value for the year 2005-06

Crop / commodity	*Production (million tonnes)	**Price (Rs./tonne)	Monitory value of the losses (Rs. crores)	Sectoral total loss (Rs. crores)
(i) Cereals				**7614**
1. Paddy	91.79	7187	3424	
2. Wheat	69.35	8326	3441	
3. Maize	14.71	5710	344	
4. Bajra	7.68	5658	209	
5. Sorghum	7.24	6985	196	
(ii) Pulses				**999**
1. Pigeon Pea	2.74	20405	301	
2. Chick Pea	5.60	18662	447	
3. Black Gram	1.25	18678	141	
4. Green Gram	0.95	21184	110	
(iii) Oilseeds				**3800**
1. Mustard	8.13	18105	1309	
2. Cottonseed	3.15	13527	117	
3. Soybean	8.27	13538	701	
4. Safflower	0.23	13890	12	
5. Sunflower	1.44	14344	94	
6. Groundnut	7.99	19473	1567	
(iv) Fruits				**5694**
1. Apple	1.76	27926	601	
2. Banana	12.10	9365	748	
3. Citrus	6.33	20874	842	
4. Grapes	1.63	23383	317	
5. Guava	1.82	7764	255	
6. Mango	12.54	17057	2725	
7. Papaya	2.32	7934	135	
8. Sapota	1.21	10135	71	

Table 6.8 (Continued)

Crop / commodity	*Production (million tonnes)	**Price (Rs./tonne)	Monitory value of the losses (Rs. crores)	Sectoral total loss (Rs. crores)
(v) Vegetables				**3972**
1. Cabbage	5.92	5386	221	
2. Cauliflower	5.26	8051	291	
3. Green Pea	2.30	13456	318	
4. Mushroom	0.04	48589	23	
5. Onion	8.68	7855	512	
6. Potato	23.91	5612	1206	
7. Tomato	9.36	7841	953	
8. Tapioca	7.62	6403	448	
(vi) Spices and plantation crops				**1631**
1. Arecanut	0.48	40810	155	
2. Black Pepper	0.09	64111	23	
3. Cashew	0.54	105997	65	
4. Chilli	1.01	11772	67	
5. Coconut	4.94	18436	488	
6. Coriander	0.22	13315	22	
7. Sugarcane	281.17	270	656	
8. Turmeric	0.85	24679	155	
(vii) Livestock produce				**4092**
1. Egg†	46.17†	2519†	762	
2. Inland Fish	2.78	57708	1110	
3. Marine Fish	3.52	68610	671	
4. Meat	0.76	138458	235	
5. Poultry Meat	0.54	53055	104	
6. Milk	97.07	16187	1210	
Total				**27802**

* All India production for the year 2005-06
(Sources: Directorate of Economics & Statistics, Department of Agriculture & Cooperation, Govt. of India, National Horticulture Board, Govt. of India, Department of Animal Husbandry and Dairying, Govt. of India)
**Wholesale price of the crop/commodity averaged for all months of the year 2005
(*Source: www.agmarknet.nic.in* for agricultural produce, *http://www.indiastat.com* for livestock produce)
†Egg production in billion numbers, price in Rs. per thousand eggs

It is, of course, obvious that by using the all India production data for any recent year along with the wholesale prices of the crops/commodities for the selected year, the monitory value of losses can be computed for the desired year. For instance with reference to the production year 2007-08, the total economic value of the losses of crops and livestock produce at national level have been calculated and found to be about Rs. 44,143 crores.

It is to be noted that even though the same estimates of percent post harvest losses are used for computing, the monitory value of losses keeps escalating with increase in production and increase in price of the agricultural produce.

The major contributors to the monitary value of losses in the country are paddy, wheat, mustard, groundnut, mango, citrus, banana, potato, tomato, sugarcane, inland fish and milk. These commodities make up almost two thirds of the total post harvest loss (Table 6.8) and warrant priority attention.

Among farm operations, threshing and harvesting have been observed to result into the maximum losses in cereals, pulses and oilseeds (Tables 6.1, 6.2 and 6.3). It is true that the extent of mechanization in harvesting and threshing is very high, mostly as custom-hiring service. But it indicates that the machines have to be suitably adjusted for specific field conditions so as to reduce these losses.

In the case of fruits and vegetables, the operations associated with higher losses are noted to be harvesting, sorting/grading and transportation (Table 6.4 and 6.5). Clearly, there is a need for greater technological input to reduce losses in these operations

Among storage channels, the farm level storage has emerged from the results of this study as the most susceptible parameter in the post harvest losses for both food grains and horticultural produce. Losses at the retailers level storage is only next to the losses at farm level in case of fruits (1.1 to 3.8%) and vegetables (1.7 to 2.6%). Inadequacy of storage infrastructure in the country is well known. The results of the study further corroborate the need to expand and strengthen the commodity-based differentiated storage infrastructure.

6.9 Conclusions

The salient findings of the study may be summarized as follows.

- Post harvest losses for 46 major crops and livestock produce contributing to the food basket of India have been estimated on all India basis. The post harvest loss comprises of essentially on-farm losses and those in transport and storage in different marketing channels.
- The losses for selected cereals, constituting 94% of the national cereal production, were observed to be in the range of 3.9 % to 6.0 %.
- The losses were observed to be 4.3% to 6.1% in case of pulses. The slightly higher losses in pulses were mainly due to high storage loss. Among all the selected pulses, black gram indicated highest losses in harvesting (1.1%), collection (1.0%) and threshing (1.6%) operations.
- In case of oilseeds, the losses were in the range of 2.8% to 10.1% with highest losses incurred in groundnut and mustard.

- For cereals, pulses and oilseeds, the losses in farm operations constituted about two-thirds of the total losses. Therefore, efficient technologies for these farm operations could lead to the reduction of losses.
- The losses in selected fruits and vegetables were observed to be in the range of 5.8% to 18.0%.
- The losses in inland and marine fisheries were found to be 6.9% and 2.9%, respectively. The losses of marine fish did not include on-board loss.
- The average losses in milk sector were observed to be 0.8%.
- The losses in meat and poultry meat sectors were found to be 2.3% and 3.7%, respectively.
- Based on the present study, it is found that there has been appreciable reduction in the post harvest losses as compared to the values reported in earlier studies.
- The monetary value of post harvest losses of major agricultural produce at national level has been computed based on production and wholesale prices of 2005 and the results of the present study. The estimated annual value of the post harvest losses is about Rs.27800 crores.

The results of this survey have been helpful in identifying the *critical operations and channels* for a given crop/commodity where losses are high and need technological interventions.

Loss reduction efforts can be concentrated initially on high loss points. First and foremost, intensified efforts are required to create awareness for adoption of already developed and readily available improved processing technologies and equipment resulting in reduction of post harvest losses and increased profitability to the growers. Harvesting and threshing need to be standardized and refinement in existing machines, especially multi crop threshers, is essential. The scientific village level storage systems recommended by experts need to be promoted to store farmers' grain. Appropriate preservation techniques and infrastructure for short term storage such as pre-cooling, cooled as well as cold storage structures for storing fruits and vegetables need to be made available. The value addition technologies need to be promoted in production catchment by providing technology incubation centres, entrepreneurship development training and appropriate publicity.

Researchers, administrators, planners, policy makers and other stakeholders need to not only design and implement future strategies for reducing the post harvest losses but also develop infrastructure for handling and storage of food. The avoidable losses reduced to a certain feasible level by saving and preserving our valuable produce will ensure food security.

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APPENDICES

Appendix I

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
KRISHI ANUSNADHAN BHAWAN- II, NEW DELHI 110012
(Agricultural Engineering Division)

PSCA Observations and responses, May, 2005

Recommendation No. 7

Post-Harvest Losses of Rs. 51,500 crore per annum of Horticultural Produces

Comments of the Committee

The Committee note that ICAR has been making efforts to develop Post-Harvest Technologies (PHT) through its Institutes and All India Coordinated Research Project (AICRP) for reduction of post-harvest losses and value addition in the post-harvest chain. During the Tenth Plan, the AICRP on PHT has been expanded to include all produce from crops, livestock and fisheries sectors and the budget allocation has been enhanced to Rs. 3,895 lakh from Rs. 1,184 lakh during the Ninth Plan.

The Committee also note that these post-harvest losses are estimated to the tune of Rs. 51,500 crore and the Apex agrarian research body, viz. ICAR has hardly done anything concrete to collect and analyse the authntic data of such losses for the whole country during the previsou Nine Five Year Plans except for a recently made very limited area study of these losses under NATP.

The Committee, therefore, urged the Department to take up the task of collecting the authentic data on post-harvest losses of agrarian and allied sector produce on All-India basis and make all out efforts in developing ang getting implemented the technologies developed by them to check such losses on top priority basis. The technologies developed or advances made by other developed countries like Malaysia, Brazil, Thailand, etc. in preserving and processing of the variety of agricultural produce may also be studied and suitably adopted, if feasible, to avoid such a huge recurring national loss.

Reply of the Government

As recommended by the Parliamentary Standing Committee on Agriculture (PSCA), it has been decided to undertake the study on collecting, compiling and analyzing the data on post harvest losses of all the major agrarian produces through the All India Coordinated Research Project on Post Harvest Technology immediatly. Besides, the centres are continuing to develop new technologies for checking post harvest losses and for value addition activities in the production catchments. The relevant technologies developed earlier are also being demonstrated by the 33 centres of the Post Harvest Scheme.

Appendix II

List of Schedules Developed for Collecting Data in the Loss Assessment Survey

S. No.	Schedule No. (with code)	Subject of the Schedule
1.	Schedule 1	Complete enumeration of households of the selected village
2.	Schedule 2 A	Losses at producer level - farm level (by enquiry)
3.	Schedule 2 B	Losses at producer level (storage)
4.	Schedule 3	Complete enumeration of wholesaler/retailer /warehouse/ processing unit
5.	Schedule 4	Losses at market level (wholesaler/retailer/warehouse/ processing unit)
6.	Schedule 5 - C	Losses at farm level in cereals and coriander (by observation)
7.	Schedule 5 - O	Losses at farm level in oilseeds & pulses (by observation)
8.	Schedule 5-H	Losses at farm level in fruits and plantation crops (by observation)
9.	Schedule 5-V	Losses at farm level in vegetable crops (by observation)
10.	Schedule 5-Pepper	Losses at farm level in pepper (by observation)
11.	Schedule 5 - S	Losses at farm level in sugarcane (by observation)
12.	Schedule 5 - E	Losses of egg at producer level (by observation)
13.	Schedule 5 - IF	Losses at farm/ fisherman level in inland fish (by observation)
14.	Schedule 5 - MF	Losses at farm/ fisherman level in marine fish (by observation)
15.	Schedule 5 - Meat	Losses of meat at producer level (by observation)
16.	Schedule 5 - P	Losses of poultry meat at producer level (by observation)
17.	Schedule 5 - Milk	Post harvest losses in milk (by observation)
18.	Schedule 6 - C	Losses during storage at farm/trader/godown/processing unit level for cereals, pulses, oilseeds and coriander (by observation)
19.	Schedule 6 - C1	Identity slip for the sample taken from farmer/traders/ godown/ processing unit level for analysis in the laboratory as per items mentioned overleaf.
20.	Schedule 6 - H	Losses during storage at farmer/trader/retailer/processing unit/godown level in fruits, vegetables and plantation crops (by observation)
21.	Schedule 6 - E	Losses of eggs during transportation and storage at farm/ wholesaler /retailer level (by observation)
22.	Schedule 6 - IF	Losses at market level (wholesale/ retail/ pre-processing/ processing unit level in inland fish (by observation)
23.	Schedule 6 - MF	Losses at market level (wholesale/ retail/ pre-processing/ processing unit level in marine fish (by observation)
24	Schedule - SR	Schedule for estimation of % storage of commodity at different levels.

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 1: Complete enumeration of households of the selected village

A) Identification particulars:

1.	Agro-climatic zone	
2.	State	
3.	District	
4.	Tehsil/Taluk	
5.	Block/Mandal	
6.	Village	

(B) Details of households in the village:

S. No.	Name of head of household	Father's name	Operational holding (ha)	Crop/ commodity grown	Area under crop (ha)/fish ponds	No. of milch/meat animal poultry bird	Remarks, if any

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 2 A: Losses at producer level : Farm Level (By Enquiry)

Date of visit: _____

(A) Identification particulars:

1.	Agro-climatic zone	
2.	State	
3.	District	
4.	Tehsil/Taluk	
5.	Block/Mandal	
6.	Village	
7.	Name of the head of household	
8.	Father/Husband's name	

Name of crops/commodities grown by farmers: _____

(B) Area information

1	i.	Owned land (ha.)	
	ii.	Leased out land (ha.)	
	iii.	Leased in land (ha.)	
	Total Operational holding (ha.)		
2.	Name of the selected crops/fish ponds		Area (ha)
3.	Name of the selected Livestock produce		No. of animals
	Milk		
	Egg		
	Meat		
	Poultry meat		

(C) Losses at farm level (by enquiry) during the enquiry period

Name of the Crop/Commodity: _____ Date of visit : _____

Operations	Methods of operation	Equipment used	Quantity handled	Quantity lost	Causes of losses
Harvesting/ Picking/ Slaughter/ Milking/ Catch from pond to land or sea to shore					
Collection					
Sorting & Grading/ Threshing/ Dehusking (nuts)					
Winnowing/Sieving Cleaning					
Drying					
Packaging					
Transport (From threshing floor to Store & Mandi)					
Any other (specify)					

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 2 B: Losses at producer level (Storage)

Date of visit: _____ Period of Enquiry: _____

(A) Identification particulars:

1.	Agro-climatic zone	
2.	State	
3.	District	
4.	Tehsil/Taluk	
5.	Block/Mandal	
6.	Village	
7.	Name of the head of household	
8.	Father/Husband's name	

Name of crops/commodities grown by farmers: _____

(B) Losses at farm level during storage (by enquiry)

Crop/ commodity	Previous balance, kg	Addition during enquiry period, kg	Quantity withdrawal during enquiry period, kg	Total quantity stored, kg	Type of storage	Quantity lost, kg	Causes of losses

Date _____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 3: Complete enumeration of wholesaler/retailer/warehouse/ processing unit

Date of visit: _____ Period of Enquiry: _____

(A) Identification particulars:

1.	Agro-climatic zone	
2.	State	
3.	District	
4.	Tehsil/Taluk	
5.	Block/Mandal	
6.	Name of market/Mandi	

(B) Detail of wholesaler/retailer/warehouse/processing unit

S. No.	Name of stockist	Address	Crop/ commodity handled	Type of storage	Capacity of storage, kg	Quantity stored, kg	Quantity handled during previous year, kg

Date_____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

(Wholesaler, retailer, processing unit and godown of selected marketing channels)

Schedule 4: Losses at market level (Wholesaler/retailer/warehouse/ processing unit)

Date of visit: _____ Period of Enquiry: _____

(A) Identification particulars:

1.	Agro-climatic zone	
2.	State	
3.	District	
4.	Tehsil/Taluk	
5.	Name of market	
6.	Name of trader/processing unit/godown and its address	
7.	Whether wholesaler/retailer	

Name of crops/commodities handles: _____

(B) Losses at farm level during storage (by enquiry)

Crop/ commodity	Previous balance, kg	Addition during enquiry period kg	Quantity withdrawal during enquiry period, kg	Total quantity stored, kg	Type of storage	Quantity lost, kg	Causes of losses

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5 -C: Losses at Farm Level in Cereals and Coriander (By Observation)

A. Identification:

	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block / Mandal	
vi.	Village	
vii.	Name of the farmer	
viii.	Total land holding (ha)	
ix.	Name of crops grown	
x.	Date of visit	

B. Particulars of the selected field:

	Particulars	
i.	Name of crop	
ii.	Area under the crop (ha)	
iii.	Variety	
iv.	Date of sowing	
v.	Date of harvesting	
vi.	Method of harvesting	Manual/ mechanical
vii.	Equipment used for harvesting	

C. Losses during harvesting from randomly selected plot:

Method of harvesting: _____

Equipment used for harvesting: _____

i. Traditional Harvesting:

Production from the selected plot of 5m×5m obtained by crop cutting (kg)	Weight/number of fallen grain (g/no) collected from selected plot of 5m×5m after harvesting

ii. Combine Harvesting:

Actual area of the field (ha)	Production of the field (kg)	Weight of fallen grain (g) collected from selected plot of 5m×5m after harvesting

D. Loss during Threshing/Shelling

S. No.	Particulars	
i.	Type of threshing floor	
ii.	Method of threshing (stone roller passing, tractor treading, mechanical thresher, etc.)	
iii.	Number of bundles from 5×5m plot/ 3 bundles (35-40 kg each) from harvested crop (*In case tractor operated bigger threshers are used*)	
iv.	Weight of grain obtained after threshing the bundles/ 10 kg cob samples	
v.	Weight of straw obtained, kg.	
vi.	Weight (kg) / number of grains going with 250g straw sample drawn from the straw of threshed crop	

E. Losses during Cleaning/Winnowing

S. No.	Particulars	
i.	Method of cleaning/winnowing	
ii.	Weight of sample grain before cleaning (sample size: 10kg)	
iii.	Weight of grain after cleaning (kg)	
iv.	Weight of straw and other materials obtained during cleaning (kg)	
v.	Weight / number of grains going with 250g straw sample drawn from the straw of cleaned crop	

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5-O: Losses at Farm Level in Oilseeds & Pulses (By Observation)

A. Identification:

	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block / Mandal	
vi.	Village	
vii.	Name of the farmer	
viii.	Total land holding	
ix.	Name of oilseed and pulse crops grown	
x.	Date of visit	

B. Particulars of the selected field:

	Particulars	
i.	Name of crop	
ii.	Area under the crop, ha	
iii.	Soil type	
iv.	Condition of soil (for groundnut only)	Moist/normal/dry
v.	Variety	
vi.	Date of sowing	
vii.	Date of harvesting	
viii.	Method of harvesting	Manual/mechanical
ix.	Equipment used for harvesting	

C (1): Losses during harvesting from randomly selected plot (*for pulses, safflower and groundnut*)

Method of harvesting _____

Production from the selected plot of 5mx5m obtained by crop cutting (kg)	Weight of fallen grains/leftover pods in the soil collected from selected plot of 5m×5m after harvesting/ last picking (for groundnut) (kg)

C (2): Losses during harvesting from randomly selected plot (*for sunflower, cottonseed, mustard and soybean)*

Method of harvesting _____

Particulars	Plant Number										Average
	1	2	3	4	5	6	7	8	9	10	
Number of pods/ siliques/seed/cotton bolls before harvest											
Number of shattered pods/ siliques/ bolls till threshing floor											
Number of seeds in three pods/ silique											

D. Loss during Threshing

S. No.	Particulars	
i.	Type of threshing floor	
ii.	Method of threshing	
iii.	Number of bundles from 5×5m plot / 3 bundles of harvested crop	
iv.	Weight of grain obtained after threshing of bundles, kg	
v.	Weight of straw obtained, kg	
vi.	Weight/number of grains going with straw of threshed crop and stem, in 250g sample	

E. Losses during to Cleaning/winnowing

S. No.	Particulars	
i.	Method of cleaning/winnowing	
ii.	Weight of sample grain before cleaning (sample size: 10 kg)	
iii.	Weight of grain after cleaning (kg)	
iv.	Weight of straw & other material obtained during cleaning, kg	
v.	Weight/number of grains going with 250g straw sample drawn from the straw of cleaned crop	

Date _____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5-H: Losses at Farm Level in Fruits and Plantation Crops (By Observation)

A. Identification:

	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of the farmer	
viii.	Total land holding	
ix.	Area under orchards	
x.	Name of fruit / plantation crops grown	
xi.	Date of visit	

B. Details of fruit/ plantation crops grown by farmer:

S. No	Particulars	Crops			
i.	Name of the crop				
ii.	Extent of area cultivated (ha)				
iii.	Variety				
iv.	Date of sowing/planting				
v.	Age of plants/orchard				
vi.	Date of harvesting				
vii.	Method of harvesting				

C: Losses at farm level:

Name of crop _____ Date of harvesting _____

i. Losses during harvest from randomly selected trees:

Method of harvesting _____

a.	Production from 4 selected trees, (kg)/ number	
b.	Weight/ number of produce damaged during harvesting (rejected due to bruise, cuts etc. only)	
c.	Loss (%)	
d.	Causes of loss	

ii. Losses during cleaning/grading and sorting:

a.	Date of cleaning, grading and sorting	
b.	Method of cleaning / grading and sorting	
c.	Weight/number of produce cleaned/graded/sorted, (10 kg / 50 numbers)	
d.	Weight/number of produce rejected/ spoiled (rejected due to damages)	
e.	Loss (%)	
f.	Causes of loss	

iii. Loading, transportation and unloading loss (Farm to market):

a.	Date of visit	
b.	Method of Loading & Unloading *(using hook /dumping/any other means specify)*	
c.	Mode of transport	
d.	Number of layers stacked	
e.	Total weight of produce transported, kg	
f.	Weight/number of sample drawn after transportation up to mandi, (10 kg/ 50 numbers/ 5 boxes)	
g.	Weight/number of produce spoiled and rejected	
h.	Loss (%)	
i.	Causes of loss	

Date _____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5-V: Losses at Farm Level in Vegetable Crops (By Observation)

A. Identification:

	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of the farmer	
viii.	Total land holding	
ix.	Area under vegetables	
x.	Name of vegetable crops grown	
xi.	Date of visit	

B. Details of vegetable crops grown by farmer:

S. No	Particulars	Crops			
i.	Name of the crop				
ii.	Extent of area cultivated (ha)				
iii.	Variety				
iv.	Date of sowing/planting				
v.	Date of harvesting				
vi.	Method of harvesting				
vii.	Equipment used				

C: Losses at farm level:

Name of crop _____ Date of harvesting _____

i. Losses during harvest from randomly selected plot:
Method of harvesting _____

Production from the randomly selected plot of 5m×5m	Weight of fallen produce collected from selected plot of 5m×5m after harvesting/ picking, kg

ii. Losses during cleaning/ grading and sorting:

a.	Date of cleaning/ grading and sorting	
b.	Weight/ number of produce sample cleaned/graded/sorted, (10 kg/ 50 numbers)	
c.	Weight/ number of produce rejected/lost (rejected due to damages during grading/ sorting operation), kg	
d.	Loss (%)	
e.	Causes of loss	

iii. Loading, transportation and unloading loss (Farm to market):

a.	Date of visit	
b.	Method of Loading & Unloading *(using hooks/dumping/any other means specify)*	
c.	Mode of transport	
d.	Number of layers stacked	
e.	Total weight of produce transported, kg	
f.	Weight/ number of sample drawn after transportation to mandi, (10kg/ 50numbers/ 5boxes)	
g.	Weight/ number of produce spoiled and rejected, kg	
h.	Loss (%)	
i.	Causes of loss	

Date_____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5-Pepper: Losses at Farm Level in Pepper (By Observation)

A. Identification:

S.No	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of the farmer	
viii.	Total land holding	
ix.	Area under pepper crop, ha	
x.	Date of visit	

B. Details of pepper crop grown by farmer:

S. No	Particulars	
i.	Extent of area cultivated (ha)	
ii.	Variety	
iii.	Date of sowing/planting	
iv.	Age of plants/orchard	
v.	Date of harvesting	
vi.	Method of harvesting	

C: Losses at farm level of pepper:

i. Losses during harvest from randomly selected vines/trees:
Method of harvesting _____

S. No	Particulars	
i.	Production from 4 selected vines/trees, (kg)	
ii.	Weight/ number of produce damaged during harvesting (rejected due to bruise, cuts etc.), kg	
iii.	Loss (%)	
iv.	Causes of loss	

ii. Loss during threshing:

S. No	Particulars	
i.	Type of threshing floor	
ii.	Method of threshing (stone roller passing, tractor treading, mechanical thresher, etc.)	
iii.	Weight of sample taken for threshing, kg (5 kg sample has to be taken)	
iv.	Weight of produce obtained after threshing the sample, kg	
v.	Weight of straw & waste obtained, kg.	
vi.	Weight of produce going with straw & waste, kg	
vii.	Loss (%)	

iii. Losses during cleaning/grading and sorting:

S. No	Particulars	
i.	Date of cleaning, grading and sorting	
ii.	Method of cleaning / grading and sorting	
iii.	Weight of produce cleaned/graded/sorted (5 kg)	
iv.	Weight of produce rejected/ spoiled (rejected due to damages)	
v.	Loss (%)	
vi.	Causes of loss	

Date _____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5-S: Losses at Farm Level in Sugarcane (By Observation)

A. Identification:

	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block / Mandal	
vi.	Village	
vii.	Name of the farmer	
viii	Father's name	
ix	Total land holding, ha	
x.	Area under sugarcane, ha	
xi	Date of visit	

B. Particulars of the selected field:

	Particulars	
i.	Area of the field, ha	
ii.	Soil type	
iii.	Variety	
iv.	Date of planting	
v.	Date of harvesting	
vi.	Method of harvesting	Manual/mechanical
vii.	Equipment used for harvesting	

C. Losses during harvesting from randomly selected plot:

Production from the selected plot of 5m×5m obtained by crop cutting (kg)	Weight of stubbles left in selected plot of 5m×5m after harvesting (kg)	Loss (%)

D. Loss due to staling of sugarcane:

	Particulars	
i.	Date of harvesting	
ii.	Weight of three bundles of sugarcane after harvest	
iii.	Date of crushing	
iv.	Period of staling (in hours and days)	
v.	Weight of the same three bundles before crushing, kg	
vi.	Loss in weight, kg	
vii.	Loss, %	

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5-E: Losses of Egg at Producer Level (By Observation)

A. Identification:

S.No	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of the farmer/producer	
viii	Name of the poultry farm	
ix.	Name of poultry species reared (for egg production)	
x.	Date of visit	

B. Particulars of the selected poultry farm/ producer:

S.No	Particulars	
i.	Status of the poultry farm	Private/ co-operative/ contract
ii.	Type of poultry house	Cage type/ Deep litter type/ any other (pl specify)
iii.	Number of sheds in the poultry house	
iv.	Containers used for egg collection	Paper pulp filter flat/ plastic filter flat/ plastic bucket/ wire basket
v.	Frequency of egg collection per day	Once/ twice/ thrice
vi.	Packaging material for egg	Plain card board box/ corrugated board box/ any other (pl specify)

C. Loss of eggs at farm/producer level:

(i) Loss during collection of eggs:

Total number of eggs collected from selected shed/birds	Number of eggs damaged/ spoiled	Causes of loss

(ii) Loss during packaging of eggs:

Total number of eggs to packed	Number of eggs damaged/ spoiled	Causes of loss

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5- IF: Losses at Farm/ Fisherman Level in Inland Fish (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of the Head of household/ fisherman	
viii.	Father's name	
ix.	Date of visit	

B. Loss during catch of inland fish:

S. No.	Particulars	
i.	Source of water body	Pond/River/Lake/Reservoir/Tank
ii.	Method of catch operation	Manual/ mechanical
iii.	Equipment used for catch	
iv.	Total catch of fish on the date of visit, kg	
v.	Weight of fish discarded (Loss), kg	
vi.	Causes of loss	

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 5- MF: Losses at Farm/ Fisherman Level in Marine Fish (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of the Boat owner (fisherman)	
viii.	Father's name	
ix.	Name of landing center	
x.	Date of visit	

B. Losses at landing center of marine fish:

S. No.	Operations	
i.	Type of fishing craft used	Local/ mechanized
ii.	Type of fishing gear used	Gill net/ Trawl net/ Trawl net with TED/ others (pl specify)
iii.	Total weight of fish received from boat at the time of landing, kg	
iv.	Loss during transferring (weight of fish left in the boat after unloading), kg	
v.	Loss of fish at landing center (weight of fish remain indisposed from fish received after landing), kg	
vi.	Loss of fish during grading at landing center (weight of fish discarded), kg	
vii.	Loss in other operation, if any, kg	

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses of (Slaughter and Post Slaughter) in Meat

Schedule 5- Meat: Losses of Meat at Producer Level (By Observation)

A. Identification:

S.No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of slaughter house / Butcher's shop	
viii.	Name of livestock species slaughtered (Buffalo, sheep, goat, pig)	
viii.	Date of visit	

B. Particulars of the selected meat producer:

S.No.	Particulars	
i.	Name of livestock slaughtered	Buffalo/sheep/goat/pig
ii.	Total number of animals slaughtered on the date of the visit	
iii.	Place of purchase	Farm/Market/ any other (pl specify)
iv.	Method of slaughtering	Manual /Mechanical

C. Loss during slaughter of animal:

S.No.	Weight of fresh carcass, kg	Weight of meat removed due to damages and injuries, kg	Causes of loss
1.			
2.			
3.			
4.			
5.			

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR)

CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses of (Slaughter and Post Slaughter) in Poultry Meat

Schedule 5- P: Losses of Poultry Meat at Producer Level (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name of slaughter house/ butcher's shop	
viii.	Name of the poultry species slaughtered	
x.	Date of visit	

B. Particulars of the selected poultry meat producer:

S. No.	Particulars	
i.	Type of slaughter house	Private/ co-operative/ contract
ii.	Place of purchase	Poultry farm/ Market/ any other (specify)
iii.	Method of transport of poultry birds	Truck/ lorry/ tractor trolley/ auto/cycle
iv.	Type of cage for keeping live poultry birds	
v.	Catching method employed	Both legs/ both wings/ one leg & one wing/ any other (pl specify)
vi.	Method of slaughtering	Manual/ Mechanical

C. Loss during slaughter of poultry birds:

S. No.	Weight of fresh carcass, kg	Weight of meat removed due to damages and injuries, kg	Causes of loss
1			
2			

D. Loss during storage of poultry meat:

S. No.	Particulars	
i.	Type of storage used for dressed chicken	Freeze/ chiller/ any other (specify)
ii.	Capacity of the storage (No.)	
iii.	Number of dressed chicken stored in freezer	
iv.	Number of carcass drawn for observation	
v.	Number of dressed chicken spoiled	
vi.	Causes of spoilage	

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses

Schedule 5-Milk: Post Harvest Losses in Milk (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village/ Address of chilling center/ processing unit	
vii.	Name of the farmer/ chilling center/ processing unit	
viii.	Number of milch animal (for farmers only)	
ix.	Quantity of milk produced/ processed/ collected per day	
x.	Date of visit	

B. Observation of research engineer regarding losses in different stages and channels:

S. No.	Stage/ Channel	Loss %	Causes of loss
i.	While milking		
ii.	Handing loss at producer level		
iii.	Loss at chilling center		
iv	Loss at processing unit		
v.	Any other loss (please specify)		

Date_____

_____

Signature of the Research Engineer

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR)
CIPHET, P.O. PAU Campus, Ludhiana - 141004 (Punjab)
Sample Survey for Assessment of Harvest and Post Harvest Losses
Schedule 6-C : Losses during Storage at Farm/Trader/Godown/Processing Unit Level for Cereals, Pulses, Oilseeds and Coriander (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village/Name of Market	
vii.	Name of the farmer/Trader/Godown/Processing unit	
viii.	Total land holding (ha)/Quantity of grain handled	
ix.	Name of crops grown/handled	
x.	Period of enquiry	
xi.	Date of visit	

B. Loss during storage:

S. No.	Crop	Initial Stock		Addition, kg	Sale / consumption/ processed/ disposal, kg	Final stock, kg	Period of storage (month)	Whether grain infested (Yes/No)	Whether attacked by rodents (yes/no)	S. No. of identity slip attached with sample	Date of dispatch of sample
		Mode of storage	Quantity stored, kg								

Date_____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses

Schedule 6-C1: Identity slip for the sample taken from farmer/Traders/ Godown/ Processing unit Level for analysis in the Laboratory as per items mentioned overleaf.

Serial No._____

	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village/Name of Market	
vii.	Name of the farmer/Trader/Godown/Processing unit	
viii.	Type of storage	
ix.	Weight of the sample drawn (g)	
x.	Date (day, month & year) of sample drawn for each of the observations.	

Date:_____ _____

Signature of the Field Investigator

(N.B.: This slip should be prepared in triplicate. One copy may be kept inside the sample bag. Second one to be tied outside the bag and the third one to be kept with the Field Investigator for record.)

Date of receipt _____ Signature of Laboratory Assistant _____

Schedule 6-C2: Observation on samples taken from each of the samples sent by the field staff for analysis in the laboratory:

	Particulars	Number	Weight, g
i.	Moisture content of grains, % (d.b.)		
ii.	No. & weight of undamaged grains		
iii.	No. & weight of damaged grains		

Date_____ _____

Signature of the Laboratory Assistant

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR)
CIPHET, P.O. PAU Campus, Ludhiana – 141004 (Punjab)

Sample Survey for Assessment of Harvest and Post Harvest Losses

Schedule 6-H : Losses during Storage at Farmer/Trader/Retailer/Processing Unit/Godown Level in Fruits, Vegetables and Plantation Crops (By Observation)

A. Identification:

S.No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village/Market/Mandi/Address of processing unit	
vii.	Name of the farmer/trader/retailer/processing unit/godown	
viii.	Name of fruits & vegetables crops handled	
ix.	Total quantity of commodities handled/stored, in pervious month, (kg)	
x.	Period of enquiry	
xi	Date of visit	

B. Loss during storage:

S. No.	Name of crop	Initial Stock		Addition (kg)	Sale/ consumption/ processed, (kg)	Final Stock, (kg)	Weight/ number of sample drawn, kg	Weight/ number of damaged produce, kg	Loss (%)	Causes of loss
		Mode of storage	Quantity stored (kg)							

Date: _____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses
Schedule 6- E: Losses of Eggs during Transportation and Storage at Farm/ Wholesaler/Retailer Level (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Village	
vii.	Name & address of the farmer/ wholesaler/ retailer	
vii.	Number of eggs handled/ marketed	
viii.	Period of enquiry	
ix.	Date of visit	

B. Loss during transportation:

S. No.	Particulars	
i.	Mode of transport	Auto / truck/ any other (pl specify)
ii.	Total distance of transportation, km	
iii.	Total number of packages transported	
iv	Time taken during transportation, days	
v.	Number of eggs in packages for loss estimation (5 packages randomly to be taken)	
vi.	Number of eggs damaged during transport	
vii.	Causes of loss	

C. Loss of eggs during storage:

S. No.	Particulars	
i.	Type of storage	
ii.	Type of packaging material used	Plain card board box/ corrugated board box/ any other (pl specify)
iii.	Method of preservation	Oil application/ any other (pl specify)
iv.	Total number of eggs in packages drawn for loss estimation (5 packages)	
v.	Number of eggs spoiled/ damaged	
vi.	Causes of loss	

Date_____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses
Schedule 6-IF: Losses at Market Level (Wholesale/Retail/Pre-processing/Processing Unit Level in Inland Fish (By Observation)

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Name of the fish market	
vii.	Name & address of the wholesaler/ retailer/ processing unit	
viii.	Period of enquiry	
ix.	Date of visit	

B. Losses during transportation:

S. No.	Particulars	
i.	Distance of market from place of loading fish, km	
ii.	Mode of transport	
iii.	Time taken for transportation, h	
iv.	Type of packaging used for transportation	
v.	Whether ice is used for packaging	Yes/ No
vi.	Fish: Ice ratio used (in case of ice)	
vii.	Weight of sample drawn for analysis (Minimum 10 kg)	
viii.	Weight of fish discarded (Loss), kg	
ix.	Causes of loss	

C. Losses during storage:

S. No.	Particulars	
i.	Type of storage	Frozen storage/ Refrigerated storage/ Bamboo basket/ Plastic insulated box with ice/ Metal box with ice/ Plastic crate/ any other (pl specify)
ii.	Capacity of storage, kg	
iii.	Duration of storage, days	
iv.	Weight of sample drawn (Minimum 10kg sample or complete pack)	
v.	Weight of fish spoiled in sample, kg	
vi.	Causes of loss	

Date_____

_____
Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses

Schedule 6-MF: Losses at Market Level (Wholesale/ Retail/ Pre-processing/ Processing Unit Level in Marine Fish (By Observation)

A. Identification:

S. No.	Particulars	
i.	Agro-climatic zone	
ii.	State	
iii.	District	
iv.	Tehsil/Taluk	
v.	Block/Mandal	
vi.	Name of the fish market	
vii.	Name & address of the wholesaler/ retailer/ processing unit	
viii	Period of enquiry	
ix	Date of visit	

B. Loss during transportation:

S. No.	Particulars	
i.	Distance of market from place of loading fish	
ii.	Mode of transport	
iii.	Time taken for transportation, h	
iv.	Type of packaging used for transportation	
v.	Whether ice is used for packaging	Yes/ No
vi.	Fish: Ice ratio used (in case of ice)	
vii.	Weight of sample drawn for analysis (Minimum 10 kg)	
viii.	Weight of fish discarded (Loss), kg	
ix.	Causes of loss	

C. Loss during storage:

S. No.	Particulars	
i.	Type and capacity of storage	
ii.	Duration of storage, days	
iii.	Weight of sample drawn (Minimum 10kg or complete pack)	
iv.	Weight of fish spoiled in sample, kg	
v.	Causes of loss	

D. Loss during drying:

S. No.	Particulars	
i.	Type of drying floor/yard/ machine used	
ii.	Time taken for drying, days	
iii.	Weight of sample drawn (5 kg sample of fish)	
iv.	Weight of fish spoiled in the sample, kg	
v.	Causes of loss	

Date _____

_____

Signature of Field Investigator

ALL INDIA COORDINATED RESEARCH PROJECT ON POST HARVEST TECHNOLOGY (ICAR) CIPHET, P.O. PAU Campus, Ludhiana 141 004 (Punjab)

Sample Survey for Assessment of Harvest and Post harvest Losses

Schedule-SR : Schedule for Estimation of Percent Storage of Commodity at Different Levels.

(A) Identification particulars:

1.	Agro-climatic zone	
2.	State	
3.	District	
4.	AICRP Centre	
5.	Name and designation of respondent	
6.	Date	

(B) Distribution of various commodities in % for storage at various levels.

S. No.	Name of commodity	Retained at farm level	Retained at godown/ warehouse/cold storage	Retained by whole-seller	Retained by retailer	Retained at processing centre	Total	Remarks, if any

Signature

Note:

- To be filled up by the Research Engineers involved in the project for the commodities handled by them in respective districts and by other experts in the area, if any.
- Please fill up this performa based on you experience/judgment. In case there is need, small number of farmers/others can be interviewed regarding disposal of their commodities.

Appendix III

Agro-Climatic Zone-wise List of Districts selected for Survey

Name of Zone	State	Districts Surveyed	PHT Centre Name
Western Himalayan Region (Zone 01)	Himachal Pradesh	Chamba	Solan
		Kinnaur	
		Shimla	
		Una	
	Uttaranchal	Almora	Almora
		Bageshwar	
	Uttaranchal	Haridwar	Pantnagar
		Nainital	
Eastern Himalyan Region (Zone 02)	Assam	Barpeta	Buralikson
		Darrang	
		Kamrup	
	Assam	Lakhimpur	Jorhat
		Nalbari	
		Nagaon	
		Tinsukia	
	West Bengal	Bankura	Kharagpur
Lower Gangetic Plain Region (Zone 03)	West Bengal	Medinipur (West)	Kharagpur
	West Bengal	Medinipur (East)	Kolkata
		Nadia	
		Jalpaiguri	
Middle Gangetic Plain Region (Zone 04)	Bihar	Bhabua	Pusa
		Darbhanga	
		Samastipur	
		Supaul	
		Vaishali	
	Uttar Pradesh	Ambedkar Nagar	Faizabad
		Azamgarh	
		Balrampur	
		Sonbhadra	
		Varansi	
	Uttar Pradesh	Deoria	Lucknow
		Chandauli	

Name of Zone	State	Districts Surveyed	PHT Centre Name
Upper Gangetic Plain Region (Zone 05)	Uttar Pradesh	Etawah	Lucknow
		Kanpur (Dehat)	
		Unnao	
	Uttar Pradesh	Pratapgarh	Faizabad
Trans Gangetic Plain Region (Zone 06)	Haryana	Fatehabad	Hisar
		Hisar	
		Jind	
		Karnal	
		Rohtak	
	Punjab	Ferozepur	Ludhiana
		Jalandhar	
		Moga	
Eastern Plateau and Hills Region (Zone 07)	Chattisgarh	Bilaspur	Raipur
		Raigarh	
		Raipur	
		Jashpur	
		Kawardha	
	Maharashtra	Bhandara	Akola
	Orissa	Dhenkanal	Bhubaneswar
		Phoolbani	
		Sonpur	
	West Bengal	Purulia	Kharagpur
Central Plateau and Hills Region (Zone 08)	Madhya Pradesh	Hosangabad	Bhopal
	Rajasthan	Alwar	Jodhpur
	Rajasthan	Banswara	Udaipur
		Baran	
		Chittorgarh	
		Udaipur	
		Karauli	Jaipur

Name of Zone	State	Districts Surveyed	PHT Centre Name
Western Plateau and Hills Region (Zone 09)	Maharashtra	Amaravati	Akola
		Nasik	
	Maharashtra	Kolhapur	Kolhapur
		Sangli	
		Satara	
	Madhya Pradesh	Dewas	Bhopal
		Jhabua	
		Neemuch	
Southern Plateau and Hills Region (Zone 10)	Karnataka	Bangalore (Rural)	Bangalore
		Chitradurga	
	Karnataka	Kolar	Raichur
		Belgaum	
		Bellary	
		Bijapur	
	Tamilnadu	Kanayakumari	Coimbatore
		Karur	
		North Arcot	
		Thiruvallur	Chennai
East Coast Plains and Hills Region (Zone 11)	Andhra Pradesh	East Godavari	Anakapalle
		West Godavari	
	Andhra Pradesh	Guntur	Bapatla
		Krishna	
		Nellore	
	Orissa	Cuttack	Bhubaneswar
		Ganjam	
		Jagatsinghapur	
	Tamilnadu	Dindigul	Coimbatore

Name of Zone	State	Districts Surveyed	PHT Centre Name
West Coast Plains and Ghats Region (Zone 12)	Karnataka	Dakshina Kannada	Raichur
	Karnataka	Shimoga	Bangalore
	Kerala	Kannur	Kasaragod
		Kasaragod	
	Kerala	Kottayam	Tavanur
		Wayanad	
	Kerala	Palakkad	Trivandrum
	Tamilnadu	Dharmapuri	Coimbatore
Gujarat Plains and Hills Region (Zone 13)	Gujarat	Amareli	Junagarh
		Valsad	
		Kheda	
		Mehasana	
		Navsari	
Western Dry Region (Zone 14)	Rajasthan	Churu	Jaipur
	Rajasthan	Rajsamand	Udaipur

Appendix IV

Sample Size (No. of Respondents) for Estimation of Loss in Farm Operations at the National Level

S. No.	Crop	Harvesting	Collection	Threshing	Sorting/ Grading	Winnowing /cleaning	Drying	Packaging	Transportation
Grains (Cereals, Millets, Pulses, Oilseeds)									
1	Paddy	2399	1660	2034	-	2189	1633	1743	1666
2	Wheat	1346	865	1072	-	940	435	767	996
3	Maize	545	468	546	-	510	470	470	438
4	Bajra	504	404	500	-	492	348	363	378
5	Sorghum	519	429	513	-	396	421	466	476
6	Pigeon Pea	325	190	326	-	260	78	239	226
7	Chick Pea	574	434	574	-	327	255	343	454
8	Black Gram	397	289	394	-	315	240	300	255
9	Green Gram	549	376	543	-	509	371	402	249
10	Mustard	894	615	864	-	787	450	570	583
11	Cottonseed	622	107	-	-	32	19	82	503
12	Soybean	556	405	539	-	178	246	470	470
13	Safflower	32	6	13	-	6	6	27	27
14	Sunflower	224	202	221	-	211	203	206	218
15	Groundnut	601	439	527	-	319	403	472	457
Fruits									
16	Apple	689	329	-	581	-	-	485	573
17	Banana	174	36	-	120	-	-	27	160
18	Citrus	590	407	-	450	-	-	330	509
19	Grapes	56	34	-	52	-	-	28	52
20	Guava	530	240	-	478	-	-	80	494
21	Mango	252	134	-	229	-	-	70	183
22	Papaya	419	339	-	329	-	-	292	416
23	Sapota	81	10	-	81	-	-	13	53
Vegetables									
24	Cabbage	774	609	-	506	-	-	493	769
25	Cauliflower	767	572	-	410	-	-	500	746
26	Green Pea	985	514	-	724	-	-	594	774
27	Mushroom	4	4	-	4	-	-	2	4
28	Onion	435	316	-	311	-	-	254	362
29	Potato	1073	495	-	741	-	-	733	908
30	Tomato	1081	765	-	1026	-	-	272	1055
31	Tapioca	170	108	-	108	-	-	44	106

S. No.	Crop	Harvest-ing	Collection	Thresh-ing	Sorting/ Grading	Winnow-ing /cleaning	Drying	Pack-aging	Transpor-tation
Plantation Crops and Spices									
32	Arecanut	808	442	294	190	261	147	336	393
33	Black Pepper	391	169	336	-	248	216	27	91
34	Cashew	267	162	152	-	-	37	148	192
35	Chilli	405	269	-	379	50	187	280	387
36	Coconut	1306	649	-	845	-	227	365	657
37	Coriander	20	9	20	-	18	7	10	14
38	Sugarcane	978	504	-	137	-	354	203	574
39	Turmeric	119	48	-	34	14	105	83	64
Livestock Produce									
40	Egg	-	135	-	-	-	-	135	59
41	Inland Fish	176	116	-	123	-	-	130	131
42	Marine Fish	-	93	-	93	-	8	-	93
43	Meat	256	-	-	-	-	-	-	-
44	Poultry Meat	218	-	-	-	-	-	-	-
45	Milk	866	650	-	-	-	-	-	93
Commodity									
46	Jaggery & Khandsari	-	2	-	-	-	3	3	3

Appendix V

Sample Size (No. of Respondents) for Estimation of Loss during Storage in Different Channels at the National Level

S. No.	Crop	Farm Level	Godown Level	Wholesaler level	Retailer Level	Processing Unit Level
Grains (Cereals, Millets, Pulses, Oilseeds)						
1	Paddy	2067	33	178	62	142
2	Wheat	1369	15	61	61	32
3	Maize	676	7	59	21	13
4	Bajra	474	10	83	44	19
5	Sorghum	493	18	42	33	4
6	Pigeon Pea	533	9	116	77	37
7	Chick Pea	681	15	64	39	23
8	Black Gram	502	7	127	109	15
9	Green Gram	630	8	180	135	16
10	Mustard	890	11	67	38	43
11	Cottonseed	388	-	25	-	10
12	Soybean	472	7	23	9	14
13	Safflower	23	1	7	-	21
14	Sunflower	19	7	38	10	12
15	Groundnut	563	9	124	100	32
Fruits						
16	Apple	262	12	30	85	3
17	Banana	30	6	70	48	1
18	Citrus	299	1	69	116	6
19	Grapes	4	-	27	33	7
20	Guava	67	-	50	44	15
21	Mango	18	-	68	63	15
22	Papaya	259	3	48	61	1
23	Sapota	11	-	19	13	-
Vegetables						
24	Cabbage	474	6	68	61	2
25	Cauliflower	426	4	54	37	-
26	Green Pea	366	4	41	74	-
27	Mushroom	-	-	-	15	-
28	Onion	242	2	80	85	2
29	Potato	590	7	30	40	2
30	Tomato	239	4	99	83	2
31	Tapioca	35	-	23	25	11

S. No.	Crop	Farm Level	Godown Level	Wholesaler level	Retailer Level	Processing Unit Level
Plantation Crops and Spices						
32	Arecanut	284	7	37	32	3
33	Black Pepper	357	8	30	30	2
34	Cashew	154	2	25	36	13
35	Chilli	227	3	76	49	6
36	Coconut	686	8	88	89	23
37	Coriander	22	2	48	28	2
38	Sugarcane	67	-	3	7	4
39	Turmeric	78	-	17	20	-
Livestock Produce						
40	Egg	118	-	71	73	1
41	Inland Fish	27	-	58	68	-
42	Marine Fish	-	-	14	10	16
43	Meat	-	-	2	22	-
44	Poultry Meat	-	-	15	27	1
45	Milk	659	-	-	-	-

Appendix VI

Extent of National Coverage by Sampling

S. No.	Crop/ commodity	No. of districts surveyed	Production in surveyed districts (,000 MT)	All India Production (,000 MT)	% of National production covered
1	Paddy	41	17200.04	91790.00	18.74
2	Wheat	33	7271.94	69350.00	10.49
3	Maize	24	2843.68	14710.00	19.33
4	Bajra	17	699.97	7680.00	9.11
5	Sorghum	15	988.76	7240.00	13.66
6	Pigeon Pea	22	164.63	2740.00	6.01
7	Chick Pea	20	390.64	5600.00	6.98
8	Black Gram	22	283.24	1245.00	22.75
9	Green Gram	20	150.97	946.30	15.95
10	Mustard	31	1225.15	8130.00	15.07
11	Cottonseed	13	1885.64	14026.67	13.44
12	Soybean	17	1533.86	8270.00	18.55
13	Safflower	3	9.17	228.60	4.01
14	Sunflower	9	204.10	1440.00	14.17
15	Groundnut	25	773.60	7990.00	9.68
16	Apple	8	1165.54	1756.00	66.37
17	Banana	17	1853.80	12104.50	15.31
18	Citrus	15	554.73	6326.00	8.77
19	Grapes	5	1112.54	1631.00	68.21
20	Guava	18	79.84	1823.00	4.38
21	Mango	18	1443.97	12538.00	11.52

S. No.	Crop/ commodity	No. of districts surveyed	Production in surveyed districts (,000 MT)	All India Production (,000 MT)	% of National production covered
22	Papaya	16	51.79	2317.00	2.24
23	Sapota	6	99.34	140.00	70.96
24	Cabbage	24	257.64	5921.60	4.35
25	Cauliflower	20	283.46	5260.10	5.39
26	Green Pea	24	120.37	2298.70	5.24
27	Mushroom	4	0.14	37.00	0.37
28	Onion	20	1080.00	8680.00	12.44
29	Potato	25	4523.05	23910.00	18.92
30	Tomato	24	934.87	9361.80	9.99
31	Tapioca	13	1620.20	7620.20	21.26
32	Arecanut	11	164.80	483.10	34.11
33	Cashewnut	11	79.46	544.00	14.61
34	Coconut	21	1251.73	14811.00	8.45
35	Sugarcane	32	28468.56	281170.00	10.13
36	Black Pepper	5	21.73	92.90	23.39
37	Chilli	17	283.27	1014.60	27.92
38	Coriander	4	58.87	223.40	26.35
39	Turmeric	8	93.45	851.70	10.97
40	Egg	7	5.85	461.66	1.27
41	Inland Fish	13	670.57	2780.00	24.12
42	Marine Fish	3	80.53	3520.00	2.29
43	Meat	5	9.30	762.00	1.22
44	Poultry Meat	5	1.88	537.00	0.35
45	Milk	11	1927.73	97066.00	1.99

Appendix VII

List of Experts Committee Members for Examining Data of Post Harvest Losses

1. Dr. Anwar Alam, Vice Chancellor, Shere-e-Kashmir University of Agricultural Sciences and Technology, Srinagar (Chairman, Expert Committee)
2. Dr. S. M. Ilyas, Director, NAARM, Hyderabad
3. Dr. Nawab Ali, Ex-Deputy Director General (Engg)
4. Deputy Director General (Crop Science) or his nominee
5. Deputy Director General (Animal Science) or his nominee
6. Deputy Director General (Fisheries) or his nominee
7. Deputy Director General (Horticulture) or his nominee
8. Asst. Director General (Process Engg), ICAR, New Delhi (Dr. P. Chandra)
9. Director, CIPHET, Ludhiana (Dr. R.T. Patil)
10. Project Coordinator, AICRP on PHT (Dr. S.K. Nanda)
11. Dr. H. V. L. Bathla, Head, Division of Sample Survey, IASRI, New Delhi
12. Dr. Anil Rai, Principal Scientist, IASRI, New Delhi
13. Prof. V. K. Sehgal, Senior Research Engineer, PAU, Ludhiana
14. Dr. Jaswant Singh, Head, Agril Engg. Department, IISR, Lucknow
15. Dr. B. Ranganna, Ex-Senior Research Engineer, UAS, Bangalore
16. Dr. R. Viswanathan, Head, Agril & Food Process Engg, TNAU, Coimbatore
17. Er. R. K. Vishwakarma, Scientist (SS), PC (PHT) Unit, CIPHET, Ludhiana

Appendix VIII

Different Names of Crops Selected for Estimation of Post Harvest Losses

S. No.	Category	Produce	Other names	Botanical name	Hindi name	हिन्दी नाम
1.	Cereals	Paddy	Rice	*Oryza sativa*	Dhaan	धान
2.		Wheat		*Triticum aestivum*	Gehun	गेंहू
3.		Maize	Corn	*Zea mays*	Makka, Bhutta	मक्का
4.		Pearl Millet	Bajra	*Pennisetum typhoides Pennisetum glaucum*	Bajra	बाजरा
5.		Sorghum	Jowar	*Sorghum bicolour Sorghum Vulgare*	Jwar	ज्वार
6.	Pulses	Pigeon Pea	Red Gram	*Cajanus cajan*	Arhar, Tur	अरहर
7.		Chick Pea	Bengal Gram	*Cicer arietinum*	Channa	चना
8.		Black Gram	White Lentil	*Vigna mungo*	Urad	उड़द
9.		Green Gram	Mung Bean Golden Gram	*Vigna radiata*	Moong	मूंग
10.	Oilseeds	Mustard	(Canola)	*Brassica juncea*	Sarson	सरसों
11.		Cottonseed		*Gossypium hirsutum*	Binoula	बिनौला
12.		Soybean		*Glycine max*	Soyabeen	सोयाबीन
13.		Safflower		*Carthamus tinctorius*	Kusum	कुसुम
14.		Sunflower		*Helianthus annuus*	Surajmukhi	सूरजमुखी
15.		Groundnut	Peanut	*Arachis hypogaea*	Moongfalee	मूंगफली
16.	Fruits	Apple		*Malus sylvestris*	Seb	सेब
17.		Banana	Plantain	*Musa* spp.	Kelaa	केला
18.		Citrus	Mandarin Sweet Orange Kinnow	*Citrus sinensis Citrus reticulata*	Santara, Narangi Kino	संतरा,किन्नू नारंगी मौसमी
19.		Grapes		*Vitis vinifera*	Angoor	अंगूर
20.		Guava		*Psidium guajava*	Amrood	अमरूद
21.		Mango		*Magnifera indica*	Aam	आम
22.		Papaya	Pawpaw	*Carica papaya*	Papeeta	पपीता
23.		Sapota	Sapodilla Sapote	*Manilkara zapota*	Cheekoo	चीकू

S. No.	Category	Produce	Other names	Botanical name	Hindi name	हिन्दी नाम
24.	Vegetables	Cabbage		*Brassica oleracca var.*	Band gobi	बंद गोभी
25.		Cauliflower		*Brassica oleracca var.*	Phul gobi	फूल गोभी
26.		Green Pea		*Pisum sativum var Arvense*	Matar	मटर
27.		Mushroom		*Agaricus bisporus*	Khumbi Kukurmutta	खुम्बी
28.		Onion		*Allium cepa*	Piyaz	प्याज
29.		Potato		*Solanum tuberosum*	Aaloo	आलू
30.		Tomato		*Lycopersicon esculentum*	Tamatar	टमाटर
31.		Tapioca	Cassava	*Manihot esculenta*	Mandshif	मण्डशिफ
32.	Plantation / Cash crops	Areca nut	Betel nut	*Areca catechu*	Supari	सुपारी
33.		Cashew		*Anacardium occidentale*	Kaju	काजू
34.		Coconut		*Cocos nucifera*	Nariyal	नारियल
35.		Sugarcane		*Saccharum officinarum*	Ganna	गन्ना
36.	Spices and Condiments	Black Pepper		*Piper nigrum*	Kali Mirch	कालीमिर्च
37.		Chilli	Chili	*Capsicum annuum*	Lal Mirch	लाल मिर्च
38.		Coriander	Chinese parsley	*Coriandrum sativum*	Dhaniya	धनिया
39.		Turmeric	Indian saffron	*Curcuma longa*	Haldi	हल्दी

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

Agrisearch with a human touch