SPGR SUB-PROJECT COMPLETION REPORT

Agricultural Economics Division

ASSESSMENT OF SOCIOECONOMIC IMPACTS OF OILSEED RESEARCH AND DEVELOPMENT IN BANGLADESH

Bangladesh Agricultural Research Institute (BARI)
Joydebpur, Gazipur

PIU-BARC, BARC complex, Farmgate Dhaka-1215

April 2014

ASSESSMENT OF SOCIOECONOMIC IMPACTS OF OILSEED RESEARCH AND DEVELOPMENT IN BANGLADESH

Duration: June 2011 to February 2014

Executing Organization

Agricultural Economics Division
Bangladesh Agricultural Research Institute, Gazipur

Team Member:

DR. M. A. MONAYEM MIAH
DR. MD. ABDUR RASHID
DR. S. M. A. SHEBLEE

Submitted to

PIU-BARC, BARC complex
Farmgate, Dhaka-1215

April 2014

Acknowledgement

This report has been prepared under the NATP-SPGR sub-project on 'Assessment of Socioeconomic Impacts of Oilseeds Research and Development in Bangladesh'. The authors are grateful to the NATP-SPGR administered by the Bangladesh Agricultural Research Council (BARC) for funding this project.

The authors express their sincere gratitude to Dr. Md. Rafiqul Islam Mondal, Director General, Bangladesh Agricultural Research Institute (BARI), Gazipur; Dr. Md. Khaled Sultan, Director (Research), BARI; Dr. S. M. Khalilur Rahman, Member Director, Agricultural Economics and Rural Sociology (AERS), Bangladesh Agricultural Research Council (BARC), Dhaka; Dr. Md. Abul Kashem, Project Director (former), PIU, NATP-BARC, Dhaka; Dr. Kabir Ekramul Haque, Project Director, PIU, NATP-BARC, Dhaka; Sahadat Hossain, Chief Scientific Officer (former), Agricultural Economics Division, BARI; and Dr. Md. Rezaul Karim, Chief Scientific Officer, Agricultural Economics Division, BARI, Gazipur for allowing as well as helping us in many ways to conduct this study.

The authors are highly grateful to Dr. Mostaque Ahmed, Chief Scientific Officer, AERS, BARC, Dhaka; Dr. Md. Anwar Ikbal, Monitoring Specialist, PIU, NATP-BARC, Dhaka; Mr. Sadique Rahman, Assistant Professor, Department of Management and Finance, Faculty of Agri-business Management, Sher-e-Bangla Agricultural University, Dhaka; DR. H. M. Naser, Senior Scientific Officer, Soil Science Division, BARI, Gazipur; Mr. Munshi. Mamunur Rashid, Data Analyst, PIU, NATP-BARC, Dhaka; Dr. Md. Abdul Matin, Principal Scientific Officer, Agricultural Economics Division (AED), BARI; Dr. T.B.M. Hossain, Senior Scientific Officer, AED, BARI, and Md. Farid Dewan, Scientific Officer, NATP-SPGR project, AED, BARI, Gazipur for their valuable assistance in preparing this report.

The authors are grateful to the respondent farmers for taking much trouble in supplying necessary information without which it would not have been possible to write this report. Our thanks are also due to all enumerators for their help during collection of data for the project. The authors also express their cordial thanks to Md. Anwar Iqbal, M&E Expert, PIU-BARC for his inspiration toward completion of the project.

Finally, we are grateful to the individuals whose names are not mentioned, but generously contributed part of their time to provide information. The errors remain ours.

The Authors
monayem09@yahoo.com

Content

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX

ABBREVIATIONS

ACI	=	Agro Chemical Industry
BARI	=	Bangladesh Agricultural Research Institute
BAU	=	Bangladesh Agricultural University
BINA	=	Bangladesh Institute of Nuclear Agriculture
BADC	=	Bangladesh Agricultural Development Corporation
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BCR	=	Benefit Cost Ratio
BSMRAU	=	Bangabandhu Sheikh Mujibur Rahman Agricultural University
CCDB	=	Christian Commission for Development in Bangladesh
CDP	=	Crop Diversification Program
CIMMYT	=	International Maize and Wheat Improvement Center
CSISA	=	Cereal System Initiative for South Asia
CV	=	Coefficient of Variation
DAE	=	Department of Agricultural Extension
DAM	=	Department of Agricultural Marketing
DAP	=	Di-Ammonium Phosphate
DRC	=	Domestic Resource Cost
FAO	=	Food and Agriculture Organization
FGD	=	Focus Group Discussion
GDP	=	Gross Domestic Product
GR	=	Growth Rate
Ha	=	Hectare
HYV	=	High Yielding Variety
ICM	=	Integrated Crop Management
IPM	=	Integrated Pest Management
IRR	=	Internal Rate of Return
Kcal	=	Kilo Calorie
MCC	=	Mennonite Central Committee
MLE	=	Maximum Likelihood Estimation
MLT	=	Multi Location Test
MoP	=	Muriate of Potash
NGO	=	Non-Government Organization
NNC	=	National Nutritional Council
NPV	=	Net Present Value
NRP	=	Nominal Rate of Protection
NPC	=	Nominal Protection Coefficient
NPKS	=	Nitrogen, Phosphorus, Potash and Sulphur
OFRD	=	On-Farm Research Division
OLS	=	Ordinary Least Square
ORC	=	Oilseed Research Centre
R&D	=	Research and Development
RDA	=	Recommended Dietary Allowance
SAU	=	Sher-e-Bangla Agricultural University
SAAO	=	Sub-Assistant Agriculture Officer
SOWT	=	Strengths, Opportunities, Weaknesses and Threats
SRDI	=	Soil Resources Development Institute
TSP	=	Triple Super Phosphate
TVC	=	Total Variable Cost
USA	=	United States of America
USDA	=	United States Development Agency
WTO	=	World Trade Organization

Acronyms

Aus	=	Pre monsoon rice
Boro	=	Irrigated rice in winter season
Kharif-I	=	Early monsoon cropping season (16 March to 15 July)
Kharif-II	=	Monsoon cropping season (16 July to 15 October)
Rabi	=	Winter cropping season (16 October to 15 March)
T. Aman	=	Transplanted monsoon rice
Upazila	=	A small administrative unit of Bangladesh
Char land	=	Attached land to the riverbanks, often create new opportunities to establish settlements and pursue agricultural activities on them.

Conversion rate:

1.00 US$ = BDT 78.00 (Bangladeshi Taka)
1 hectare = 2.47 acre = 7.4 *Bigha*
1 *Bigha* = 33 decimal

Executive Summary

The acute shortage of edible oils has been prevailing in Bangladesh during last several decades and spending on edible oils and oilseeds imports has been increasing to meet the country's demand. But, oilseeds area has been decreasing for the period from 1990 to 2012 due to various economic and technical reasons. Bangladesh experienced positive growth rates of the productivity of mustard, groundnut, and sesame in the above mentioned period.

Bangladesh government has given emphasis on R&D (Research and Development) of these crops and invested a lot of money for attaining self-sufficiency. BARI and BINA have released a good number of improved varieties of these crops. Adoptions of these varieties have created additional employment, income, and saved foreign exchange for the country. Conversely, a large number of farmers are still reluctant to grow these improved oilseeds varieties for various unknown reasons that need to be investigated properly. The present study will provide up-to-date data and information on the adoption, profitability, and impacts of oilseed R&D which will be the basis of formulating concrete policy for investing more on oilseeds improvement programs in Bangladesh. Therefore, the present study has been conducted to assess the technological adoption and relative profitability of oilseed cultivation at farm level, and to estimate the socioeconomic impacts of oilseed R&D in Bangladesh.

Both primary and secondary data were used in this study. Primary data were collected through household survey, while secondary data were collected from various published sources. The household survey was conducted by purposively selecting 11 districts namely, Manikgonj, Faridpur, Tangail, Mymensingh, Rajshahi, Pabna, Dinajpur, Noakhali, Luxmipur, Comilla, and Jessore. Four major oilseed crops, namely mustard, sesame, groundnut, and soybean were considered for the study. For survey, a total of 180 households cultivating oilseeds were randomly selected and interviewed from one district for each crop. Due to non availability of soybean growing areas, soybean data were collected from two districts. Thus, the total sample size was 1980. The study used different statistical tools for analyzing collected data. An *ex-post* evaluation with the help of economic surplus model under both closed and small-open market economy situations was also adopted to estimate the rate of returns (BCR, IRR & NPV) of the investment in oilseeds R&D in Bangladesh.

Most of the adopters and non-adopters of improved oilseeds varieties were relatively young (age 31-50 years). About 21% of the adopters and 26% of the non-adopters had no formal education. More than 40% of the adopter and non-adopters had primary level education. Agriculture was the principal occupation of both adopter (93%) and non-adopter (97%) oilseed farmers. More than 32% adopters and 34% non-adopters were in the experience group of 6-10 and 1-5 years, respectively. About 14% adopters and 10% non-adopters received training on oilseed cultivation once in life. However, 50% of the adopters and 38% non-adopters received training on agriculture mostly from the Department of Agriculture (DAE). The average farm size of the adopter (1.349 ha) and non-adopter (1.216 ha) oilseed growers was more or less similar. The highest farm size (1.9 ha) was reported for groundnut adopters followed by mustard (1.3 ha) and sesame (1.0 ha). Sub Assistant Agriculture Officer (SAAO) significantly created interest among them to adopt improved oilseed varieties. Most of the farmers belonged to different social organizations and had regular contact with extension personnel. Cosmopolite farmers used more improve oilseed varieties than that of less cosmopolite farmers.

Majority of the farmers used BARI old varieties of oilseeds. About 60% mustard, 82% groundnut, 78.5% sesame, and 84.4% soybean farmers used BARI old varieties. Farmers were very much enthusiastic towards BARIMustard-14 & -15 varieties due to their short duration and high yielding characteristics. In 2010-11, the areas planted to improved mustard, groundnut, and sesame varieties were about 27, 7, and 11% of the total respective oilseed areas, respectively. Except sowing period and sowing method, the levels of adoptions of other crop management practices were low. Majority of them often did not follow the recommended seed rate, fertilizer dose, irrigation, and weeding. The common factors that significantly influenced oilseed farmers to adopt improved varieties of oilseeds were the availability of family labour, availability of improved seed, cosmopolitness, and extension contact.

The yields of improved oilseed varieties were found to be much better than that of BARI old or local varieties at farm level. The yield of improved mustard was 1.64 t/ha which was significantly higher (46.4%) than that of BARI old variety (Tori-7). The yield of improved groundnut (2.40 t/ha) was 48.7% higher than that of Dhaka No.-1 variety, but 25% lower than the yield of BARI Groundnut-5 & -6. The yield of improved sesame variety was 27.8% higher as compared to Til-6 variety. The yield of BARI improved soybean was 25% lower than its potential yields, and about 5.2% higher than the yield of Sohag variety.

Irrespective of varieties, the cultivation of oilseeds was profitable from both financial and economic point of view. The cultivations of improved varieties were much higher than their corresponding BARI old or local varieties. The average net returns of cultivating improved mustard, groundnut, sesame, and soybean were respectively Tk 28,859, Tk 84,200, Tk 13,879, and Tk 3,761, whereas BCRs were 1.56, 2.36, 1.32, and 1.1, respectively. These net returns and BCRs were significantly higher than that of BARI old oilseeds varieties. Unfortunately, the overall profitability of mustard, sesame, and soybean production was lower than most of their competing crops. The highest net return under import parity level was calculated for groundnut (Tk 82,594/ton) followed by sesame (Tk 44,578/ton) and soybean (Tk 5,544/ton). The value of DRC implied that the domestic production of mustard, groundnut, sesame, and soybean was more profitable than their imports from foreign countries.

Different factors, namely improved seed, human labour, organic fertilizer, urea, TSP, loamy soil, pesticide, and land rent had positive and significant influence on oilseeds production. The personal quality and managerial capability of farmers also influenced oilseed production. The farmers with higher education, more farming experience, extension contact, improved seed, and innovativeness were technically more efficient than other farmers. The oilseed farmers could produce oilseeds to 72-89% of the potential (stochastic) frontier production levels, given the recommended levels of inputs and technologies currently being used. It means that the levels of technical inefficiency involved in the oilseed production ranged from 11 to 28%. Area-specific technical efficiency revealed that the level of technical efficiency was higher for the intensive oilseed growing district and less intensive for low growing areas.

The adoptions of improved oilseed technologies at farm level have made some positive impacts on productivity growth, farmers' income, employment generation, and foreign exchange savings through producing more of these crops. Highly significant structural breaks occurred in the area, production and yield of these two crops between pre- and post-adoption period. Improved mustard variety cultivating farmers got about 75% higher net incomes. Almost similar benefits were also received by improved variety groundnut and sesame cultivating farmers. The adoptions of improved mustard, groundnut, sesame, and soybean variety varieties at farm level created an additional employment of 12.7, 11.6, 15.4, and 6.1 man-days/ha for the respondent farmers, respectively. It was also found that the livelihood status of the adopting households was much better than that of non-adopting households.

Ex-post analysis of the past investment (Tk.1268.91 million) on oilseeds R&D during 1998 to 2012 revealed an internal rate of return (IRR) to be 24%. Under various assumptions, the IRR ranged from 22 to 26% and BCR from 2.84 to 3.50. The yield advantages of different improved oilseeds varieties as compared to BARI old varieties ranged from 5.27 to 48.67%. The amounts of NPV and foreign exchange savings due to R&D of oilseeds (i.e. higher production and less importation) for the period from 1997/98 to 2011/12 were Tk. 4,769.04 million (US$ 61.14 million) and Tk 7,574.19 million (US$ 97.105 million) respectively. Therefore, the investment on R&D of oilseeds was found encouraging in Bangladesh.

SWOT analysis was done to explore the constraints and investment opportunities put behind the R&D of oilseeds in Bangladesh. The analysis identified different strengths and opportunities in oilseed cultivation, such as research capability, good varieties, higher profitability, farmers' interest, existing extension services, availability of potential areas, and private sector involvement. In addition, there were also some weaknesses and threats in oilseed cultivation which were climate variability, high competition with other crops, lack of short-duration variety, low adoption of improved varieties, and insects & diseases infestation. Overall findings suggested that the strength and opportunities of oilseed cultivation outweigh the weaknesses and threats of its cultivation in Bangladesh.

The following recommendations were thus made for consideration to enhance oilseed production for attaining self-sufficiency in Bangladesh.

- Dissemination of existing improved rice and oilseed varieties
- Availability of improved seeds of oilseeds and rice
- Strengthening existing extension services
- Bringing potential areas under oilseed cultivation
- Involving private sectors to oilseed production and value addition
- Strengthening oilseed research and development
- Conducting regular training programme
- Providing institutional credit facilities
- Availability of production inputs at reasonable prices
- Strengthening international collaboration

Besides varietal improvement research of oilseeds, the following socio-economic studies related to oilseeds production, consumption, and marketing need to be implemented.

- Assessment of demand and supply of oilseeds in Bangladesh.
- In-depth value chain analysis of oilseeds in Bangladesh.

SPGR SUB-PROJECT COMPLETION REPORT

1. **Sub-project Title:** Assessment of Socioeconomic Impacts of Oilseed Research and Development in Bangladesh
2. **Principal Investigator (PI):** Dr. Md. Abdul Monayem Miah
3. **Full Address of PI**: Agricultural Economics Division (AED), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701. Tel: 01757739542 (cell); 9252558 (Off), *Email:* monayem09@yahoo.com
4. **Duration of the Sub-project**: From June 2011 to April 2014
5. **Date of Approval** (by the Executive Council/signing of LoA): June 21, 2011
6. **Approved Budget of the Sub-project:**

   Total approved budget (Taka) : 36,66,480/=

   Total fund received (Tk) : 33,54,161/=

   Total fund spent (Tk) : 33,54,161/=

   Unspent/balance fund (Tk.) : None

7. Justification of undertaking the sub-project

At first, some base information and underlying knowledge that are important and closely related to oilseed cultivation were discussed under different headings. Afterward the rationale or justification of study was discussed based on those base data and information (see pages 1-21).

Chapter I

INTRODUCTION

1.1 Importance of Oilseeds and Edible Oil

Edible oil or fat is the most important nutrient of human foods. It plays vital roles in our national economy as well as in human nutrition for meeting calorie requirement. Some oilseed crops are important source of edible oil, industrial oil, good quality protein, vitamins, fuel, and can play an important role in solving the malnutrition problems in Bangladesh. Oilcake is also an important source of manure for crop production and soil fertility.

Oil/fat provides double energy (1gm of oil/fat supplies 9 Kcal energy) than that of protein or carbohydrates. It also insulates our body and protects our organs, such as the kidneys, from injury. This nutrient is also necessary to help absorb vitamins A, D, E, and K. In addition, oil/fat in a meal helps the food to digest more slowly, maintaining satiation longer. It also adds flavor and texture to foods. Fats are more calorically dense than carbohydrate and protein: one gram provides nine calories, whereas carbohydrate and protein supply four calories per gram. A teaspoon of fat (solid or oil) contains 120 calories. According to the USDA guidelines (www.mypyramid.gov), an adult woman should take in about five to six teaspoons a day, while an adult man should consume between six and seven teaspoons.

According to the National Nutrition Council (NNC) of Bangladesh, the Recommended Dietary Allowance (RDA) of oil is 6 gm/capita/day for a diet with 2700 Kcal (BNNC, 1984). At least 15% (405 kcal) of the total calories must come from visible and invisible oil or fat. The major sources of visible oils are mustard, soybean, groundnut, sesame, and sunflower, whereas the main sources of invisible oils are fish, meat, milk, egg, vegetables etc.

1.2 Brief History of Oilseed Research and Development in Bangladesh

Different research institutes, universities and government agencies are engaged in oilseed research and development (R&D) in Bangladesh. The Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA) and Department of Agricultural Extension (DAE) are playing crucial role in this regard. Three universities namely Bangladesh Agricultural University (BAU), Sher-e-Bangla Agricultural University (SAU) and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) are conducting research on oilseed crops for their MS and Ph.D. levels.

BARI is the largest multi-crop research institute conducting research on a variety of crops including oilseeds since 1976. It has already released a good number of improved oilseed varieties. BINA, a specialized national agricultural research institute, is also conducting research on oilseed crops along with many other crops using nuclear and other advanced techniques in agriculture. BINA also developed some promising oilseed varieties for farm level cultivation. Finally, DAE is responsible for transferring oilseed technologies so far developed by the research institutes to the end users. The mission of DAE is to provide efficient and effective need based extension services to all categories of farmer, to enable them to optimize their use of resources, in order to promote sustainable agricultural and socio-economic development.

A brief history of R&D of major oilseed crops has been discussed in the following sections.

1.2.1 Rapeseed and mustard

The English word "mustard" derives from the Anglo-Norman *mustarde* and Old French *mostarde*. The first element of mustard came from Latin *mustum* ("must" means young wine). The Romans were probably the first to experiment with the preparation of mustard as a condiment. It is first attested in English in 1390, though it is found as a surname a century earlier (http://en.wikipedia.org/wiki /Mustard).

Rapeseed and mustard is a major oilseed crop occupied 78.21% of the total oilseed area in Bangladesh (BBS, 2012). It contributes a lion share to the total edible oil production in the country. The Oilseed Research Centre (ORC) of BARI has developed 16 rapeseed & mustard varieties, which comprises 8 from *Brassica rapa*, 5 from *Brassica juncea*, and 3 from *Brassica napus* (Table 1.1). BINA has also developed 8 rapeseed & mustard varieties including two salt tolerant varieties (Table 1.2). Most of the developed varieties do not fit well in the existing Transplanted *Aman*-Mustard-*Boro* cropping pattern due to long duration.

Figure 1.1 Mustard plant with pods
Source: http://upload.wikimedia.org/wikipedia/

Due to higher competition with different high value crops in the winter season, mustard cultivation has been decreased over the years. National statistics (BBS, 2012) show that the area under mustard cultivation was 338.55 thousand hectares in 1990, whereas it was decreased (22.61%) to 276.11 thousand hectares in 2012 (Appendix A-1).

Table 1.1 Improved rapeseed and mustard varieties developed by BARI

Variety	Releasing year	Crop duration (Day)	Yield (t/ha)	Oil content (%)
1. Rai-5	1976	110-120	1.0-1.2	39-40
2. Tori-7	1976	75-80	1.6-2.0	38-41
3. Kallyani (TS-72)	1979	80-85	1.2-1.4	40-42
4. Sonali (SS-75)	1979	90-100	1.8-2.0	44-45
5. Daulat (RS-81)	1988	90-100	1.3-1.5	39-40
6. BARI Mustard-6	1994	90-100	2.1-2.5	44-45
7. BARI Mustard-7	1994	90-100	2.0-2.5	42-45
8. BARI Mustard-8	1994	90-100	2.1-2.4	43-45
9. BARI Mustard-9	2000	80-85	1.2-1.4	43-44
10. BARI Mustard-10	2000	85-90	1.2-1.4	42-43
11. BARI Mustard-11	2001	105-110	2.0-2.5	40-42
12. BARI Mustard-12	2001	80-85	1.2-1.4	43-44
13. BARI Mustard-13	2004	90-95	2.2-2.8	42-43
14. BARI Mustard-14	2006	75-80	1.4-1.6	40-45
15. BARI Mustard-15	2006	80-85	1.4-1.7	48-52
16. BARI Mustard-16	2009	105-110	2.2-2.3	40-42

Source: http://www.bari.gov.bd; Banu et al. 2013

Table 1.2 Improved rapeseed and mustard varieties developed by BINA

Variety	Releasing year	Crop duration (Day)	Yield (t/ha)	Oil content (%)
1. Safal	1991	90-95	1.75-2.20	44
2. Agrani	1991	83-88	1.75-2.50	44
3. Binasarisha-3	1997	85-90	1.85-2.40	44
4. Binasarisha-4	1997	80-85	1.90-2.50	44
5. Binasarisha-5 (Salt tolerant)	2002	85-90	1.40-2.10	43
6. Binasarisha-6 (Salt tolerant)	2002	90-95	1.30-2.20	44
7. Binasarisha-7	2011	100	2.80	44
8. Binasarisha-8	2011	96	2.40	43

Source: http://www.bina.gov.bd/

1.2.2 Groundnut

The groundnut (*Arachis hypogaea*), is a species in the legume or 'bean' family (Fabaceae). It was probably first domesticated and cultivated in the valleys of Paraguay. Although the groundnut was mainly a garden crop for much of the colonial period of North America, it was mostly used as animal feed stock until the 1930s. In the United States, a US Department of Agriculture program to encourage agricultural production and human consumption of groundnuts was instituted in the late 19th and early 20th centuries. (http://en.wikipedia.org/wiki/Peanut#History).

Figure 1.2 Uprooted groundnut plants

Source: http://www.agritech.tnau.ac.in/agriculture/

Groundnut is an important oilseed crop which occupied 8.83% of the total oilseed areas in Bangladesh (BBS, 2012). It can be grown well in *Char* areas during winter season under rainfed condition. It can also be grown round the year due to its photo insensitive character. Groundnut is well suited as intercrop with other long duration crops and fits well in various cropping patterns. It enriches soil fertility by fixing nitrogen from atmosphere. Apart from its rich sources of oil content (48-52%), groundnut seed is a good source of protein (22-25%), carbohydrate (20%) and vitamin B and E. The foods made of groundnut can help meeting part of the children's nutritional needs. In spite of having great advantages for growing groundnut in Bangladesh, its yield is poor as compared to other developed countries.

The ORC of BARI has developed nine groundnut varieties of which six Spanish, two Valencia and one Virginia type. BINA has also developed six improved groundnut varieties including two salt tolerant varieties (Table 1.3). Most of the varieties (bold seeded) take long duration for maturity particularly in the winter season and susceptible to leaf spot and rust diseases, which reduce the yield substantially. It has another major constraint that most of the varieties have no dormancy of seed and seed viability is lost within 2/3 months after harvest.

The area and production of groundnut decreased over the time. It is observed that the area under groundnut cultivation has been decreasing since 1990 till 2004. The area was 38.60 thousand ha in 1990, whereas it was decreased to 33.93 thousand ha in 2004 (Appendix A-3). After that the situation has improved due to adoption of improved groundnut technologies. In 2012, the area under groundnut cultivation decreased to 31.17 thousand hectares with the production of 52.00 thousand MT (BBS, 2012).

Table 1.3 Improved groundnut varieties developed by BARI and BINA

Variety	Releasing year	Crop duration (Day)	Yield (t/ha)	Oil content (%)
A. BARI developed				
1. Dhaka No.-1	1976	120-140	1.6-2.0	
2. Dhaka No.-4	1976			
3. Dhaka Groundnut-2	1979	150-165	2.2-2.4	
4. DM-1 (Tridana)`	1987	145-155	2.5-3.0	
5. Jhingha Badam	1988	110-130	2.0-2.2	
6. BARI Groundnut-5	1998	120-150	2.7-3.0	
7. BARI Groundnut-6	1998	120-150	2.8-3.0	
8. BARI Groundnut-7	2004	145-155	2.8-3.0	
9. BARI Groundnut-8	2006	140-150	2.3-2.5	48-52
10. BARI Groundnut-9	2010	140-150	2.3-2.5	48-52
B. BINA developed				
1. BINAchinabadam-1	2000	150-160	2.4-3.8	47
2. BINAchinabadam-2	2000	125-135	1.7-3.2	50
3. BINAchinabadam-3	2000	125-135	1.6-3.0	52
4. BINAchinabadam-4	2008	140-150	2.6-3.5	49
5. BINAchinabadam-5 (Salt tolerant)	2011	140-150	2.3-3.4	49
6. BINAchinabadam-6 (Salt tolerant)	2011	140-150	2.4-2.9	49

Source: http://www.bina.gov.bd; http://www.bari.gov.bd; Banu et al. 2013

1.2.3 Sesame

Sesame (*Sesamum indicum*) is a flowering plant in the genus *Sesamum* and one of the oldest oilseed crops known, domesticated well over 3000 years ago. It was a major summer crop in the Middle East for 1000s of years. It is widely naturalized in tropical regions around the world and is cultivated for its edible oil. It is also a robust crop that can be grown in various abiotic stress conditions (http://en.wikipedia.org/wiki/Sesame#Origins. 'The world harvested about 3.84 million metric tons of sesame seeds in 2010.

Figure 1.3 Sesame plant at flowering stage
Source: http://en.wikipedia.org/wiki/File:Sesamum

The largest producer of sesame seeds in 2010 was Burma. The world's largest exporter of sesame seeds was India, and Japan the largest importer' (http://en.wikipedia.org/wiki/Sesame#Origins).

Sesame is an important summer oilseed crop occupied 9.4% of the total oilseed area in Bangladesh (BBS, 2012). Its oil is of good quality containing 42% essential linoleic acid. The major obstacle to sesame expansion is low seed yield. Many factors contribute to the low yield of sesame as lack of non-shattering, water logged and disease and insect resistant variety. The ORC of BARI has released four improved varieties of sesame. The first variety of sesame is T-6 which was released by BARI in 1976. BINA has also released three improved sesame varieties for farm level cultivation (Table 1.4). These varieties are late in maturity and very much susceptible to excess water in .

The acreage and production of sesame have decreased dramatically over the years due to higher competition with different high value crops. The area under sesame cultivation was 90.82 thousand ha in 1989, whereas it was decreased to 35.67 thousand ha in 2012 (Appendix A-5). The present area under sesame cultivation was 33.20 thousand ha in 2012 with the production of 30.00 thousand MT (BBS, 2012).

Table 1.4 Improved sesame varieties developed by BARI and BINA

Variety	Releasing year	Crop duration (Day)	Yield (t/ha)	Oil content (%)
A. BARI developed				
1. Til-6	1976	85-90	1.0-1.2	
2. BARI Sesame-2	2001	90-100	1.2-1.4	
3. BARI Sesame-3	2001	90-100	1.2-1.4	
4. BARI Sesame-4	2009	90-95	1.25-1.5	
B. BINA developed				
1. BINAtil-1	2004	85-90	1.3-1.4	40
2. BINAtil-2	2011	86-92	1.8	44
3. BINAtil-3	2013	85	1.5	40

Source: http://www.bina.gov.bd; http://www.bari.gov.bd; Banu et al. 2013

1.2.4 Soybean

Soybean (*Glycine max*) is a species of legume widely grown for its edible bean which has numerous uses. It was first introduced to Europe in early 18th century and to British colonies in North America in 1765, where it was first grown for hay. It was introduced to Africa from China in the late 19th century, and is now widespread across the continent. In USA, soy was considered an industrial product only, and was not used as a food prior to the 1920s. It was also a crucial crop in East Asia long before. Except USA, soybeans remain a major crop in Brazil, Argentina, India, China, and Korea. (http://en.wikipedia.org/wiki/Soybean).

Figure 1.4 Soybean plant at pod maturing stage

Source: http://www.bina.gov.bd/

Soybean is a minor oilseed crop in Bangladesh. Its production and utilization have increased in recent years due to large-scale use as poultry and fish feed. Although the use of soybean as human food is limited in Bangladesh, some private food companies are preparing some soya food products such as soyamilk, soyabread, soyabiscuit, soyaflour, soyasauce, chanachur, tofu, and some confectionary beverages. Most people in Bangladesh consume soybean oil because of its high quality and low price compared to traditional mustard oil. But soybean is not crushed in Bangladesh for extracting oil.

Mennonite Central Committee (MCC), a leading NGO of Bangladesh, first introduced and demonstrated soybean in the early 70s. But its formal research [other than conducted by MCC] started in 1975 when a coordinated soybean research project was undertaken by Bangladesh Agricultural Research Council (BARC). Later on, Bangladesh government implemented an action plan through a Crop Diversification Program (CDP) for its large scale cultivation and product utilization. The purpose of the program is to alleviate protein and calorie malnutrition from cereal based diet in Bangladesh.

The ORC of BARI has developed six improved soybean varieties and released two varieties for farm level cultivation in 1981. BINA has also developed four improved varieties of soybean since 2011 (Table 1.5).

The acreage of soybean has been increased over the time with fluctuating nature (Appendix A-7). The acreage has increased steadily from less than 40.5 ha in 1995 to about 890.7 ha in 1988; then it jumped to 1902.8 ha in 1989, increased to about 2510.1 ha in 1993 (Ali, 1996). At present soybean is extensively cultivated in Noakhali and Luxmipur district. The present area under soybean cultivation is 41459 ha with a total production of 65,883 MT (BBS, 2011).

Table 1.5 Improved soybean varieties developed by BARI and BINA

Variety	Releasing year	Crop duration (Day)	Yield (t/ha)	Oil content (%)
A. BARI developed				
1. Brag	1981	--	1.3-1.5	
2. Davis	1981	--	1.2-1.5	
3. Sohag	1992	80-110	1.6-1.8	
4. Bangladesh Soybean-4	1994	90-120	1.6-2.5	
5. BARI Soybean-5	2002	90-115	1.6-2.0	
6. BARI Soybean-6	2009	100-110	2.0-2.2	20-21
B. BINA developed				
1. BINAsoybean-1	2011	105-110	3.0-3.3	19
2. BINAsoybean-2	2011	95-100	2.4-2.8	18
3. BINAsoybean-3	2013	109-116	2.3-2.5	-
4. BINAsoybean-4	2013	110-125	2.3-2.5	-

Source: http://www.bina.gov.bd; http://www.bari.gov.bd; Banu et al. 2013

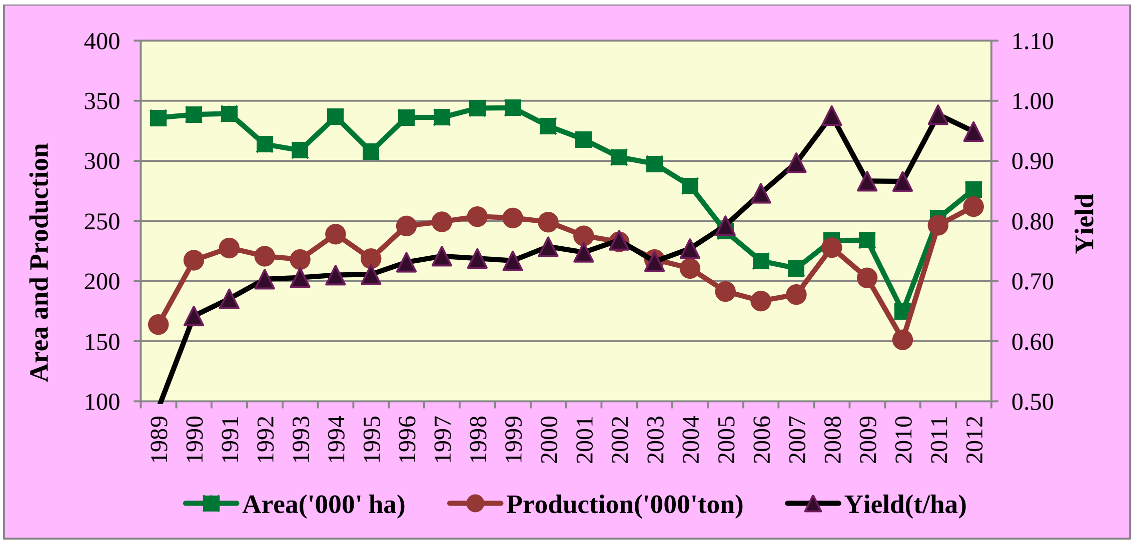
1.3 Trends of Area and Production of Oilseeds in Bangladesh

The aim of trend analysis is to find out the extent and causes of instability of area and production of oilseed crops over the time. These information may lead research manager as well as policy makers to prepare appropriate policy documents for the improvement of oilseed crops for the country. The trends of area and production of different oilseed crops are discussed below.

Rapeseed and mustard: Rapeseed and mustard is locally called as 'Mustard' which is a leading oilseed crop, covering about 80% of the total oilseed area and contributing to more than 60% of the total oilseed production in Bangladesh. It is a cool loving crop and grows during *Rabi* season (Appendix A-9). The present mustard yield is very low as compared to other oilseeds growing countries of the world. The main reasons of lower yield are lack of good quality seed and inadequate adoption of improved production technologies developed by different institutes.

Figure 1.5 reveals that the overall area and production of mustard in the country are decreasing from 1999 to 2007. After that it shows increasing trend with fluctuating nature. The reason behind this decrease was that it had to compete with many high-value winter crops. Mustard is mainly cultivated after harvesting *T.Aman* and before cultivating *Boro* rice. Due to long duration of mustard many farmers usually keep their lands fallow for *Boro* rice cultivation. The ORC of BARI has already released two short duration improved varieties of mustard, namely BARI Mustard-14 and BARI Mustard-15 for farm level cultivation. The successful adoption of these varieties will obviously increase the area and production as well as farmers' income in the country. The area and production of mustard at national level showed increasing trend from 2010 due to adoption of improved mustard varieties (Fig 1.5). In spite of decrease in area, the per hectare yield of mustard has gone up in those period which was mainly due to the adoption of improved variety and management technologies.

Fig 1.5 Area, production and yield of mustard, 1989-2012



Source: Using data from various issues of BBS

The overall indices show that the area and production of mustard increased to some extent from its base period of 1989-1994 during 1995-2000. But the overall indices of area and production show a decreasing trend over the period from 1995-2000 to 2006-2012. On the other hand, the productivity indices revealed an increasing trend during the period from 1989-1994 to 2006-2012. The regional indices for area showed higher increasing trends in Khulna, Rajshahi, and Rangpur divisions compared to other divisions during 1995-2000. After that both area and production showed decreasing trend for Barisal, Chittagong, Sylhet and Rangpur divisions during the period from 2001 to 2012. In the case of production, the performances of Rajshahi and Khulna divisions were found to be better than other regions of the country. Except Chittagong and Rajshahi divisions, the productivity indices showed increasing trend for the period from 1989-1994 to 2006-2012 for all the divisions (Table 1.6).

Table 1.6 Index of area, production and yield of mustard

Time period	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Rangpur	Bangladesh
Area (ha)								
1989-1994	100 (8786)	100 (52816)	100 (130127)	100 (54230)	100 (48900)	100 (8035)	100 (25917)	100 (328812)
1995-2000	100	98	99	110	101	97	104	101
2001-2006	77	76	74	109	96	83	77	84
2007-2012	18	18	84	63	119	16	46	70
Production (ton)								
1989-1994	100 (3653)	100 (38526)	100 (75979)	100 (38119)	100 (34884)	100 (5487)	100 (17634)	100 (214449)
1995-2000	106	86	119	123	126	111	116	114
2001-2006	85	76	92	130	108	103	97	99
2007-2012	22	23	118	91	179	26	62	99
Yield (t/ha)								
1989-1994	100 (0.412)	100 (0.730)	100 (0.584)	100 (0.703)	100 (0.722)	100 (0.683)	100 (0.680)	100 (0.653)
1995-2000	107	88	120	112	123	115	111	113
2001-2006	112	104	124	120	112	123	127	118
2007-2012	125	127	139	139	161	165	134	141

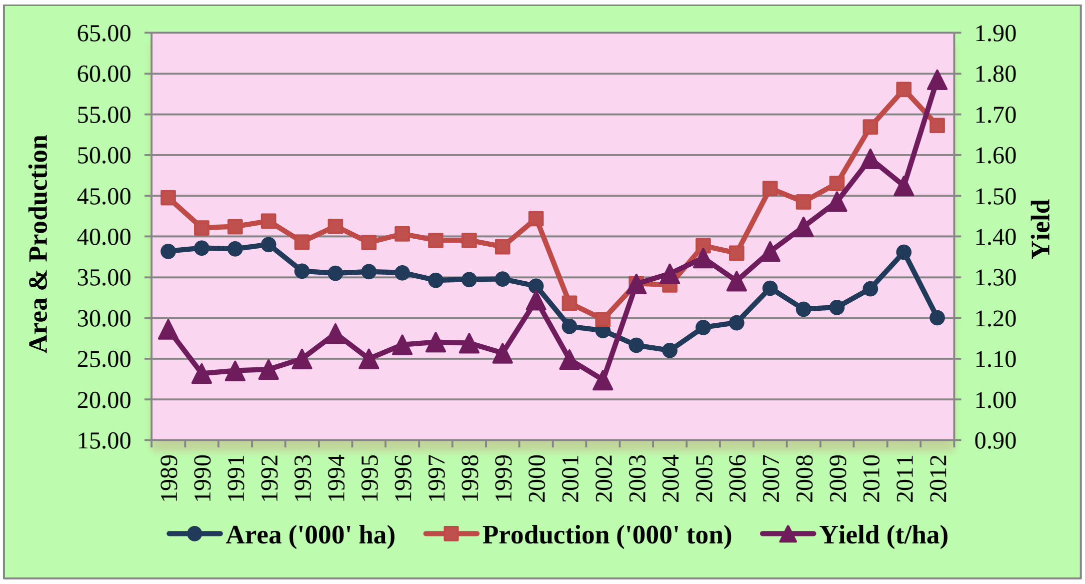
Note: Figures within parentheses indicate 6 (six) year average value in the base year of the indices.
Source: Various issues of BBS

Groundnut: Groundnut, popularly known as *Badam*, is the second most important oilseed crop next to mustard which has multipurpose uses. It contains vegetable oil (45-50%), protein (25-30%), carbohydrate (20%) and vitamin A and E (Ready and Kaul, 1986). It can be grown well in char land both in Rabi and Kharif-2 seasons (Appendix A-9). Its current yield (1.59 t/ha) is much higher as compared to other oilseed crops but not at satisfactory level. The major causes of low yield of groundnut were no balanced use of fertilizer and poor quality seed (Farid, 2001).

It is evident from Fig-1.6 that the area, production and yield of groundnut were fluctuating from 1989 to 2012. The area under groundnut cultivation started decreasing from 1990 and continued up to 2004. After that the area under groundnut cultivation started increasing with fluctuating nature. This might be due to higher profitability of its cultivation to the farmers. Similarly, the production of groundnut showed decreasing trend for the period 1989 to 2002 and after that it showed increasing trend up to 2011. Despite decrease in area, the productivity of groundnut showed an increasing trend during the period 1989-2012. This might be due to adoption of improved groundnut technologies.

The overall index constructed for groundnut area reveals a decreasing trend for the period from 1989-1994 to 2001-2006. After that the area index shows increasing trend during the period of 2007-2012. Similar observations were found in different divisions, such as Dhaka, Khulna, Chittagong, Rajshahi, and Rangpur. The area indices constructed for Barisal, Chittagong, and Sylhet divisions revealed more or less decreasing trend for the period from 1995-2000 to 2006-2012. Like area, the overall production index showed decreasing trend between the period 1989-1994 and 2001-2006. Similar decreasing trends of production were also observed in Dhaka, Rajshahi, and Rangpur divisions. The production indices for other divisions showed fluctuating trend during the study period. Similar increasing trends were also observed in Chittagong, Khulna, and Sylhet divisions. This might be due to adoption of improved groundnut technologies (Table 1.7).

Fig 1.6 Area, production and yield of groundnut, 1989-2012



Source: Using data from various issues of BBS

Table 1.7 Index of area, production and yield of groundnut

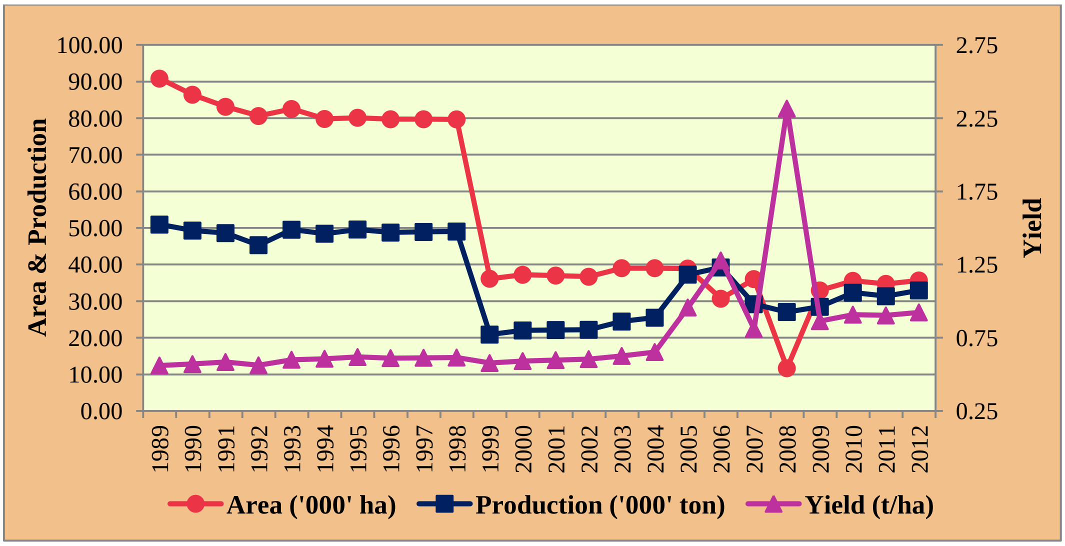
Year	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Rangpur	Bangladesh
Area (ha)								
1989-1994	100 (3158)	100 (13850)	100 (12404)	100 (582)	100 (1778)	100 (1445)	100 (4273)	100 (37597)
1995-2000	113	89	91	85	124	94	83	93
2001-2006	89	69	77	127	121	81	35	75
2007-2012	63	70	86	229	149	81	113	85
Production (ton)								
1989-1994	100 (3081)	100 (14137)	100 (14948)	100 (598)	100 (3293)	100 (1579)	100 (4413)	100 (41593)
1995-2000	109	101	86	83	100	110	89	96
2001-2006	86	93	75	233	91	107	33	83
2007-2012	134	100	117	350	112	121	166	119
Yield (t/ha)								
1989-1994	100 (0.99)	100 (1.02)	100 (1.20)	100 (1.02)	100 (1.83)	100 (1.09)	100 (1.03)	100 (1.11)
1995-2000	96	113	94	99	81	118	107	103
2001-2006	95	143	99	157	76	133	90	111
2007-2012	216	142	136	163	75	149	148	141

Note: Figures within parentheses indicate 6 (six) year average value in the base year of the indices.
Source: Various issues of BBS

Sesame: Sesame, popularly known as *Til*, is an important oilseed crop in Bangladesh. It can be grown both in *Rabi* and *Kharif-I* seasons (Appendix A-9). Due to its drought tolerant character, it can be grown even without irrigation. Sesame is also a good quality edible oil, because it contains about 80% essential fatty acids (i.e., oleic and lenolic acid). It also contains 42-45% oil and 25% protein (Anon, 2011). Sesame oil is used in pharmaceutical and cosmetic industries to some extent. Its cake is a good feed for livestock and poultry birds.

It is evident from Fig-1.7 that the area under sesame and its production were found fluctuating during the period 1989 to 2012. The area and production of sesame remaind more or less static for the period from 1992 to 1999. After that both area and production decreased sharply. This might be due to increase in the area under cultivation of different comptitive crops like paddy (Salam *et al.*, 2011), chili, wheat, and jute. A slow but steady increasing trend was observed for both in area and production of sesame for the period from 2000 to 2012. Again, the yield of sesame remained more or less static during the period 1989 to 2004. After that, it jumped to a high level only for one year. The reason of such increase is unknown. The yield again started decreasing from 2005 and contitued up to 2008. In the recent years, the yield is increasing due to the adoption of improved sesame technologies.

Fig 1.7 Area, production and yield of sesame, 1989-2012



Source: Various issues of BBS

Different indices were constructed for studying the past trends of area and production of sesame for the period 1989 to 2012. The overall indices constructed for area and production showed decreasing trend, but productivity indices showed an increasing trend during the study period. This might be due to introduction of improved sesame technologies. The regional indices constructed for area and production of sesame were observed to have fluctuating trends among different divisions. However, some exceptions were found only in Chittagong and Sylhet divisions. The yield indices revealed that sesame yields were increasing during the period 2000-2004 and 2005-2009 among most of the divisions (Table 1.8).

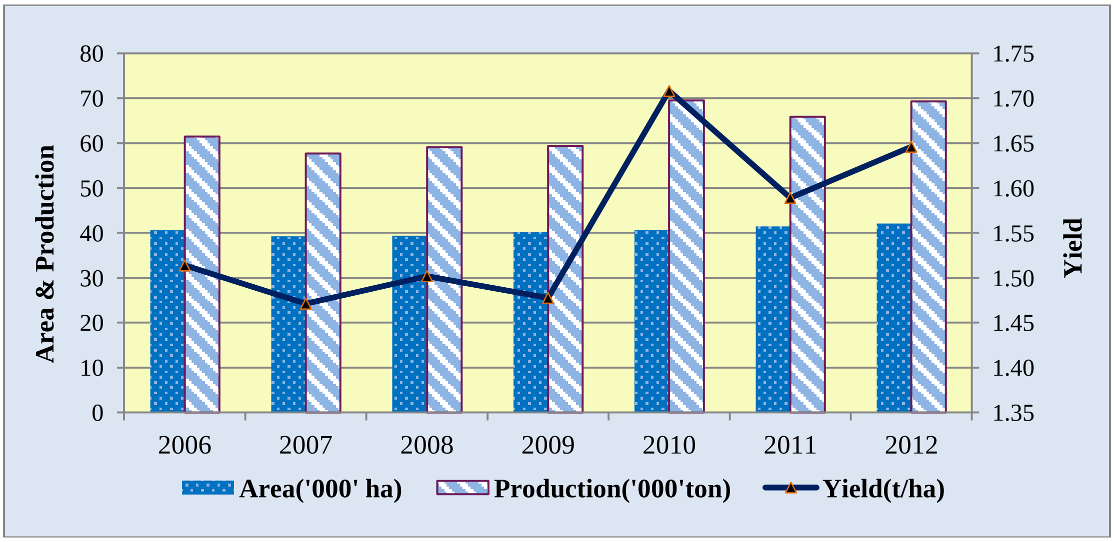
Table 1.8 Index of area, production and yield of sesame

Year	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Rangpur	Bangladesh
Area (ha)								
1989-1994	100 (12040)	100 (19465)	100 (31214)	100 (7925)	100 (6544)	100 (397)	100 (5809)	100 (83880)
1995-2000	65	84	67	101	74	38	126	78
2001-2006	10	35	10	123	69	3	199	44
2007-2012	12	17	27	124	118	5	49	37
Production (t)								
1989-1994	100 (7247)	100 (12245)	100 (17634)	100 (4464)	100 (3872)	100 (163)	100 (2965)	100 (48685)
1995-2000	73	85	71	107	74	42	133	82
2001-2006	9	37	12	241	76	5	248	58
2007-2012	11	23	42	211	175	15	78	62
Yield (t/ha)								
1989-1994	100 (0.602)	100 (0.631)	100 (0.566)	100 (0.566)	100 (0.595)	100 (0.412)	100 (0.510)	100 (0.581)
1995-2000	108	101	105	106	100	108	105	104
2001-2006	98	107	122	213	108	171	125	135
2007-2012	127	134	153	172	147	339	174	193

Note: Figures within parentheses indicate 6 (six) year average value in the base year of the indices.
Source: Using data from various issues of BBS

Soybean: Soybean is an important oil crop in the southern region of Bangladesh particularly in the districts of Noakhali and Laxmipur. It can be grown both in *Rabi* and *Kharif-2* seasons (Appendix A-9). The present total area under soybean cultivation is 0.041 million ha with a production of 0.07 million tons in 2011 (BBS, 2011). It is not yet popular as a crop, but very much popular as cooking oil. Soybean has multipurpose uses such as soyadal, soyakhechuri, soyamisty, soyamilk and soyabread etc (Kaul and Das, 1986). At present, it is widely used in the poultry and fisheries industries. In every year 0.44 million tons of soybean is needed for poultry industry which is mostly imported from abroad (Bakr *et al.*, 2008). It contains 42-45% protein and 20-22% edible oil (Fehr, 1989). Because of its rich nutritional value, it could be a good source of nutrient for undernourished and malnourished people of Bangladesh.

Fig 1.8 Area, production and yield of soybean, 2006-2012



Source: Various issues of BBS

Owing to unavailability of secondary data, only 5 year data were analyzed to study the past trend and growth rates of soybean. Fig-1.8 shows that the area under soybean cultivation remained almost static for the period 2006 to 2012[1]. On the other hand, fluctuating but more or less increasing trend was observed in the production of soybean over the above period. The yield of soybean shows an increasing trend during the same period which was due to the adoption of some improved technologies.

Comparative trends of oilseeds: A decreasing trend in area and a fluctuating trend in production of oilseeds were observed in Bangladesh during the period from 1995-1999 to 2005-2009 compared to their base period. In India, the indices for both area and production have been fluctuating over the study period. Pakistan, on the other hand, experienced a significant growth in area, production and yield of oilseed. Despite the decreasing trend in area, the productivity indices depict an impressive increasing growth in Bangladesh. This might be due to the adoption of improved varieties (Table 1.9).

Table 1.9 Comparative indices of area, production and yield of oilseeds

Time period	**Bangladesh**			**India**			**Pakistan**		
	Area	Prod^n	Yield	Area	Prod^n	Yield	Area	Prod^n	Yield
1990-1994	100	100	100	100	100	100	100	100	100
1995-1999	98	102	104	106	110	103	111	112	101
2000-2004	73	80	111	97	99	101	112	134	119
2005-2009	68	83	122	112	133	118	118	153	130

Note: Area in acre, production in metric ton and yield in ton per acre
Source: FAOstat

1.4 Growth and Instability of Oilseeds Production in Bangladesh

Rapeseed and mustard: The annual growth rates scenario reveals that the area and production of mustard registered negative growth rates during the period of 1989-2012. These observations were true for all the regions with some exceptions found in Rajshahi division. However, the productivity per hectare showed positive growth rates for all the divisions which were due to the adoption of improved mustard technologies. Some significant positive growth registered in area was found at Sylhet division during 1989-1994, and Barisal and Khulna divisions during 1995-2000. Similarly, the significant positive growth rates of production were observed at Dhaka and Sylhet divisions in 1989-1994, Barisal, Chittagong, Khulna, Sylhet and Rangpur divisions in 1995-2000, and Rajshahi division in 2007-2012. The growth rates of yield were positive and highly significant for all the divisions during 1989-2012 (Table 1.10).

Sources of mustard production growth: Change in mean area appeared to be the largest source of change in mean production of mustard in all the divisions except Dhaka, Khulna, and Rajshahi. At the national level, change in mean yield was the main source of change in mustard production. Change of yield contributed 359% of the changes in mean production of mustard at national level. This means that the positive change of production has contributed to the positive change of yield which was due to introduction of improved mustard varieties and crop management technologies (Table 1.11).

[1] Data for 2012 are extrapolated, because data are not available in the national statistics (BBS, 2012)

Table 1.10 Annual growth rates of area, production and yield of mustard, 1989-2012

Year	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Rangpur	Bangladesh
Area (ha)								
1989-1994	2.15	-1.48	-0.33	-1.00	-2.63	1.06***	-1.61	-0.97
1995-2000	1.15*	1.23	-1.10	5.26***	2.02	0.09	2.16	1.22
2001-2006	-8.79***	-29.59**	-5.03***	-5.00*	-1.14	-16.39**	-9.67***	-7.58***
2007-2012	-8.65	-2.26	1.91	2.69	12.42	-4.16	-1.67	3.70
1989-2012	-9.01***	-9.26***	-1.37***	-2.57**	0.57	-9.31***	-4.61***	-2.08***
Production (ton)								
1989-1994	6.29	-2.91	10.32**	2.66	11.33	2.72***	-0.02	5.33*
1995-2000	3.22**	2.90*	-0.79	6.75**	1.78	2.10*	3.84*	2.13
2001-2006	-8.10**	-24.71**	-3.05**	-3.92	0.95	-18.80**	-7.19**	-5.47***
2007-2012	-2.82	-0.66	2.37	1.75	11.28**	1.11	1.85	4.51
1989-2012	-7.70***	-7.76***	0.49	-0.88	2.92***	-6.78***	-2.88***	-0.20
Yield (t/ha)								
1989-1994	4.15	-1.44	10.65**	3.66**	13.97*	1.66*	1.59**	6.30**
1995-2000	2.07*	1.67	0.31	1.49**	-0.24	2.01*	1.69***	0.91**
2001-2006	0.70	4.88**	1.98*	1.08	2.09	-2.40**	2.48*	2.11*
2007-2012	5.84**	1.60	0.46	-0.94	-1.13	5.26***	3.51*	0.81
1989-2012	1.13***	1.49***	1.85***	1.69***	2.35***	2.52***	1.73***	1.88***

Note: '***' '**' and '*' represent 1%, 5% and 10% level of significant

Table 1.11 Growth decomposition in the production of mustard during 1989-2012

Division	Effect (%)				
	Area	Yield	Interaction	Residual	Total
Barisal	126	-41	-15	30	100
Chittagong	127	-16	11	-22	100
Sylhet	151	-43	8	-16	100
Dhaka	-15	149	34	-68	100
Khulna	-99	505	305	-611	100
Rajshahi	-5	8	-96	193	100
Rangpur	502	-328	-38	-36	100
Bangladesh	**-181**	**359**	**78**	**-156**	100

Source: Author's calculation using BBS data

*Instability of mustard cultivation***:** The estimates of instability in area, production, and productivity of rapeseed and mustard are presented in Table 1.12. The instabilities of mustard area and yield at national level were not so high, but production instability was a little bit higher than area instability. Instability related to productivity was about 6.66% during 1989-2012. The productivity of mustard was more stable compared to that of area and production. When improved technology of mustard spread to larger areas, the variability in productivity declined further.

Table 1.12 Instability indices for area, production and yield of mustard, 1989-2012

Division	Instability (%)		
	Area (ha)	Production (ton)	Yield (t/ha)
Barisal	27.95	30.36	7.53
Chittagong	29.50	27.38	11.58
Dhaka	10.00	17.56	11.91
Khulna	21.94	23.77	9.98
Rajshahi	23.57	22.76	23.92
Sylhet	28.65	30.24	8.18
Rangpur	20.47	21.36	4.14
Bangladesh	10.87	13.05	6.66

Source: Author's calculation using BBS data, See also Appendix A-10

Groundnut: The annual growth rates of area, production and yield of groundnut are presented in Table 1.13. The overall area of groundnut cultivation registered significant negative growth rate (-1.17%) during the period 1989-2012. The positive and significant growth rates of area were found in two divisions namely Khulna (4.29%) and Rajshahi (1.73%). At national level, the growth rate of groundnut production was found to be positive (0.70%) but insignificant. The overall groundnut production registered positive and significant growth rates during 2001-2006 and 2007-2012 which were mainly due to the adoption of improved groundnut technologies. The highly significant growth rate of production (7.37%) was found only in Khulna division in 1989-2012. The productivity of groundnut registered highly significant growth rate (1.87%) at national level during the period from 1989 to 2012. Positive and significant growth rates were also observed in most of the divisions except Rajshahi and Rangpur for the same period. These higher productivity growths were attributed to the adoption of improved groundnut technologies at farm level across the country (Table 1.13).

Table 1.13 Annual growth rates of area, production and yield of groundnut, 1989-2012

Year	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Rangpur	Bangladesh
Area (ha)								
1989-1994	3.90*	-5.24***	-0.78	-7.04	6.86*	0.74	0.74	-1.66*
1995-2000	1.65	0.11	-0.61	-5.56**	-3.45***	-1.75*	-4.76	-0.91***
2001-2006	-0.76	-11.60*	-0.20	40.97***	3.84	-5.06***	8.44**	0.26
2007-2012	-2.22	0.82	-1.69	-5.78	-11.20***	-10.83**	3.48*	-1.23
1989-2012	-2.54***	-2.36***	-1.02***	4.29***	1.73***	-1.57***	-0.70	-1.17***
Production (t)								
1989-1994	-3.26	-4.89	-3.10	-11.01**	10.33	6.34	3.32	-1.49
1995-2000	7.07	0.35	2.51	-3.92*	-4.73***	0.68	-3.89	0.68
2001-2006	-3.37***	-1.14	5.97	56.75***	3.07	0.22	42.28***	4.78***
2007-2012	8.77	4.31	8.39***	-1.86	-14.25**	-11.49**	4.10**	4.27***
1989-2012	0.59	-0.16	0.70	7.37***	0.23	0.70	1.15	0.70
Yield (t/ha)								
1989-1994	-7.17	0.36	-2.32*	-3.97*	3.47	5.60*	2.58	0.17
1995-2000	5.42	0.23	3.12	1.64	-1.28	2.42	0.87***	1.59
2001-2006	-2.61*	10.46*	6.17	15.78***	-0.76	5.28*	33.84***	4.52**
2007-2012	10.99	3.49*	10.08***	3.92	-3.05	-0.66	0.62	5.51***
1989-2012	3.13***	2.20***	1.72***	3.08***	-1.50***	2.27***	1.85	1.87***

Note: '***' '**' and '*' represent 1%, 5% and 10% level of significant

Sources of growth of groundnut production: At the national level, change in mean yield was the principal source of change in groundnut production. It contributed 143% of the changes in mean production of groundnut at national level. Similar sources of change in production growth were observed for Chittagong, Sylhet, and Dhaka divisions. Again, change in mean area appeared to be the largest source of change in mean production of groundnut at Barisal, Rajshahi, and Rangpur divisions. This means that the positive change of production has contributed to the positive change of area (Table 1.14).

Table 1.14 Growth decomposition in groundnut production during 1989-2012

Division	Effect (%)				
	Area	Yield	Interaction	Residual	Total
Barisal	103	69	72	-144	100
Chittagong	-264	127	-237	474	100
Sylhet	-89	173	-15	31	100
Dhaka	-43	136	-8	15	100
Khulna	-24	2	-122	244	100
Rajshahi	224	-147	-24	47	100
Rangpur	103	45	48	-96	100
Bangladesh	-49	143	-5	11	100

Source: Author's calculation using BBS data

Instability of groundnut cultivation: The estimates in area, production and yield of groundnut at national level were more or less stable, but more stability was observed in groundnut yield. The highest level of instabilities in area and production were found at Khulna division followed by Rangpur division which was due to higher growth rate. Instability related to productivity was about 8.39% during 1989-2012. The highest level of instability in the yield of groundnut was recorded for Barisal and Rangpur divisions due to the lowest and highest growth rates respectively. When improved technology became spread to larger areas the variability in productivity declined further (Table 1.15).

Table 1.15 Instability indices for area, production and yield of groundnut, 1989-2012

Division	Instability (%)		
	Area (ha)	Production (ton)	Yield (t/ha)
Barisal	14.37	42.39	59.74
Chittagong	13.75	10.65	15.11
Dhaka	9.21	21.30	18.31
Khulna	53.33	61.18	23.37
Rajshahi	17.04	23.77	13.27
Sylhet	10.61	16.69	8.26
Rangpur	37.37	51.42	27.43
Bangladesh	8.22	14.13	8.39

Source: Author's calculation using BBS data, See also Appendix A-11

Sesame: The annual growth rates of both area and production of sesame were significantly negative during the period from 1989 to 2012. Similar negative growth rates were also found in different regions, namely Barisal, Chittagong, Dhaka, and Sylhet during the above mentioned period. Instead of the negative growth in both area and production, overall productivity growth was found to be excellent during the same period. Again, highly significant and positive growths in sesame area were registered in Khulna and Rangpur divisions during 1995-2000, in Rajshahi division during 2001-2006, and in Sylhet division during 2007-2012. On the other hand, highly significant and positive growth rates were recorded in Khulna, Rajshahi, and Sylhet divisions during 2001-2006. Instead of decreasing the area under sesame cultivation, the yield registered positive and highly significant growth rate during 1989-2009 (Table 1.16). The significant and positive growth rates of yield were observed in all divisions except Barisal. This might be due to adoption of improved sesame production technologies at farm level.

Table 1.16 Annual growth rates of area, production and yield of sesame, 1989-2012

Year	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Rangpur	Bangladesh
Area (ha)								
1989-1994	-2.76***	2.53	-2.99**	-4.28**	-8.12*	1.88	-0.70	-2.33**
1995-2000	-52.15**	-22.02**	-52.49**	9.29*	-10.43*	-66.09**	15.13**	-17.74**
2001-2006	3.04	-14.06	3.13	-6.05**	14.04**	-7.19	-3.86	-2.17
2007-2012	-9.88	-1.24***	3.72	0.35	-4.41	2.95***	-5.34	9.41
1989-2012	-14.23***	-10.12***	-9.34***	1.31***	0.57	-18.61***	-2.70	-5.96***
Production (mt)								
1989-1994	-2.06	2.99***	-1.69	-1.05	-7.17**	-1.06	1.12	-0.87
1995-2000	-54.76**	-22.16**	-52.08**	7.79*	-9.94**	-64.93*	16.45**	-18.87**
2001-2006	2.70	-11.39	3.95	29.66**	15.83***	24.61**	-1.18	12.75***
2007-2012	9.55	6.11*	8.67	3.79***	-5.39	5.99**	-0.63	3.37*
1989-2012	-13.60***	-8.54***	-7.02***	5.13***	2.53**	-11.93***	0.13	-2.77***
Yield (t/ha)								
1989-1994	0.70	0.46	1.30	3.23**	0.95	-2.94	1.82	1.46*
1995-2000	-2.61	-0.14	0.41	-1.50	0.50	1.16	1.32	-1.14*
2001-2006	-0.34	2.67*	0.81	35.71**	1.79***	31.81**	2.68**	14.92**
2007-2012	19.43	7.34**	4.95***	3.44	-0.98*	3.04**	4.70	-6.04
1989-2012	0.63	1.58**	2.32***	3.82***	1.96***	6.68***	2.83***	3.19***

Note: '***' '**' and '*' represent 1%, 5% and 10% level of significant

Sources of sesame production growth: Change in mean area appeared to be the largest source of change in mean production of sesame in Bangladesh during 1990-2011. It contributed 89% of the changes in mean production of sesame at national level. This is also true for all the divisions except Khulna and Rajshahi. Change in mean yield appeared to be the largest source of change in mean production of sesame only at Rajshahi division (Table 1.17).

Table 1.17 Growth decomposition in the production of sesame during 1989-2012

Division	Effect (%)				
	Area	Yield	Interaction	Residual	Total
Barisal	157	-5	52	-103	100
Chittagong	95	4	0	1	100
Sylhet	103	-22	-20	39	100
Dhaka	115	-27	-12	24	100
Khulna	-75	-34	-209	418	100
Rajshahi	-21	155	34	-68	100
Rangpur	2084	-282	1125	-2827	100
Bangladesh	89	-2	-13	26	100

Source: Author's calculation using BBS data

Instability of sesame cultivation: The estimates of instability in area and production of sesame at national level were more or less same, but comparatively high instability was observed in the productivity of sesame during 1989-2012. The higher level of instabilities in area and production were observed at Barisal, Dhaka, Sylhet, and Rangpur divisions. Due to higher growth performance, the instabilities in area and production were much lower at Khulna and Rajshahi divisions as compared to other divisions. Comparatively stable productivities were recorded at Dhaka, Chittagong, and Rajshahi divisions during 1989-2012 (Table 1.18).

Table 1.18 Instability indices for area, production and yield of sesame, 1989-2012

Division	Instability (%)		
	Area (ha)	Production (ton)	Yield (t/ha)
Barisal	52.08	55.97	24.55
Chittagong	24.36	27.43	10.88
Dhaka	55.77	61.77	9.10
Khulna	14.74	39.03	52.47
Rajshahi	29.73	39.83	9.67
Sylhet	63.76	78.77	37.93
Rangpur	50.18	54.24	20.31
Bangladesh	25.84	24.53	35.62

Source: Author's calculation using BBS data, See also Appendix A-12

Soybean: The overall growth rates of production and yield of soybean were positive and significant at 10% level for the period from 2006 to 2012. Similar observations were found in Chittagong division. The growth rates of area and production were positive and very high but found insignificant in Dhaka and Khulna divisions (Table 1.19).

Sources of soybean production growth: Table 1.20 reveals that change in both mean area and yield appeared to be the sources of change in mean production of soybean in Bangladesh during 1990-2011. Change in mean area and yield contributed 33% and 69% of the changes in mean production of soybean at national level. This was also true for Chittagong and Khulna divisions.

Table 1.19 Annual growth rates of area, production and yield of soybean, 2006-2012

Year	Area (ha)	Production (ton)	Yield (t/ha)
Chittagong	0.61	2.55*	1.93*
Dhaka	20.48	15.74	-4.74
Khulna	15.38	15.77	0.39
Rangpur	-16.03	-17.56	-1.54
Bangladesh	0.64	2.55*	1.92*

Note: '*' represents 10% level of significant

Table 1.20 Growth decomposition in the production of soybean, 2006-2012

Division	Effect (%)				
	Area	Yield	Interaction	Residual	Total
Chittagong	31	70	2	-3	100
Dhaka	107	-24	-18	35	100
Khulna	5	74	-21	42	100
Bangladesh	33	69	2	-4	100

Source: Author's calculation using BBS data

*Instability of soybean cultivation***:** The instability estimate of area at national level revealed that the area under soybean cultivation was very much stable across the country during 2006-2012. Similar results were found at Chittagong division. The reason was that the lion share of the total soybean area was under Chittagong division. In other words, the instability of soybean area was too small implying that soybean area did not expand over the years. The instability estimates calculated for production and yield of soybean were more or less same for that time. It indicated that the adoption of improved varieties did not take place at farm level during the period from 2006 to 2012 (Table 1.21).

Table 1.21 Instability indices for area, production and yield of soybean, 2006-2012

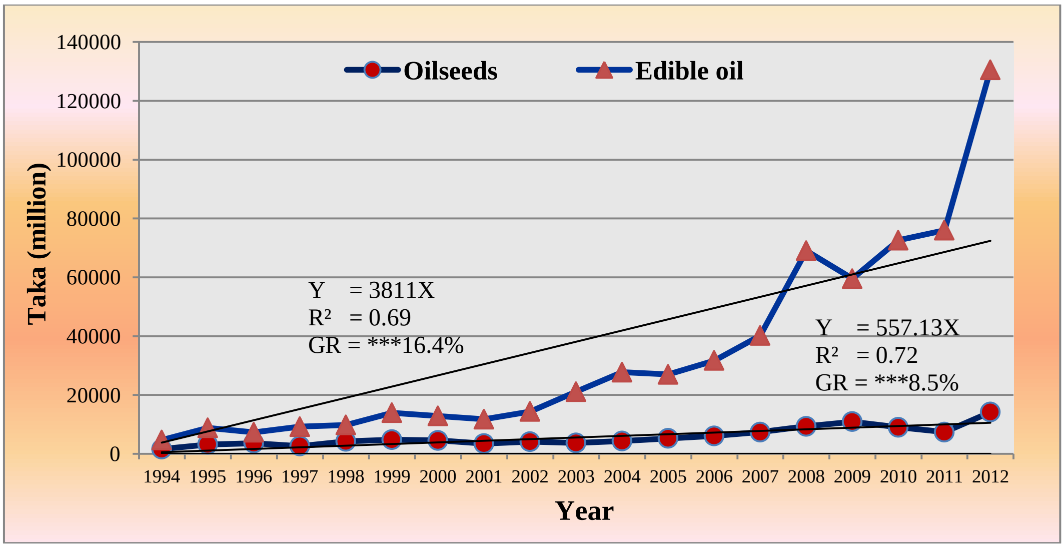
Division	Instability (%)		
	Area (ha)	Production (ton)	Yield (t/ha)
Chittagong	1.60	5.13	4.33
Dhaka	28.47	29.74	11.85
Khulna	42.85	39.79	15.04
Rangpur	57.67	60.57	18.33
Bangladesh	1.54	5.08	4.30

Note: Soybean productions/data are not available at Rajshahi, Barisal and Sylhet division
Source: Author's calculation using BBS data, See also Appendix A-13

1.5 Importation of Oilseed and Edible Oil in Bangladesh

The present requirement of edible oil of the country is about 1.4 million tons (22g/capita/day for 153 million people). Against this requirement the domestic productions of oilseeds and edible oils are 0.847 million tons and 0.360 million tons respectively (Mallik, 2013). As a result, a big gap (74.3%) existed between requirement and domestic production. Bangladesh Bank (2012) statistics revealed that the values of imported oilseeds and edible oils in 1994 were Tk 1600 million and Tk 4680 million respectively, whereas these values were increased to Tk 3690 million (131% higher from the year 1994) and 21100 million (351% higher) in 2003 respectively. Again, the values of imported oilseeds and edible oils in 2012 were 285% and 519% higher compared to the values of 2003 (Fig 1.9). Therefore, Bangladesh government has to import a huge amount of oilseeds and edible oils every year spending a lot of foreign exchange to meet up country's increasing demand.

Figure 1.9 Trend of imported oilseeds and edible oils in Bangladesh during 1994-2012



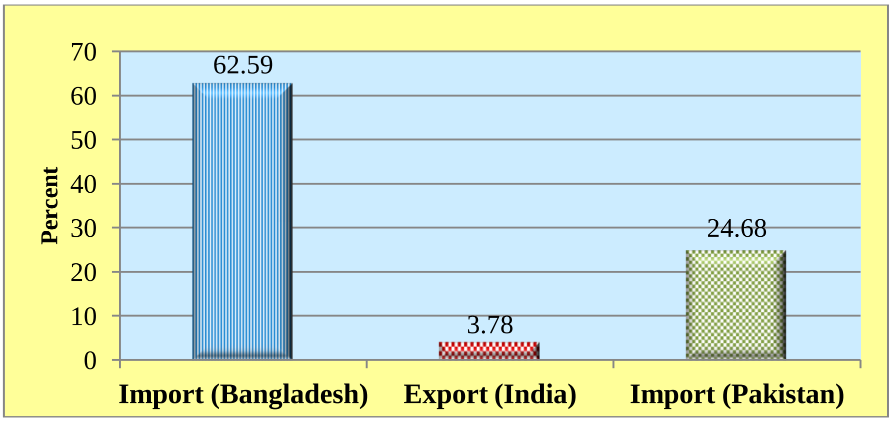
Source: Bangladesh Bank, 2012, See also Appendix A-14

Share of import: Bangladesh is a net importer of pulses, edible oils, spices, fruits, sugar, milk, and milk products. The import bill on account of food has grown at more than 10% in the current decade, and now accounts for over one-fifth of the export earnings of the country (SFYP, 2011). An attempt has been made to show the extent of dependency on imports of edible oils in Bangladesh, and has been compared with the dependencies of those in India and Pakistan using FAO statistics.

Bangladesh and Pakistan imported edible oils every year for meeting their country's demand, but the share of import to their total availabilities was much higher in Bangladesh compared to Pakistan. India was found to be self-sufficient in oilseed production and exported a small share to other countries. The average share of net import of edible oils to its total availability (including oil extracted from imported oilseeds) was about 62.59% in Bangladesh during 1990-2009. In the same period neighbouring country India exported 3.78% of their total production to other countries and Pakistan imported 24.68% of their total availability of oils (Fig 1.10).

Again, the shares of import have been increasing year after year both in Bangladesh and Pakistan, whereas the opposite scenario was observed in India. The highest shares of import were found for both the countries during 2005-2009 (Table 1.22).

Figure 1.10 Percent share of net import and export in total availability of edible oil, 1990-2009



Source: Constructed using data from FAOStat

Table 1.22 Comparative scenario of the share of net import and export to total availability of edible oils

Period	Bangladesh	India	Pakistan
	% of import	% of export	% of import
1990-1994	44.23	1.24	5.28
1995-1999	65.09	3.12	10.63
2000-2004	70.21	5.54	38.68
2005-2009	70.82	5.23	44.15

Source: Calculated using data from FAOStat

1.6 Rationale of the Study

Acute shortage of edible oil has been prevailing in Bangladesh during last several decades. This shortage inherited from the past has been met through imports spending a huge amount of foreign exchange every year. On the other side, the area under oilseeds cultivation is decreasing over the year due to various economic and technical reasons. Realizing the importance and demand of oilseeds, Bangladesh government has given emphasis on research and Development (R&D) of these crops and invested a lot of money for attaining their self-sufficiencies in the country. BARI, BINA, and BSMRAU started conducting research for developing improved oilseeds varieties. These national institutes have so far released a good number of high yielding varieties and improved management technologies of different oilseeds. The DAE has been involved in developmental programs for the technology transfer of these crops through its countrywide networks. All these initiatives make the productivity growth of oilseeds increasing to a great extent. This impressive information indicates the immediate need of strengthening the current efforts of improved variety adoption at farm level.

Although the released technologies have been found to be suitable for farmers, for various unknown reasons, a large number of farmers throughout the country are still reluctant to adopt these improved varieties which need to be evaluated properly. Since many farmers have not adopted these technologies, the level of oilseeds production remains far below of its potential. With the detailed farm level adoption information, the concern authority and agencies can formulate appropriate policy for the development of oilseed crops across the country. Again, potential adoption of the improved varieties would generate employment and additional income for the oilseed farmers and save foreign exchange by producing more of these crops utilizing fallow and under used lands in the country. The farm level adoptions of improved oilseeds have already created some socio-economic impacts that need to be evaluated properly to understand the output of research and development. This information could be useful for both government and donor agencies in investing more on oilseeds improvement programs in Bangladesh.

The rate of sustainable growth of oilseeds production depends largely on its economic, financial, and relative profitability. Therefore, it is important to know the level of economic profitability of growing oilseeds at farm level. Some socio-economic studies on different oilseeds cultivation (Kawser, 1993; Hasan and Miah, 2003; Miah and Alam, 2008; and Akter et al., 2010) were conducted in the past, but those information are backdated and do not represent the country. Therefore, nationally representative and up-to-date data and information on the adoption, profitability, and impacts of oilseed cultivation are lacking in Bangladesh. However, these information are very much useful for both government and donor agencies in investing more on oilseeds improvement programs in Bangladesh.

1.7 Organization of the Report

This report comprises eight chapters. *Chapter 1* deals with an introduction which highlights a brief history of oilseed Research and Development (R&D) in Bangladesh; importance of oilseeds production in crop agriculture; objectives and significance of the study. The framework of the study, data collection and analytical procedures are discussed in *Chapter 2*. *Chapter 3* presents the socio-economic profiles of the oilseed farmers. Adoptions of oilseed technologies at farm level are discussed in *Chapter 4*. *Chapter 5* contains the detailed profitability and comparative advantage scenarios of oilseed cultivation in Bangladesh. Factors of production and technical efficiency of oilseed farmers are presented in *Chapter 6*. In *Chapter 7*, socioeconomic impacts of oilseed research and development are discussed. Constraints and opportunities in oilseeds research and development are discussed in *Chapter 8*. Finally, conclusions and policy implications are included in the *Chapter 9*.

8. Sub-project Objectives

Keeping all these issues discussed above in consideration the present study was undertaken with the following objectives.

i) To assess the adoption of improved oilseed technologies at farm level and to find out the factors affecting their adoptions and sustainability.

ii) To study the economics of improved oilseed cultivation in Bangladesh along with its impact on the livelihood of the farmers.

iii) To estimate the returns to investment (IRR, NPV, BCR) in oilseeds research and development in Bangladesh through ex-post evaluation method.

9. Methodology Followed in Conducting Research or Investigation

Different techniques and models were followed in conducting the present study. All these techniques and models are discussed in different subsequent paragraphs under Chapter II.

Chapter II

METHODOLOGY OF THE STUDY

2.1 Sampling Design

The Oilseed Research Centre (ORC) deals with six oilseed crops, namely mustard, sesame, groundnut, soybean, linseed, and sunflower. Among these oilseed crops, the first four important/major oilseed crops were considered for socio-economic evaluation. Based on the area coverage of individual oilseed crop during 2008-2009, three districts consisting high (covered ≤10% of the total area), medium (covered >10% area), and low (covered >5% area) growing areas were purposively chosen for studying each type of oilseed crop[2]. The selected districts were Manikgonj, Faridpur, Tangail, Mymensingh, Rajshahi, Pabna, Dinajpur, Noakhali, Luxmipur, Comilla, and Jessore. Again, three suitable (in terms of data availability, ease of data collection, accessibility, and logistic supports) *Upazilas* of data, from each district were purposively selected in consultation with DAE personnel for collecting primary data from oilseed growers. Finally, a total of 540 households (3 districts×3*Upazilas*×60HHs) for each type of crop (improved & local varieties) were selected for interview by applying simple random sampling technique to collect primary data. Thus, a total of 2160 (540 HHs×4 crops) oilseeds cultivating farmers were to be interviewed (Appendix A-16) for the study. But, in practical the total sample size was 1980, because no third district was found suitable for collecting data and information on soybean cultivation. Selected oilseed crops and study areas are shown in Table 6.1.

Table 2.1 Name of selected oilseed crops and study areas

Oilseed crops	Study areas		
	High growing areas	*Medium growing areas*	*Low growing areas*
Mustard	Manikgonj	Rajshahi	Dinajpur
Groundnut	Noakhali	Pabna	Tangail
Sesame	Jessore	Faridpur	Comilla
Soybean	Noakhali	Luxmipur	--

Primary data were collected by interviewing oilseed farmers using a structured pre-tested interview schedule during the period from October 2011 to October 2012. Farm level primary data and information were collected by different project personnel, such as Principle Investigator, Co-Investigator, Scientific Officer, and trained Scientific Assistants. In order to cross check the information collected from farm survey, a number of Focus Group Discussions (FGD) were conducted with oil scientists of BARI and the extension personnel of DAE of different districts (Appendix A-15).

2.2 Estimation of Compound Growth Rates

In order to gain some perspective on the growth rates of area, production and yield of different oilseeds, time series data for 24 years (1989-2012) were used. The compound

[2] In the case of mustard and groundnut, the numbers of districts under high, medium and low growing areas were 3, 3, and 16 respectively, while the respective numbers were 3, 6, and 14 for sesame. In the case of soybean, about 96% areas were under two districts (Noakhali & Luxmipur) and 3% under Comilla district.

growth rates of area, production and yield of oilseeds were worked out by fitting a semi-log trend equation (1) of the following form:

$$y = e^{a+bt} \text{ or } l_n y = a + bt \quad \ldots\ldots\ldots\ldots \quad [1]$$

Where, y defines the time series data of area, production, and yield of oilseeds; 't' is the trend term (time) and 'a' is the constant coefficient. The slope coefficient 'b' measures the relative change in y for a given absolute change in the value of explanatory variable 't'. If we multiply the relative change in y by 100, we will get percentage change or growth rate in y for an absolute change in variable 't'. The slope coefficient 'b' also measures the present rate of growth.

2.3 Decomposition of Output Growth

To analyze the sources of changes in oilseeds production, Hazell's Variance Decomposition procedure[3] (Hazell, 1982; Hazell, 1985) was used. The relative contribution of area and yield towards the total output change can be measured through this procedure. In the literature, several researchers used this model to study growth performance of the crops (Siju and Kombairaju, 2001; Akter and Jaim, 2002; Kakali and Basu, 2006).

$$\Delta P = \bar{A}\,\Delta\bar{Y} + \bar{Y}\Delta\bar{A} + \Delta\bar{A}\Delta\bar{Y} + \Delta Cov(A, Y)$$

$$\frac{\bar{A}\Delta\bar{Y}}{\Delta\bar{P}} \times 100 + \frac{\bar{Y}\Delta\bar{A}}{\Delta\bar{P}} \times 100 + \frac{\Delta\bar{A}\Delta\bar{P}}{\Delta\bar{P}} \times 100 + \frac{\Delta Cov(A,Y)}{\Delta\bar{P}} \times 100 = 100 \quad \ldots\ldots\ldots \quad [2]$$

Δ represents change in the variable between two periods, P is production, Y is yield, and A is area.

Thus, the total change in production is attributed to area and yield that can be decomposed into four effects viz: yield, area, yield & change in area and yield interaction, and covariance effects. Covariance term shows the interaction between variances in areas and variances in yield because cov(A,Y) is defined as **correlation × √[(variance(A) × variance (Y)].** This is also known as **residual effect** or effects not explained by either area or yield.

2.4 Construction of Instability Index

Instability index is used to calculate the extent of variability involved in area, production, and yield of a particular crop. It is also used to calculate risk in cultivating a crop. The variability in area, yield, and production of oilseed crops for the period of 1989-2012 was computed by using Cuddy Della Valle Index (Weber and Sievers, 1985; Singh and Byrlee, 1990; Deb *et al*., 2004). Since the simple coefficient of variation over-estimates the level of instability in time-series data characterized by long-term trends, this index was used as it corrects the co-efficient of variation. The variability was computed for all the selected divisions for the above periods by using the following formula (3):

$$\text{Coefficient of Variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100 \quad \ldots\ldots\ldots \quad [3]$$

The values for Cuddy Della Valle Index (CV*) can be calculated by using the formula as:

$$CV^* = CV \times (1-R^2)^{0.5} \quad \ldots\ldots\ldots \quad [4]$$

Where, R^2 is the estimated coefficient of multiple determinations.

[3]It allows the quantification of contribution of different sources of change in mean and sources of change in variance of the total production such as change in mean yield, change in mean area, change in yield variance, change in area variance, interaction between mean yield and mean area etc.

2.5 Adoption of Improved Oilseed Technologies

The first objective of the study is to assess the variety-wise adoption of improved oilseed technologies at farm level and to find out the factors affecting their adoptions and sustainability. The following approach and methodology were used to study the status of adoption of oilseed technologies in the country.

The adoptions of improved technologies were measured in three ways: variety adoption, acreage covered, and use of crop management technology. At first 180 growers of each type of oilseed crop were randomly selected and interviewed irrespective of variety used by the farmers. Collected samples were categorized into adopters[4] and non-adopters and expressed in percentage term. Secondly, for assessing the level of adoption of crop management technology, respondent farmers were grouped into three categories such as high, medium, and low adopter based on the percent of farmers followed recommended practice with respect to each technology. A higher percentage scored by a particular technology indicates a higher level of adoption, while a lower percentage indicates its lower level of adoption. Adoption level was categorized as high (scored 70-100%), medium (50-69%), and low (<50%). Such categorization of adoption levels was used in different studies (Hossain et al., 1997; Miah et al., 2004; Akter et al. 2010; Islam et al, 2013). Besides, Probit regression model was used to find out the factors of adoption of improved varieties of oilseeds. The theoretical and empirical Probit model are discussed below.

2.5.1 Theoretical probit model

Qualitative response models (e.g., Probit model, Logit model, etc.) are used extensively by agricultural production and farming systems economists for studying and analyzing farmer adoption and diffusion of agricultural interventions. Probit/Logit model is based on a cumulative normal distribution function which is symmetric around zero with variance equal to 5.

Now, the Probit model is:

$$\text{Log } P = \alpha + \beta i Xi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

Where, P = Adoption (1 for adoption, 0 for non-adoption), Xi = Explanatory variables (i = 1, 2, 3.........n); α = Constant term; and βi = Coefficients (i = 1, 2, 3.........n). Relative change in P with a constant increase in Xi can be measured by the above model.

When P approaches 1, a relative change in P can be obtained with a constant increase in Xi by equation (6); here 1-P is used.

$$\text{Log } (1-P) = \alpha + \beta i Xi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [6]$$

When Equations (5) and (6) are combined, we get Equation (7) that can be transformed into Equation (8).

$$\text{Log } P - \text{Log } (1-P) = \alpha + \beta i Xi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [7]$$

$$\text{Log } \{P/(1-P)\} = \alpha + \beta i Xi \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [8]$$

[4] Adopters were treated those farmers who cultivated improved varieties of selected oilseed crops.

The ratio of P/(1-P) is called the odd ratio and log {P/(1-P)} is called the log odds or Logit/Probit. Equation (8) can be rearranged and solved for P;

$$P = [1/(1 + e^{-(\alpha + \beta iXi)})] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[9]$$

The probability function used in Equation (9) is called the logistic distribution function and ensures that the predicted value (P) of the relative frequency of the independent variable is always between 0 and 1. The Equation (9) was used to analyze the determinants of farmer adoption of an intervention. Equation (9) is expanded to use more variables as depicted in Equation (10).

$$P = [1/(1 + e^{-(\alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_n X_n)})] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[10]$$

2.5.2 Empirical probit model

In order to determine the relationship between the adoption of improved variety and socio-economic factors, the following empirical Probit model (equation 11) was carried out. The dependent variable of this model was adoption of improved varieties. Since the dependent variable is dichotomous, OLS cannot be used. The model was as follows-

$$A_i = \alpha + \beta_i X_i + \ldots\ldots.+ U_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[11]$$

Where,

Ai = Farmers adopting improved oilseed variety (If adopt = 1; Otherwise = 0)
α = Intercept
Xi = Explanatory variables (socioeconomic characteristics)
β_i = Coefficients of respective factors
Ui = Error term

The adoption of improved variety is likely to be influenced by the following explanatory variables;

X_1 = Age of the respondent (year)
X_2 = Education (Year of schooling)
X_3 = Farm size (decimal)
X_4 = Family labour (No./ha)
X_5 = Training received on oilseed (No.)
X_6 = Training received on agriculture (No.)
X_7 = Availability of HYV seed (Score)
X_8 = Influence of neighbouring farmers (Score)
X_9 = Influence of SAAO (Score)
X_{10} = Cosmopolites of the farmer (Score)
X_{11} = Societal membership (Score)
X_{12} = Extension contact (Score)

2.6 Profitability Analysis of Oilseed Cultivation

An attempt was made to estimate the detailed cost and return, relative profitability, resource use efficiency and comparative advantage of cultivating both improved and local/traditional oilseeds in Bangladesh under the second objective. In addition, farmers' livelihood status improved due to the cultivation of improved oilseed varieties was also measured. The methodologies of these measurements are briefly discussed below.

The financial profitability of improved oilseeds production over their traditional varieties was calculated using simple accounting procedures. Nevertheless, the financial profitability of different competing crops was also estimated and compared with selected oilseeds in this study. Hence, data relating to input use for the production of selected oilseed crops and competing crops and their market prices were collected. Besides, data on outputs and their prices were also gathered for the study. Finally, the cost and return of improved oilseed variety were compared with the respective cost and return of local/traditional oilseed variety and their competing crops.

2.6.1 Domestic resource cost

Domestic resource cost (DRC) was estimated for evaluating the efficiency of production of oilseeds in relation to comparative advantage. DRC is the ratio of cost of domestic resources and non-traded inputs (valued at their shadow prices) of producing a commodity to the net foreign exchange earned or saved by producing the good domestically. Mathematically DRC is defined as (equation 12):

$$DRC = \frac{\sum D_{ij} V_i}{B_i - \sum T_{ik} V_k} \quad \text{.......... [12]}$$

(j = 1-------------m; k = 1-----------n)

Where,

D_{ij} = Quantity of j^{th} domestic resources and non-traded inputs used for producing **i** crop per metric ton

V_i = Price of j^{th} domestic resources and non-traded inputs (Tk/mt)

B_i = Border price of **i** crop (Tk/mt)

T_{ik} = Quantity of k^{th} tradable inputs for producing **i** crop per metric ton

V_k = Border price of tradable inputs k per metric ton.

If DRC<1, the economy can save foreign exchange by producing the **i** crop domestically either for export or for imports substitution. This is because the opportunity cost of domestic resources and non-traded inputs used in producing **i** crop is less than the foreign exchange earned or saved. In contrast, if DRC>1, domestic costs was in excess of foreign exchange or savings indicating that the **i** crop should not be produced domestically and should be imported instead.

2.7 Measuring Technical Efficiency of Oilseed Farmers

Efficiency in economics is usually defined in terms of the optimal conditions (output/profit maximization or input/cost minimization) associated with the perfectly competitive market situations. A farm is efficient if and only if it is not possible to increase output without more inputs or decrease input without decreasing output with a given set of technology (Cooper and Kumbhakar, 1995). The amounts by which a farm lies below its production and profit frontiers, and the amount by which it lies about its cost frontier, can be regarded as measures of inefficiency.

An attempt was made in this study to identify the factors influencing oilseed production and to measure the technical efficiency of oilseed farmers using **stochastic frontier models** (Aigner *et al*., 1977; Meeusen and van den Broeck, 1977).

2.7.1 Theoretical model of technical efficiency

Technical efficiency (TE) of a farm can be defined as the ability and willingness of the farm to obtain the maximum possible output with a specified endowment of inputs (represented by a frontier production function), given the technology and environmental conditions surrounding the farm. In other words, TE is the ratio of a farmers' actual output to the technically maximum possible output at the farmers' level of resources. It is an indicator of productivity of the farm and the variation in TE can reflect the productivity differences among farms. It helps hunting the potentiality of the existing level of technology used by the producers.

To measure the technical efficiency of a farm producing a specific crop, production function needs to be estimated. In general, the production function can be specified as (equation 13):

$$Y_i = f(X_i; \beta_i) + \varepsilon_i \quad \text{.......} \quad [13]$$

Where, Y_i is the crop output of the i^{th} farm, X_i represents a (1 x K) vector whose values are functions of inputs and other explanatory variables for the i^{th} farm, β_i's are (k x 1) vector of unknown parameters to be estimated, f (.) represents the suitable functional form, and ε_i represents the error terms.

The stochastic frontier model is theoretically reasonable and empirically competent method of measuring efficiency. This model permits random variation of the frontier across farms, and captures the effects of measurement error, other statistical noises, and random shocks outside the farm control. It postulates that the error term ε_i is made of the following two independent components (equation 14).

$$\varepsilon_i = (v_i - u_i) \quad \text{.......} \quad [14]$$

Therefore, the production frontiers (equation 15) may be written as:

$$Y_i = f(X_i; \beta) + (v_i - u_i) \quad \text{.......} \quad [15]$$

v_i assumed to be independently and identically distributed random errors, having N (0, σ_v^2) distribution. It intended to capture the effects of random shocks outside the farmer's control, measurement errors and other statistical noises. u_i are non-negative ($u \geq 0$) one sided random variables. It intended to capture the effects of technical inefficiency effects which is assumed that it is independently distributed with a half normal distribution ($U \sim |N(0, \sigma_u^2)|$). Thus producers operate on or beneath their stochastic frontier [$f(X_i; \beta) + (v_i)$] according as u = 0 or u ≥ 0. Technical inefficiency effects, associated with the technical inefficiency of farms involved may be controlled by the farmers.

Various socioeconomic factors are responsible for the influence of farm-specific technical efficiency or inefficiency in production. The technical inefficiency effects u_i for the i^{th} farmer will be obtained by truncation normal distribution with mean zero and variance σ_u^2. The model of the technical inefficiency effects in the stochastic production frontier equation can be defined as (equation 16):

$$U_i = \delta_0 + \delta_h z_{ji} + L_i \quad \text{.......} \quad [16]$$

Where, Z_i represents the factors of inefficiency in production, L_i unobservable random variables. δ are unknown parameters to be estimated together with variance parameters. The estimates for all parameters of the stochastic production frontier model (15) and inefficiency model (16) can be estimated in a single stage by using the Maximum Likelihood Estimation (MLE) method. FRONTIER 4.1 (Coelli, 1996) was applied to estimate these parameters.

Given the specifications of the stochastic frontier models (equations 15 & 16), the technical efficiency of i-th farmer can be shown to be equal to:

$$TE = exp.(-U_i) = exp. [-E \{U_i/(V_i-U_i)\}] = 1- E \{U_i/(V_i-U_i)\}$$

The mean technical efficiency can be defined by

$$\text{Mean TE.} = E [exp. [-E \{U_i/(V_i-U_i)\}]] = E [1 - E \{ U_i/(V_i-U_i)\}]$$

Thus, the technical efficiency of a farmer is between zero and one, and is inversely related to the inefficiency effect. The efficiencies are predicted using the predictor that is based on the conditional expectation of $exp(-U_i)$ (Battese and Coelli, 1993).

The MLE of equation (15) provides estimators for β, γ, and σ, where, total variance of output is $\sigma_\varepsilon{}^2 = \sigma_u^2 + \sigma_v^2$; and $\gamma = \sigma_u^2 / \sigma_\varepsilon^2$. γ is the ratio of variance of the farm specific technical efficiency to the total variance of output, and has a value between zero and one.

Test of null hypothesis: It is important to note that the above models for the inefficiency effects (equation 16) can only be estimated if the inefficiency effects are stochastic and have a particular distributional specification. Hence, there is an interest to test the null hypotheses that the inefficiency effects are not present:

$$H_0: \gamma = \delta_0 = \delta_1 = \delta_2 \ldots\ldots\ldots\ldots\ldots = \delta_4 = 0; \text{ and}$$

The coefficients of the variables in the model for the inefficiency effects are zero,

$$H_0: = \delta_1 = \delta_2 = \delta_3 \ldots \ldots\ldots\ldots\ldots\ldots = \delta_4 = 0$$

These null hypotheses are tested using the generalized likelihood ratio statistic, γ defined by

$$\gamma = -2 \ln\{L(H_0)/L(H_1)\} = -2 [\ln\{L(H_0)\} - \ln\{L(H_1)\}]$$

Where, $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the specifications of the null and alternative hypotheses (i.e., H_0 and H_1), respectively. If the null hypothesis is true, then γ has approximately a Chi-square (or a mixed Chi-square) distribution (Coelli, 1995).

2.7.2 Empirical Cobb-Douglas production frontier function

The empirical Cobb-Douglas production frontier function with double log form can be expressed as follows:

$$Ln\ Y_i = \beta_0 + \beta_1 Ln\ X_{1i} + \beta_2 Ln\ X_{2i} + \beta_3 Ln\ X_{3i} + \beta_4 Ln\ X_{4i} + \beta_5 Ln\ X_{5i} + \beta_6 Ln\ X_{6i} + \beta_7 Ln\ X_{7i} + \beta_8 Ln\ X_{8i} + \beta_9 Ln\ X_{9i} + \beta_{10} Ln\ X_{10i} + \beta_{11} Ln\ X_{11i} + \beta_{12} Ln\ X_{12i} + \beta_{13} Ln\ X_{13i} + \beta_{14} Ln\ X_{14i} + \eta_1 D_{1i} + \eta_2 D_{2i} + v_i - u_i \quad \ldots\ldots [17]$$

Where,

Ln = Natural logarithm;

Y_i = Yield of oilseed of the i-th farm (kg/ha);

X_{1i} = Human labour used by the i-th farm (man-days/ha);
X_{2i} = Land preparation cost spent by the i-th farm (Tk/ha);
X_{3i} = Seed used by the i-th farm (kg/ha);
X_{4i} = Organic fertilizer used by the i-th farm (kg/ha);
X_{5i} = Urea used by the i-th farm (kg/ha);
X_{6i} = TSP used by the i-th farm (kg/ha);
X_{7i} = MoP used by the i-th farm (kg/ha);
X_{8i} = Di-Ammonium Phosphate (DAP) used by the i-th farm (kg/ha);
X_{9i} = Gypsum used by the i-th farm (kg/ha);
X_{10i} = Zinc sulphate used by the i-th farm (kg/ha);
X_{11i} = Boron used by the i-th farm (kg/ha);
X_{12i} = Irrigation cost of the i-th farm (Tk./ha);
X_{13i} = Pesticides used by the i-th farm (Tk/ha);
X_{14i} = Land rent of the i-th farm (Tk./ha);
D_{1i} = Dummy variable for soil type of the i-th farm (1 = Loam, 0 = Otherwise);
D_{2i} = Dummy variable for variety used of the i-th farm (1 = Improved, 0 = Otherwise);
β's and η's were unknown parameters to be estimated;
$v_i - u_i$ = error term; and
v_i's were assumed to be independently and identically (iid) distributed random errors, had $N(0, \sigma_v^2)$ distribution.

2.7.3 Empirical technical inefficiency effect model

The empirical technical inefficiency effect model can be expressed as follows (equation 18):

$$U_i = \delta_0+\delta_1 Z_{1i}+\delta_2 Z_{2i}+\delta_3 Z_{3i}+\delta_4 Z_{4i}+\delta_5 Z_{5i}+\delta_6 Z_{6i}+\delta_7 Z_{7i}+\delta_8 Z_{8i}+\delta_9 Z_{9i}+\delta_{10} Z_{10i} + \delta_{11} Z_{11i} + W_i \quad \ldots\ldots\ldots [18]$$

Where,
Z_{1i} = Farm size the i-th farm operator (ha);
Z_{2i} = Proportion of family labour to total labour;
Z_{3i} = Age of the i-th farm operator (year);
Z_{4i} = Education level of the i-th farm operator (year of schooling);
Z_{5i} = Experience in wheat farming of the i-th farm operator (year);
Z_{6i} = Training on oilseed crops (No.);
Z_{7i} = Availability of improved seed (Score);
Z_{8i} = Society member (Score);
Z_{9i} = Cosmopolitness of the farm operator (Score);
Z_{10i} = Farm operator's innovativeness (Score);
Z_{11i} = Extension contact of the i-th farm operator (Score);

W_i's were unobservable random variables or classical disturbance term, which are assumed to independently distributed, obtained by truncation of half normal distribution with mean zero and unknown variance, σ^2, such that u_i's is non-negative.

2.8 Estimating Returns to Investment in R&D

The third objective of the present study is to estimate the returns to investment in oilseeds research and development in Bangladesh. An *ex-post* evaluation with the help of economic surplus model was adopted in this study to estimate the benefit-cost ratio (BCR), internal rate of return (IRR), and net present value (NPV) of the investment on oilseeds research and development (R&D) in Bangladesh. Economic surplus approach estimates the benefits to agricultural research by measuring the change in consumers' surplus and producers' surplus from a rightward shift in the supply curve that is brought about through technological change. Aggregate consumers' surplus, producers' surplus and total surplus are usually calculated by summing up corresponding surpluses of all commodities rather than summing up from the areas of the model. In order to calculate the net benefits of research and extension, expenditures are subtracted from total surplus. All these estimates of benefits were expressed in real term by using the price of 2011-2012 as base year. The rate of returns and net benefit are then discounted using 10% interest rate for obtaining the efficiency of investment. Due to multiple oilseed crops under study, the present analysis was done under both closed and small open-economy market[5] situations. Hasan and Miah (2003) also analyzed returns to investment in rapeseed and mustard R&D under small open-economy market condition. Theoretical and empirical concepts of the economic surplus model are given below.

2.8.1 Theoretical concept of economic surplus model

The concept of economic surplus has been used to measure economic welfare and the changes in economic welfare from policy and other interventions (Alston et al., 1995 and Currie et al., 1971). Usually, the economic surplus concept is adopted to estimate the social benefits from the adoption of improved varieties. The components of economic surplus are consumer surplus and producer surplus resulting from a shift in the supply curve, caused by an increase in productivity. This outward shift in the supply function results from an upward shift in the aggregate production function resulting from the adoption of improved varieties.

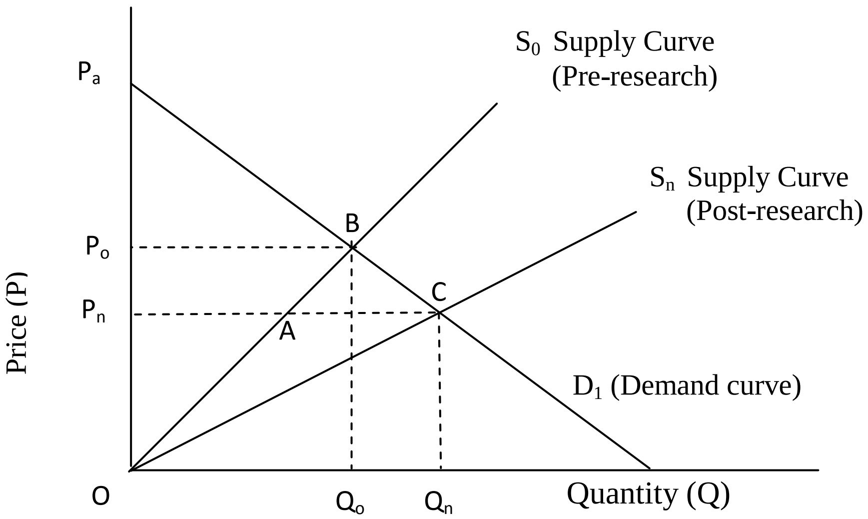


Figure 2.1 Economic surplus model under closed-economy market situation

[5]Bangladesh produces oilseeds (e.g. rapeseed & mustard, groundnut, soybean, etc.) domestically, but imports oilseeds from world market. A commodity that is produced domestically and traded internationally is in an open economy market. Open economy markets are characterized as being either small or large. A small economy market is one, where the amounts of exports and imports are small relative to total world trade of the commodity.

This relation is shown in Figure-1 in which D_1 and S_o represent the actual market demand and pre-research supply curve, whereas S_n represents the post-research supply curve that would have existed due to the adoption of improved variety.

Distribution of Economic Benefits:

Change in consumer surplus/benefit	=	Area ABC + Area P_oBAP_n
Change in producer surplus/benefit	=	Area AOC - Area P_oBAP_n
Change in total economic surplus/benefit	=	Area ABC + Area AOC

Given a shift in the supply curve from S_o to $S_{n,}$ the change in consumer surplus depicted in Fig-1 as Area ABC+Area P_oBAP_n, the producer surplus as Area AOC-Area P_oBAP_n, and the total social benefit or economic surplus as Area ABC + Area AOC. The shift in the supply curve has decreased the price that made consumers better off. The change in consumers' surplus (benefits) can be measured as a monetary value. Besides, area AOC represents the decrease in the cost of production (i.e. benefits of the farmers) for the same unit of commodity due to the adoption of improved variety and can also be measured and quantified in monetary terms. The adoption of improved variety, however, has increased the quantity produced, thereby decreasing the price of the commodity (from P_0 to P_n in Figure 1) which is a loss to farmers income. Farmers can recover some of this loss since they can sell excess quantity (Q_n to Q_0 in Figure 1) of the commodity. Farmers will be benefited from the adoption of improved technology intervention if Area AOC is greater than Area P_oBAP_n. In the present case, the Area AOC is less than the Area P_oBAP_n. The size of the two areas depends on the elasticities of the supply and demand curves and the size of the supply curve shift. The total social benefit (i.e. economic surplus) from the adoption of improved variety is the summation of the change in consumer surplus plus the change in producer surplus (Area ABC + Area AOC). For a closed economy model, the estimated price elasticity of demand is used in the above formulae.

For small open-economy model, where the elasticity of demand is perfectly elastic, use a sufficiently large number of η (Nagy *et al.*, 2000). In a small open economy market, there is little or no effect on the world price of the commodity (the small country assumption). In this situation, the price of commodity does not change with the shift in the supply curve. For this study, the oilseed market of Bangladesh is modelled as a small open economy market.

The change in economic surplus for a small open-economy that is domestically produced, but allows imports to cover shortfall is depicted in Figure 2. The world price P_w and quantity demanded by Bangladeshi consumers Q_1 defines the initial equilibrium. At price P_w, producers supply Q_n amount of oilseed, when faced by the pre-research supply curve S_1. Oilseed imports are equal to QT_n, when faced by the research induced supply curve S_2 (the supply curve that exist because farmers have adopted new high yielding varieties). Oilseed producers increased production to quantity Q_n and increase Q_nQ_0. Oilseed imports are decreased by the same amount as the increase in production Q_nQ_0 and are now at QT_0. Since P_w does not change (small economy assumption), there is no change in consumer surplus-consumers are neither better off nor worse off. The entire change in economic surplus from the adoption of new oilseed varieties is thus a change in producer surplus only and is identified by area Oab in Figure 2 (corresponds to area OAC in Figure 1). The amount of foreign exchange saved by the adoption of improved varieties is equal to P_w x (Q_nQ_0).

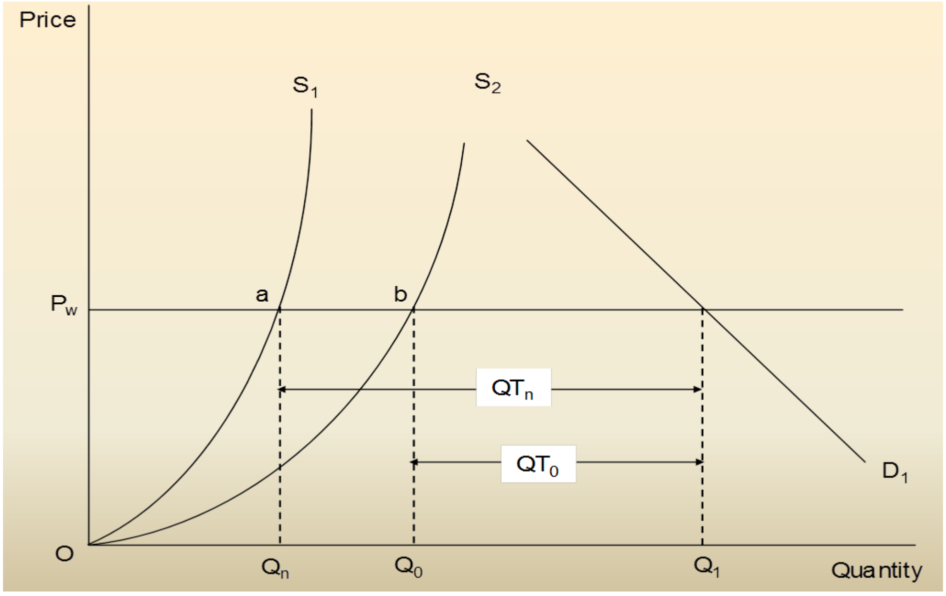


Figure 2.2 Small open-economy importer economic surplus model

2.8.2 The empirical model

The Akino and Hayami (1975) approximation formula for calculating changes to producer and consumer economic surplus was used in the proposed study. The approximation formula for calculating the change in economic surplus for a closed-economy situation (Fig 1) is as follows:

Area ABC = $((\frac{1}{2} P_nQ_n)((k(1+\lambda))^2/(\lambda+\eta)))$ ………..…………………………..…..…. [19]

Area AOC = (kP_nQ_n) …………………………………..……………………….…… [20]

Area P_oBAP_n=$((P_nQ_nk(1+\lambda))/(\lambda+\eta))x((1-(\frac{1}{2} k((1+\lambda)\eta))/(\lambda+\eta))$ - $(\frac{1}{2} k(1+\lambda)))$ …[21]

Where,

P_o = Output price (Tk/ton) that would exist in absence of research (existing market price)
Q_o = Quantity of output (ton) produced that would exist in absence of research
P_n = Actual output price (existing market price)
Q_n = Actual quantity of output (existing production)
k = Horizontal supply shifter
λ = Price elasticity of output supply
η = Absolute price elasticity of the demand for the output.

(For a closed-economy model, the estimated η is used in the above formulas. For a small open-economy model where the η is perfectly elastic, use a sufficiently large no. for η.)

2.8.3 Estimation of supply shifter (k)

The overall yield advantage of improved technology over the traditional varieties, weighed by the proportion of the total production saved due to improved technology adoption is called the supply shifter (k). In Akino and Hayami (1975) approximation formulae, k is the horizontal shift from the equilibrium price P_n given S_1 to the equilibrium price Po given S_2, which corresponds to a distance equal to Q_nQ_o in Figure-1 (Gardiner *et al.*, 1986; Nagy and

$$k_t = \sum_{i=1}^{n}[1-\frac{Y_t}{Y_{it}})]\times A_{it} \quad \text{......} [22]$$

Furtan, 1978). In estimating yield advantage, the yields of selected crops (both improved and old variety) were collected through HH survey. The supply shifter k is calculated as follows:

Where,

Y_{it} = Yield of improved variety in year t

Y_t = Yield of traditional variety in year t

A_{it} = Proportion of the total production saved due to improved variety adoption in year t

n = Number of farms (Sample respondent).

2.8.4 Estimation of rates of return

The internal rate of return (IRR) is calculated by taking the total social benefit (TSB) minus total expenditure for research and development (C) in each year. The IRR is the discount rate that results in a zero net present value (NPV) of the benefits. The IRR is calculated as (Equation 23):

$$O = \left[\sum_{t=1}^{n}(TSB_t - C_t)(1+IRR)^{-t}\right] \quad [23]$$

The formal mathematical statements of benefit cost ratio (BCR) and NPV are as follows:

$$BCR = \frac{\sum_{t=1}^{n}\frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n}\frac{C_t}{(1+i)^t}} \quad \text{------} [24]$$

$$NPV = \sum_{t=1}^{n}\frac{(B_t - C_t)}{(1+i)^t} \quad \text{------} [25]$$

Where,

B_t = Benefit in time t

C_t = Expenditure in time t

i = Interest (discount) rate;

n = Number of years; and t = 1,2,3 ………, n.

2.8.5 Type and sources of data for the model

Both primary and secondary data were used to run the economic surplus model. The procedure of collecting primary data has been discussed in the previous section. Three years (2009-20011) data on area and production of the selected four oilseeds and percent adoption of the improved varieties were collected from 64 district level offices of the Directorate of Agricultural Extension (DAE). Consumer price index (CPI) and time series data (1989-2012) on area and production of selected oilseeds were collected from various issues of the Bangladesh Bureau of Statistics (BBS). In addition, the demand and supply elasticity estimates used by Norton (1993) for oilseeds were considered in this study. The costs incurred in the past years for oilseed research was collected from the Finance and Accounts section of BARI and BINA. Extension and promotional activities were conducted by DAE and the related costs were obtained from this organization. The administrative costs were gathered from the apex body of agricultural research, the Bangladesh Agricultural Research Council (BARC). The following primary and secondary data collected from different sources are presented in Table 2.2.

Table 2.2 Type and sources of data used in economic surplus model

Data type	Sources of data
Year-wise district level area, production and yield	BBS and DAE
Local level area, production and yield	Field survey
Adoption profile of oilseed varieties	DAE & expert opinion
Retail prices of oilseeds	DAM
Consumer price index (CPI)	BBS
Supply and demand elasticity	Norton, 1993
Oilseeds research and extension costs	ORC-BARI, BINA, DAE, & BARC
Year-wise quantity and price of imported oilseed	FAOstat
f.o.b price of oilseeds	FAOstat

2.8.6 Research and development expenditure

The total expenditures incurred for the development of improved technologies of oilseeds, and the dissemination of these improved technologies at farm levels included the costs of different institutes, such as ORC of BARI, BINA, BARC, and DAE (see Table 7.8). Different agricultural universities namely BAU, SAU, and BSMRAU conducted some research on oilseeds for their MS and Ph.D. levels which has little or no impact at farm level. Therefore, oilseed research costs at university levels were not taken into consideration in this study. For the analysis, the current total expenditures were converted to 2011-12 constant prices (inflated price) using the national CPI Index.

The costs incurred for oilseeds research were collected from the Finance and Accounts section of BARI and BINA. The costs of these two research institutes included capital, revenue and foreign exchange costs. The ORC of BARI mainly works on six oilseed crops, but the present study deals with four crops. Hence, based on the assumptions and suggestions of ORC scientists, about 66.7% of the total ORC cost was taken for this analysis and was assumed constant throughout the study period. Again, 5% of the total costs of BINA were considered as the costs for oilseeds development programme. BARC is the apex body of National Agricultural Research System (NARS) of Bangladesh. Currently, major ten research institutes belong to the BARC. Therefore, the administrative costs were also gathered from BARC. It was assumed that BARC administrative expenditure for BARI was about 10% of total BARC expenditures. Again, BARI conducts researches on both crops and non-crops enterprises. However, 0.50% of the total BARC cost was taken for analysis and was assumed constant throughout the study period. Finally, extension and promotional activities were conducted by DAE and the related costs were obtained from this organization. The expenditures of DAE for the dissemination of improved technologies of oilseeds were calculated based on the percentage of oilseeds cropped area relative to total cropped area. On average, 0.483% of the land was planted to concerned four oilseeds and 1.84% of total DAE cost was incurred for oilseeds extension.

2.8.7 Limitations of the economic surplus model

A period of time has been considered in economic surplus model for estimating the economic rates of returns or social benefits of a technological intervention in the society. Different time series data are required to make the model functioning properly. Unfortunately, time series data on many aspects are not available in Bangladesh. Therefore, the following time series data were used in the model based on some assumptions.

a) The elasticity estimates for demand and supply used in this study were considered constant throughout the study period.
b) The percentages of areas planted to different improved varieties of oilseeds used for the period from 1997 to 2008 were estimated based on expert opinions.
c) The calculation of yield advantages of an improved oilseed variety over traditional one for different years was based on a single year (2011-12) observation.
d) Various expenditures incurred by different organizations directly involved in oilseeds R&D were taken on the basis of assumption over the study period. Nevertheless, fixed percentage of the total cost was considered throughout the study period.

2.9 Estimation of Employment Generation

The amount of additional employment generated due to the adoption of improved varieties of oilseeds and production practices was estimated using the following formula (Equation 26). This equation was also used by Miah et al, 2009.

$$TEG = \sum_{t=1}^{16}(LABI_{ti} - LABT_{ti})(AREA_{ti} \times ADOP_{ti}) \text{------------------------------------} \quad [26]$$

Where,

TEG = Total additional employment generation (man-day) due to improved oilseed adoption
LABI = No. of labour (man-day/ha) required for improved i^{th} oilseed cultivation in the t^{th} year
LABT = No. of labour (man-day/ha) required for old i^{th} oilseed crop cultivation in the t^{th} year
AREA= Total area (ha) cultivated to i^{th} oilseed crop in the t^{th} year
ADOP = Adoption rate of improved i^{th} oilseed crop in the t^{th} year

i = 1, 2, 3, 4 (*1= Mustard, 2= Groundnut, 3 = Sesame, 4= Soybean*)

2.10 Assessing Livelihood Development

Finally, the livelihood development due to cultivating improved oilseed varieties were measured by analyzing data and information regarding livelihood improved indicators under the *'with improved variety'* and *'without improved variety'*.

2.11 Sustainability of Oilseed Production

Sustainable production of agricultural commodities is very much important in agriculture. It involves the complex interactions of biological, physical and socioeconomic factors and requires a comprehensive approach to research for improving existing systems and develop new ones that are more sustainable (Plucknett, 1990). Therefore, the sustainability of oilseed production was assessed through analyzing various social, environmental, institutional, and economic factors. In this case, SOWT analysis was adopted. Several FGDs (Appendix A-15) were also conducted with different scientists and extension personnel.

10. Results and Discussion

The results of the present study are discussed in detailed under different chapters. *Chapter III* presents the socio-economic profiles of the oilseed farmers. Adoptions of oilseed technologies at farm level are discussed in *Chapter IV*. *Chapter V* contains the detailed profitability and comparative advantage scenarios of oilseed cultivation in Bangladesh. Factors of production and technical efficiency of oilseed farmers are presented in *Chapter VI.* In *Chapter VII,* socioeconomic impacts of oilseed R&D are discussed. Constraints and opportunities in oilseeds research and development are discussed in *Chapter VIII*. Finally, conclusions and policy implications are included in *Chapter IX*.

Chapter III

SOCIOECONOMIC PROFILES OF THE OILSEED FARMERS

3.1 Introduction

Socio-economic characteristics of the farmers are important in influencing farm decision making and production planning. Persons differ from one another in many respects. Behavior of a person is determined by his/her characteristics. There are numerous interrelated and constituent attributes that characterize a person and these profoundly influence development behavior. The socioeconomic characteristics of the farmers such as age, education, occupational status, farming experience, training, land holding, status of societal membership, cosmopolitans, innovation, extension contact and livelihood status etc. are discussed in this chapter.

3.2 Age Distribution

Age of farmers plays an important role in the crop production and better management of the farming activities. The age of the oilseed farmers was examined by classifying the farmers into six groups: 20-30, 31-40, 41-50, 51-60, 61-70 and above 70 years (Table 3.1). Most of the adopter and non- adopter farmers belonged to the age group 31-40 and 41-50 years. This information imply that majority of the farmers were relatively younger in age and were in a position to put more physical effort for oilseed production. Farmers belonging to this age group were supposed to have enormous vigor and risk bearing ability.

Table 3.1 Percent distribution of oilseed farmers according to age group

Age group (year)	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All *(n=1980)*
A. Adopter	***n=197***	***n=95***	***n=116***	***n= 56***	***n= 464***
20-30	20.81	17.89	22.41	26.79	21.34
31-40	28.43	16.84	22.41	23.21	23.92
41-50	26.40	24.21	25.00	23.21	25.22
51-60	16.75	26.32	20.69	14.29	19.40
61-70	6.09	11.58	6.90	10.71	7.97
Above 70	1.52	3.16	2.59	1.79	2.15
Total	100	100	100	100	100
B. Non-adopter	***n=343***	***n=445***	***n=424***	***n= 304***	***n= 1516***
20-30	22.74	16.18	17.45	19.41	18.67
31-40	23.91	19.78	18.63	23.03	21.04
41-50	23.03	27.19	27.59	27.96	26.52
51-60	18.95	19.10	21.46	15.79	19.06
61-70	9.04	15.05	12.04	10.53	11.94
Above 70	2.33	2.70	2.83	3.28	2.77
Total	100	100	100	100	100

3.3 Educational Status of the Sample Farmers

Literacy may be defined as the ability of an individual to read and write or formal education received up to certain standard. Education helps individuals to become conscious of their environment and develop rational insight into many matters of life. Farmer's education is expected to play an important role in increasing the farming output. Education is likely to influence the farmers to adopt the modern technology and it makes them more capable to manage scarce resources efficiently so that they can earn higher profit. On the basis of education level, the literacy status of the respondent farmers has been grouped into five categories. The categories are (1) illiterate, (2) primary, (3) secondary, (4) higher secondary and (5) degree and above. Information on the educational levels of the respondents is presented in Table 3.2. It is observed that 20.69 % of adopter farmers and 25.46 % of non-adopter farmers respectively did not have formal education. Of the educated respondents, highest 43.10% adopter and 41.69 % non-adopter had primary level of education. All of the soybean adopter farmers were literate. Most of the mustard non-adopter farmers (77.84%) were educated. In case of different crop, most of the soybean adopter farmers (67.86 %) had primary level education. This case is same for non-adopter soybean farmers. A few number of mustard (5.08%) and sesame (2.59%) adopter farmers had degree and above level of education. In case of groundnut and soybean, there were no degree level adopter farmers.

Table 3.2 Percent distribution of oilseed farmers by literacy levels

Literacy level	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All *(n=1980)*
A. Adopter	***n=197***	***n=95***	***n=116***	***n= 56***	***n= 464***
Illiterate	19.80	28.42	25.86	--	20.69
Primary	48.22	28.42	34.48	67.86	43.10
Secondary	19.80	35.79	31.03	30.36	27.16
Higher secondary	7.11	7.37	6.03	1.78	6.25
Degree & above	5.07	--	2.60	--	2.80
Total	100	100	100	100	100
B. Non-adopter	***n=343***	***n=445***	***n=424***	***n= 304***	***n= 1516***
Illiterate	22.16	26.74	27.12	25.00	25.46
Primary	46.94	37.53	34.67	51.64	41.69
Secondary	18.95	27.64	30.66	18.75	24.74
Higher secondary	5.25	6.52	5.66	3.29	5.34
Degree & above	6.70	1.57	1.89	1.32	2.77
Total	100	100	100	100	100

3.4 Occupation

The work for which a man is engaged throughout the year is known as his main occupation (Ray, 1988). As Bangladesh is an agro-based country, the majority of the people in the rural area adopt agriculture as their main occupation. Oilseed farmers were engaged in various types of occupation. Table 3.3 shows that most of the farmers had single occupation and agriculture was the dominant among different occupations. It appeared that agriculture was the principal occupation of both adopter (93.32 %) and non-adopter (96.57 %) oilseed farmers. But some farmers depended on services and business. It could seen from the table that, all non-adopter sesame farmers were engaged in agriculture.

Table 3.3 Percent distribution of oilseed farmers by type of occupations

Type of occupation	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All *(n=1980)*
A. Adopter	***n=197***	***n=95***	***n=116***	***n= 56***	***n= 464***
Agricultural farming	90.36	92.63	99.14	92.86	93.32
Business	0.51	1.05	--	1.79	0.65
Service	2.54	--	0.86	1.79	1.51
Agriculture +Business	4.06	4.21	--	1.79	2.80
Agriculture +Service	1.52	2.11	--	1.79	1.29
Service +Business	1.02	--	--	--	0.43
Total	100	100	100	100	100
B. Non-adopter	***n=343***	***n=445***	***n=424***	***n= 304***	***n= 1516***
Agricultural farming	91.55	95.28	100.00	99.34	96.57
Business	0.87	1.35	--	--	0.59
Service	0.58	0.45	--	0.33	0.33
Agriculture +Business	1.75	2.70	--	--	1.19
Agriculture +Service	4.66	0.22	--	--	1.12
Service +Business	0.58	--	--	0.33	0.20
Total	100	100	100	100	100

3.5 Farming Experience

Farm experience is an important factor to ensure farm productivity. Farmers who have more experience in farm operations generally attain higher levels of technical efficiency. Technical inefficiency of the production is significantly related to farming experience of the farmers. It was found that, 32.11 % of adopter farmers belonged to years of experience group 6-10 and 33.84% of non-adopter farmers belonged to years of experience group 1-5. Small number of adopter farmers (1.94%) and non-adopter farmers (4.16%) fell in 36-40 years of experience group. In case of different crop, most of the mustard adopter and non-adopter farmers belonged to years of experience group 1-5 and 6-10. This scenery is same for other crops. So it is clear from the table that, most of the farmers had a little experience in oilseed production.

3.6 Training Received

Training is a most important tool for acquiring knowledge about technology. It can increase farmer's skill regarding production practices and related aspects. It is revealed from Table 3.5 that about 23% of the adopters and 15% of non-adopters received training on oilseed cultivation. It implies that lion share of the oilseed farmers are still lacking in appropriate training on oilseed production. Most of the improved soybean adopting farmers (57.14%) received 1-2 nos. of training on oilseeds followed by groundnut (20.0%), mustard (19.8%) and sesame (5.17%) farmers. In the case of non-adopting farmers, the highest percentage (17.10%) (16.63%) of soybean farmers received 1-2 nos. of training on oilseed production followed by groundnut and mustard farmers. Only 1.02% adopters of mustard and 0.45% groundnut adopters had 5-6 times training on oilseed. More or less similar observations were found in the case of training on agriculture (Appendix A-17).

Table 3.4 Percent distribution of oilseed farmers by farming experience

Farming experience (year)	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All *(n=1980)*
A. Adopter	***n=197***	***n=95***	***n=116***	***n= 56***	***n= 464***
01-05	28.43	36.84	29.31	25.00	29.96
06-10	25.89	34.74	25.86	62.50	32.11
11-15	14.21	7.37	12.07	3.57	10.99
16-20	14.21	10.53	13.79	8.93	12.72
21-25	4.06	2.11	6.03	--	3.66
26-30	6.60	5.26	8.62	--	6.03
31-35	3.05	3.16	2.59	--	2.59
36-40	3.55	--	1.72	--	1.94
Total	100	100	100	100	100
B. Non-adopter	***n=343***	***n=445***	***n=424***	***n= 304***	***n= 1516***
01-05	28.86	39.55	17.22	54.28	33.84
06-10	26.82	33.26	27.83	31.25	29.88
11-15	9.91	9.89	9.20	5.92	8.91
16-20	10.79	8.76	14.86	7.89	10.75
21-25	5.54	3.82	9.20	0.33	5.01
26-30	6.12	3.15	14.39	0.33	6.40
31-35	0.58	0.22	3.07	--	1.06
36-40	11.37	1.35	4.25	--	4.16
Total	100	100	100	100	100

Table 3.5 Percent distribution of oilseed farmers according to training received on oilseed cultivation

No. of training received	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All *(n=1980)*
A. Adopter	*n=197*	*n=95*	*n=116*	*n= 56*	*n= 464*
No training	77.15	80.00	93.97	37.50	77.14
1-2 Nos.	19.80	20.00	5.17	57.14	20.69
3-4 Nos.	2.03	--	0.86	5.36	1.73
5-6 Nos.	1.02	--	--	--	0.44
Total	100	100	100	100	100
B. Non-adopter	*n=343*	*n=445*	*n=424*	*n= 304*	*n= 1516*
No training	87.47	80.90	90.80	80.93	85.15
1-2 Nos.	11.66	16.63	9.20	17.10	13.53
3-4 Nos.	0.87	2.02	--	1.97	1.19
5-6 Nos.	--	0.45	--	--	0.13
Total	100	100	100	100	100

It is revealed from Table 3.6 that most of the adopter (97.61%) farmers received training from DAE. Most of the adopter farmers of sesame (99.06%) received their training from DAE and the rest (1.89%) from NGOs.

Table 3.6 Percent distribution of oilseed farmers according to training agencies

Training agency	Mustard *(n= 231)*	Groundnut *(n=225)*	Sesame *(n=212)*	Soybean *(n=128)*	All *(n=796)*
1. DAE	92.64	95.56	99.06	107.81	97.61
2. NGOs	5.19	8.00	1.89	8.59	5.65
3. Research institutes	9.52	6.22	0.94	2.34	5.15
4. IPM school	19.91	3.56	--	--	6.78

3.7 Land Holding

Land is the most important asset for farm household because farm families depend on the land. Farm size is computed by the entire land area operated by the respondent farmers. It included the area of cultivated land owned with the area rented in from others and subtracting the area rented out to others. It includes the homestead land (housing plot), fallow land, orchard and pond. It appears from Table 3.7 that, the average farm size of all adopter and non-adopter oilseed growers was 1.349 ha and 1.216 ha, respectively. From them, groundnut adopter and non-adopter farmers had highest farm size which was 1.866 ha and 1.63 ha, respectively. Mustard adopter farmers had highest cultivated land which was about 1.199 ha followed by groundnut 1.66 ha, sesame 0.723 and soybean 0.593 ha. But non-adopter groundnut farmers had highest cultivated land (1.102 ha).

Table 3.7 Category of land and farm size of the respondent oilseed farmers

(Figure in ha)

Land category	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All category *(n=1980)*
A. Adopter	*n=197*	*n=95*	*n=116*	*n= 56*	*n= 464*
1. Own land	1.199	1.660	0.723	0.593	1.101
2. Rented in	0.473	0.055	0.100	0.409	0.286
3. Rented out	0.628	0.123	0.024	0.046	0.303
4. Mortgaged in	0.355	0.168	0.079	0.086	0.215
5. Mortgaged out	0.547	0.061	0.011	0.007	0.248
6. Homestead	0.091	0.108	0.075	0.152	0.098
7. Fallow land	0.121	0.014	0.001	0.003	0.055
8. Orchard	0.122	0.030	0.063	0.038	0.078
9. Pond	0.118	0.015	0.028	0.051	0.066
Farm size	**1.304**	**1.866**	**1.034**	**1.279**	**1.349**
B. Non-adopter	*n=343*	*n=445*	*n=424*	*n= 304*	*n= 1516*
1. Own land	0.890	1.102	0.801	0.567	0.863
2. Rented in	0.534	0.410	0.139	0.447	0.370
3. Rented out	0.432	0.123	0.071	0.048	0.163
4. Mortgaged in	0.296	0.064	0.084	0.060	0.121
5. Mortgaged out	0.793	0.041	0.047	0.004	0.205
6. Homestead	0.075	0.116	0.083	0.130	0.100
7. Fallow land	0.087	0.042	0.001	0.004	0.033
8. Orchard	0.134	0.034	0.029	0.039	0.056
9. Pond	0.084	0.026	0.017	0.050	0.041
Farm size	**0.875**	**1.630**	**1.036**	**1.245**	**1.216**

Note: Farm size = (1+2+4+6+7+8+9)-(3+5)

3.8 Status of Societal Membership

Social participation is an indicator of respondent's likely exposure to new knowledge and improved decision making. There are many social organizations, such as Farmer's Cooperative Society, Youth Cooperative Society, School Committee, IPM/ICM Club, Mosque Committee, Bazaar Committee, and Union Council. Membership of these social organizations was considered as a measure for social participation.

Table 3.8 reveals that most of the oilseed farmers had no involvement with any social organization. About 32% of the adopter farmers were reported to be the member of local Mosque Committee followed by 31.4% IPM/ICM Club, 17.5% School Committee, and 13.2% Farmer's Cooperative Society. Most of the non-adopter oilseed farmers (18%) also belonged to local Mosque Committee. However, the involvement of adopting farmers with different social organizations was much higher compared to non-adopting farmers. On the other side, the respondent oilseed farmers who belonged to any social organization were involved mostly as general member. Their involvement as an organizational head or executive member was reported to be very minimum (Appendix A-18 to A-21).

Table 3.8 Percent of oilseed farmers involved with different social organizations

Type of organization	Mustard	Groundnut	Sesame	Soybean	All category
A. Adopter	*n=197*	*n=95*	*n=116*	*n=56*	*n=464*
1. Farmer`s coop society	14.2	11.6	0.9	37.5	13.2
2. Youth coop society	9.1	2.1	1.7	--	4.7
3. School committee	18.8	12.6	8.6	39.3	17.5
4. IPM/ICM club	42.1	28.4	10.3	42.9	31.4
5. Mosque committee	37.1	26.3	34.5	17.9	31.9
6. Market committee	7.6	3.2	0.9	26.8	7.3
7. Union council	2.5	3.2	0.9	1.8	2.2
B. Non-adopter	*n=343*	*n=445*	*n=424*	*n=304*	*n=1516*
1. Farmer`s coop society	4.4	2.9	1.4	1.6	2.6
2. Youth coop society	2.9	1.1	0.9	--	1.2
3. School committee	8.5	4.9	6.6	10.2	7.3
4. IPM/ICM club	14.6	4.0	4.2	8.2	7.3
5. Mosque committee	19.0	13.7	20.0	20.4	18.0
6. Market committee	3.5	2.0	2.6	2.6	2.6
7. Union council	2.3	1.1	--	1.3	1.1

3.9 Influencing Persons in Variety Adoption

At the initial stage of adopting various improved oilseed varieties, the respondent adopters in the study areas were influenced by different persons at different levels. The influencing persons were reported to be family member, neighbouring farmer, Sub-Assistant Agricultural Officer (SAAO), Agriculture Officer (AO), and the members of IPM/ICM club. The influences of these persons were not mutually in nature.

Table 3.9 depicts that the overall influences of SAAO in adopting improved oilseed varieties were higher than the influences of other persons. In the case of mustard, more or less all the persons influenced mustard farmers to a varying degree to adopt improved varieties. Again, major influences came from SAAO and neighbouring farmers in the case of groundnut and sesame cultivation. Family members also influenced to a greater extent in adopting improved variety in soybean cultivation.

Table 3.9 Level of influence by different persons in adopting improved oilseed varieties

Persons	Level of influence (%)				
	Very high	High	Medium	Low	No influence
Mustard (n=197)					
1. Family member	6.60	15.23	19.29	12.69	46.19
2. Neighbor	11.17	17.76	24.37	15.74	30.96
3. SAAO	35.53	26.40	15.23	11.68	11.16
4. Agril. Officer	9.14	18.27	11.17	15.23	46.19
5. IPM/ICM club	2.54	1.02	1.52	8.12	86.80
Groundnut (n=95)					
1. Family member	--	--	1.05	47.37	51.58
2. Neighbor	--	--	97.89	2.11	--
3. SAAO	21.05	44.21	22.11	12.63	--
Sesame (n=116)					
1. Family member	7.76	5.17	--	13.79	73.28
2. Neighbor	23.28	47.41	29.31	--	--
3. SAAO	28.45	48.28	19.82	--	3.45
Soybean (n=56)					
1. Family member	--	3.57	53.57	--	42.86
2. Neighbor	8.93	--	44.64	7.14	39.29
3. SAAO	21.43	32.14	41.07	5.36	--
4. Agril. Officer	--	8.93	14.29	--	76.78

3.10 Cosmopolitness of the Respondent Farmers

Pradhan and Chauhan (2012) stated that cosmopolitness is the character of an individual for delineating his outer exposure towards the environment and the source of information. The increased cosmopolitness of an individual emphasizes the knowledge endowment and exposure as well as experience on the information received from different sources regarding good agricultural practices to augment his livelihood status. They found that cosmopolitness had positively and significantly correlated and associated with attitude towards technology dissemination activity. It is expected that more cosmopolitness farmers used more improved varieties of oilseeds compared to less cosmopolitness farmers.

It was reported that the higher percentage of adopting farmers visited *Upazila Sadar* and *Zila Sadar* (district) more frequently than that of non-adopting farmers. The perusal of Table 3.10 that about 78% and 20% of the adopters of improved oilseed varieties traveled frequently in *Upazila Sadar* and *Zila Sadar* for different purposes, whereas, these percentages were 58 and 7 in the case of non-adopters. Most of the adopters of improved oilseed varieties (38%) often visited capital city, while only 10.1% non-adopters reported that they often visited capital city. More or less similar observations were found in the case of different oilseeds (Appendix A-22 to A-25).

Table 3.10 Percent responses on the level of cosmopolitans of the oilseed farmers

Place of visit	Frequently	Often	Rarely	Never
A. Adopter *(n=464)*				
1. Upazila Sadar	77.4	21.8	0.8	--
2. District	19.8	74.2	5.8	0.2
3. Capital city	1.1	37.7	56.0	5.2
4. Foreign country	--	0.7	14.0	85.3
B. Non-adopter *(n=1516)*				
1. Upazila Sadar	58.0	37.2	4.7	0.1
2. District	7.1	73.0	18.6	1.3
3. Capital city	0.3	10.1	69.7	19.9
4. Foreign country	--	0.2	2.0	97.8

3.11 Association with Innovative Activities

It is expected that adopter farmers are more dynamic than that of non-adopters. Therefore, adopter farmers are likely to be tending more on various innovative activities. Table 3.11 reveals that irrespective of oilseed types the highest percentage of both adopting (62%) and non-adopting farmers (50.1%) used artificial insemination (AI) followed by the use of composed fertilizer. A good percentage of improved oilseed variety adopters and non-adopters also used IPM technology to control insect-pests infestation. However, the overall innovative activities used by adopting farmers were more compared to non-adopters in the study areas.

Table 3.11 Percent of oilseed farmers adopting innovative activities in the study areas

Innovative activity	Mustard	Groundnut	Sesame	Soybean	All
A. Adopter	*n=197*	*n=95*	*n=116*	*n= 56*	*n= 464*
Use of green manure	44.2	46.3	42.2	--	38.8
Use of compost	53.4	23.2	42.2	25.0	41.0
Crop cultivation on *ail*	12.2	12.6	6.9	14.3	11.2
Use of IPM technology	36.5	22.1	37.1	35.7	33.6
Artificial insemination	58.4	64.2	59.5	73.2	61.6
Bee keeping	5.0	--	28.4	--	9.2
B. Non-adopter	*n=343*	*n=445*	*n=424*	*n= 304*	*n= 1212*
Use of green manure	23.3	9.2	5.4	--	11.9
Use of compost	34.4	9.0	23.6	6.3	22.9
Crop cultivation on *ail*	8.2	4.3	0.5	5.3	5.4
Use of IPM technology	19.2	9.7	7.8	10.5	14.4
Artificial insemination	37.6	41.6	47.2	30.6	50.1
Bee keeping	1.7	2.5	--	--	1.4

3.12 Level of Extension Contact

Extension agents play an important role in technology dissemination. The Government of Bangladesh has a very large extension network under the Department of Agricultural Extension (DAE) for the dissemination of crop related agricultural technologies from research institutes to farmers. The SAAO of DAE is the key person to make contacts with the farmers for any kind of technology dissemination and crop related issues. In addition, farmers can gather up-to-date knowledge on modern variety, improved production practices, intercultural operations, insect-pest control, and many other related issues of crop production from different extension medias, such as agriculture fair, booklets, leaflets, field day, demonstration plots, research institutes, and mass media. An attempt was made to study oilseed farmers to assess their level of contact with different extension agents.

Table 3.12 revealed that the respondent adopters of improved oilseed varieties had frequent contact with extension personnel and neighbouring farmers which was more than the contact made by non-adopting farmers in the study areas. Most of the adopter farmers (85-88%) did not visit agricultural research institutes and attended the field days. This was similar for non-adopter farmers. Contact with mass media (i.e. radio, TV, newspaper) was also higher for adopting farmers compared to non-adopters. However, the levels of contact with different extension agents were found to be higher for adopters compared to non-adopters in the study areas. The overall findings on the level of extension contact of different oilseed farmers were more or less similar to the above findings (Appendix A-26 to A-29).

Table 3.12 Level of extension contact of oilseed farmers with different extension medias

Extension medias	Farmers' responses (%)				
	Frequent	Often	Sometimes	Rare	None
A. Adopter *(n=464)*					
1. Extension personnel	33.4	49.8	14.9	1.7	0.2
2. Neighbour (farmer)	28.9	42.9	25.6	2.1	0.5
3. Agriculture fair	0.6	5.6	25.0	30.2	38.6
4. Demonstration plot	1.3	2.8	20.5	25.2	50.2
5. Agril. book/booklets	0.7	2.0	17.0	15.5	64.8
6. Attend in the field day	0.4	0.6	1.1	10.1	87.8
7. Research institute visit	0.2	0.2	3.9	10.1	85.5
8. Radio	0.4	2.8	20.5	16.6	59.7
9. Television	4.3	12.7	36.0	7.6	39.5
10. Newspaper	6.9	8.6	18.6	4.7	61.2
B. Non-adopter *(n=1516)*					
1. Extension personnel	12.6	55.2	27.7	2.8	1.6
2. Neighbour (farmer)	17.5	44.9	32.7	2.7	2.2
3. Agriculture fair	0.2	0.9	14.1	15.8	69.0
4. Demonstration plot	0.2	1.4	13.7	9.2	75.6
5. Agril. book/booklets	0.2	0.9	8.0	3.7	87.1
6. Attend in the field day	--	0.2	0.3	1.6	97.9
7. Research institute visit	--	--	1.1	4.0	94.9
8. Radio	0.5	1.1	9.2	4.2	84.9
9. Television	1.9	3.9	22.9	5.9	65.4
10. Newspaper	3.9	2.0	9.6	4.1	80.4

Chapter IV

ADOPTION OF OILSEED TECHNOLOGY AT FARM LEVEL

Use of improved variety, appropriate input use, and timely operations are essential for achieving higher yield and economic benefit from any crop production. Therefore, it is important to know the existing level of production technology in terms of agronomic practices, time of operations, and input use. The existing level of technologies employed in oilseed production, their level of adoptions, and the factors influenced farmers to adopt improved variety of oilseeds are also discussed in the subsequent sections.

4.1 Adoption of Mustard Varieties

The farm level adoption of mustard varieties mostly depended on the dissemination process used by BARI in association with the DAE. BARI has developed and disseminated 16 improved rapeseed and mustard varieties to the farmers since 1976. It was found at household level that about 40% farmers adopted improved varieties of mustard and 60% adopted BARI old variety (Tori-7)[6]. Short duration and to some extent tolerant to biotic and abiotic stresses are the main characteristics that make Tori-7 popular to most of the farmers in the study areas. Among improved varieties, BARI Mustard-15 and BARI Mustard-9 were the most highly adopted varieties in the study areas. However, BAU Sampod, BARI Mustard-9 and BARI Mustard-15 were the highly adopted varieties in Dinajpur, Rajshahi, and Manikgonj district respectively (Table 4.1).

Table 4.1 Percent of adoption of different mustard varieties at household level

Variety	Manikgonj	Rajshahi	Dinajpur	All area
A. Improved	**40.0** (72)	**30.0** (54)	**50.5** (91)	**40.2** (217)
BARI Mustard-9	5.6 (10)	16.7 (30)	8.3 (15)	10.2 (55)
BARI Mustard -14	16.1 (29)	2.8 (5)	1.1 (2)	6.7 (36)
BARI Mustard -15	17.2 (31)	10.6 (19)	12.2 (22)	13.3 (72)
BARI Mustard -16	1.1 (2)	--	--	0.4 (2)
BAU Sampod	--	--	17.8 (32)	5.9 (32)
Indian Mustard	--	--	11.1 (20)	3.7 (20)
B. BARI old variety				
Tori-7	60.0 (108)	70.0 (126)	49.5 (89)	59.8 (323)
All varieties	100 (180)	100 (180)	100 (180)	100 (540)

Note: Figures in the parentheses are respondent farmers

Most of the respondent farmers were found to be very much enthusiastic towards BARI Mustard-14 & -15 varieties due to their short duration (80-85 days) and high yielding characteristics. But the rate of adoption of these two varieties was not satisfactory in the study areas mainly due to the unavailability of seed. However, the adoption rates of these two varieties may be higher in other mustard growing areas compared to study areas. Experienced farmers and extension personnel opined that the availability of seeds of short duration BINA

[6]Mustard varieties released by BARI before 1994 are treated as BARI old mustard varieties. A total of five mustard varieties were released before 1994 (see Table 1.1). Tori-7 is the most prominent and extensively cultivated old variety of mustard.

Dhan-7 (*T. Aman*), BARI Mustard-14, and BARI Mustard-15 could bring revolution in mustard cultivation in Bangladesh.

The national level data on area occupied by mustard further reveals that Tori-7 is the dominant mustard variety across the country which covered 65.8% mustard area in 2010-11. BARI released other improved mustard varieties covered 30% of total mustard area in 2010-11 which was higher than the previous two years. On the other hand, the area under Tori-7 variety in 2010-2011 was lower than the previous years. This trend indicates that the area under improved mustard varieties is gradually increasing and the area under BARI old variety (Tori-7) is decreasing over the year. The areas under two promising improved varieties, namely BARI Mustard-14 and BARI Mustard-15 were low due to scarcity of seed and low adoption. (Table 4.2).

Table 4.2 Area under different mustard varieties at national level (61 districts)

Variety	2010-2011		2009-2010		2008-2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
A. Improved	**1,30,445**	**30.0**	**1,15,041**	**29.4**	**1,00,582**	**23.9**
*BINA Mustard (3-6)	4,807	1.1	4,853	1.2	1,944	0.5
**BARI Mustard (2-13)	1,02,572	23.6	96,961	24.8	90,041	21.4
BARI Mustard-14	13,390	3.1	7,418	1.9	5,457	1.3
BARI Mustard-15	9,666	2.2	5,104	1.3	3,135	0.7
BARI Mustard-16	10	0.0	705	0.2	5	0.0
B. BARI old variety						
Tori-7	2,85,437	65.8	2,60,379	66.5	3,00,620	71.6
C. Local	18,017	4.2	15,957	4.1	18,803	4.5
All variety	4,33,899	100	3,91,377	100	4,20,005	100

Note: *BINA Mustard-3, -4, -5, and -6. ** BARI Mustard-2, -3, -4, -5, -6, -7, -8, -9, -10, -11, -12, and -13
Source: District level DAE Office, 2012; For details, see Appendix A-30

4.2 Adoption of Groundnut Varieties

BARI has developed 10 improved groundnut varieties since 1976. But the adoption scenario of these improved varieties is very gloomy. It is evident that more than 82% groundnut farmers cultivated BARI old groundnut variety (Dhaka No.-1)[7] and only 18% farmer cultivated improved varieties. The adoption status of improved varieties was found to be better at Pabna district compared to Noakhali and Tangail district (Table 4.3).

Although BARI has developed and released Dhaka No.-1 variety since 1976, currently it is being considered a popular local variety to the farmers in different names. The reasons behind this popularity are short duration (120-140 days), medium yielder and to some extent tolerant to insect and diseases. On the other side, the adoption rates of BARI Groundnut-5 & 6 are very gloomy in the study areas although these varieties require more or less same duration and give more yield than Dhaka No.-1 variety. The main reason of this low adoption is unavailability of seed and lack of knowledge about these varieties as mentioned by the respondent farmers.

[7] Groundnut varieties released by BARI before 1979 are treated as BARI old groundnut varieties. Two groundnut varieties were released before 1979 (see Table 1.3). Dhaka No.-1 is the most prominent and extensively cultivated old variety of groundnut.

Table 4.3 Percent of adoption of different groundnut varieties at household level

Variety	Noakhali	Pabna	Tangail	All areas
A. Improved	**8.3** (15)	**44.4** (80)	**--**	**17.6** (95)
BARI Groundnut-5	8.3 (15)	--	--	2.8 (15)
BARI Groundnut-6	--	12.8 (23)	--	4.3 (23)
Dhaka Goundnut-2	--	24.4 (44)	--	8.1 (44)
Indian Groundnut	--	7.2 (13)	--	2.4 (13)
B. BARI old variety				
Dhaka No.-1	61.1 (110)	32.8 (59)	17.2 (31)	37.0 (200)
C. Local	30.6 (55)	22.8 (41)	82.8 (149)	45.4 (245)
All variety	100 (180)	100 (180)	100 (180)	100 (540)

Note: Figures in the parentheses are respondent farmers

Groundnut is now cultivated at 46 districts of Bangladesh. The area under improved groundnut varieties also presents an unpleasant picture. In 2010-2011, only 9.46% groundnut areas was covered by improved varieties and the rest 90.54% was covered by BARI old variety (Dhaka No.-1) and other local varieties. The area under local variety is also much higher than that of improved varieties. However, the areas under improved varieties have gradually increased from 2008-2009 to 2010-2011 (Table 4.4). It also implies that groundnut farmers are becoming conscious about cultivating improved varieties.

Table 4.4 Area under different groundnut varieties at national level (46 districts)

Variety	2010-2011		2009-2010		2008-2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
A. BARI variety	**5,810**	**9.05**	**7,355**	**12.18**	**5,306**	**8.95**
*BARI Groundnut (5-9)	363	0.57	263	0.44	172	0.29
Basanti Badam	2,219	3.46	2,402	3.98	2,856	4.82
Jhingha Badam	2,221	3.45	3,861	6.39	1,543	2.60
DM-1 (Tridana)	1,007	1.57	829	1.37	735	1.24
B. BINA variety						
**BINA Groundnut (1-3)	262	0.41	78	0.13	64	0.11
C. BARI old variety						
Dhaka No.-1	48,866	76.12	42,221	69.90	47,083	79.49
D. Local variety						
Maizchar & local	9,254	14.42	10,745	17.79	6,781	11.45
Total	64,192	100	60,399	100	59,234	100

Note: *BARI Groundnut-5, -6, -7, -8, and -9; **BINA Groundnut-1, -2, and -3
Source: District level DAE Office, 2012; For details, see also Appendix A-31

4.3 Adoption of Sesame Varieties

BARI has developed four sesame varieties since 1976. Til-6 is one of the BARI developed varieties currently known as local variety among sesame farmers. The adoption of improved sesame varieties was found to be very low at farm level. This was true even in highly intensive sesame growing area Comilla. About 21.5% sesame farmers adopted improved varieties (BARI Sesame-3 & -4) and the rest 78.5% adopted BARI old sesame variety (Til-6)[8] and other local varieties (Table 4.5).

It was reported that Cereal System Initiative for South Asia (CSISA) project has played important role in disseminating improved sesame varieties in the study areas. Most of the sesame farmers do not know about BARI developed improved varieties in the study areas.

Table 4.5 Percent of adoption of different sesame varieties at household level

Variety	Comilla	Faridpur	Jessore	All area
A. Improved	**18.9** (34)	**5.5** (10)	**40.0** (72)	**21.5** (116)
BARI Sesame-3	18.9 (34)	--	29.4 (53)	16.1 (87)
BARI Sesame-4	--	5.5 (10)		1.9 (10)
BINA Sesame-1	--	--	10.6 (19)	3.5 (19)
B. BARI old variety				
Til-6	48.9 (88)	41.7 (75)	50.6 (91)	47.0 (254)
C. Local	32.2 (58)	52.8 (95)	9.4 (17)	31.5 (170)
All varieties	100 (180)	100 (180)	100 (180)	100 (540)

Note: Figures in the parentheses are respondent farmers

Sesame is now cultivated at 46 districts of Bangladesh. The scenario of sesame area covered by different varieties for three years (2008-2009 to 2010-2011) also presents an unpleasant picture in Bangladesh. Currently a vast area is covered by BARI old variety (Til-6) and other local varieties of sesame. Table 4.6 revealed that about 11.2% area was planted to improved sesame varieties in 2010-2011 which was less than the previous year and higher than the area planted in 2008-2009. Therefore, the area coverage picture indicates the need for strengthening current variety adoption efforts in Bangladesh.

Table 4.6 Area under different sesame varieties at national level (46 districts)

Variety	2010-2011		2009-2010		2008-2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
A. BARI improved	**5,686**	**11.2**	**6,460**	**12.5**	**3,019**	**6.4**
BARI Sesame-2	2,063	4.1	2,198	4.3	1,663	3.5
BARI Sesame-3	3,363	6.6	4,129	8.0	1,299	2.8
BARI Sesame-4	260	0.5	133	0.3	57	0.1
B. BARI old variety						
Til-6	37,932	75.1	36,544	70.9	36,263	77.1
C. Local variety						
All variety	50,522	100	51,551	100	47,019	100

Source: District level DAE Office, 2012

4.4 Adoption of Soybean Varieties

BARI has developed six soybean varieties since 1981. The name of first introduced soybean variety is Davis which is completely out of the field. It has no local variety at all. Most of the soybean farmers (84.4%) adopted BARI developed Sohag variety which was released in 1992

[8] Sesame variety released by BARI before 2001 is treated as BARI old sesame variety. Only one sesame variety was released before 2001 (see Table 1.4). T-6 is the most prominent and extensively cultivated old variety of sesame.

for farm level cultivation (Table 4.7). The adoptions of other BARI varieties were very low in the study areas which were due to lack of knowledge about the variety, lack of seed, and low extension efforts for its dissemination.

Table 4.7 Percent of adoption of different soybean varieties at household level

Variety	Laxmipur	Noakhali	All area
BARI Soyabean-5	3.3 (6)	13.9 (25)	8.6 (31)
BARI Soyabean-6	10.0 (18)	3.9 (7)	6.9 (25)
Sohag (BARI old variety)	86.7 (156)	82.2 (148)	84.4 (304)
All variety	100 (180)	100 (180)	100 (360)

Note: Figures in the parentheses are respondent farmers

Soybean cultivation is concentrated only in a few (8) districts of Bangladesh. Most of the soybean varieties are introduced and high yielder. It is seen from Table 4.8 that the lion share of soybean area (78.4%) was cultivated by Sohag variety in 2010-2011which was also an old released variety of BARI in 1992. The adoptions of other improved varieties namely BARI Soybean-5 & -6 which were released in 2001 and 2009 respectively were very low at farm level. However, an increasing trend is observed in the study areas under BARI Soybean-5 variety in Bangladesh.

Table 4.8 Area under different soybean varieties at national level (8 districts)

Variety	2010-2011		2009-2010		2008-2009	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Bangladesh Soybean-4	--	--	--	--	10	0.0
BARI Soybean-5	13,074	21.6	12,139	50.9	6,913	14.5
Brag	--	--	12	0.1	14	0.0
Sohag	47,394	78.4	11,699	49.1	40,856	85.5
All variety	60,468	100	23,850	100	47,793	100

Source: District level DAE Office, 2012

4.5 Crop Management Technologies and Their Adoption

The Oilseed Research Centre (ORC) of BARI and BINA have recommended different improved crop management practices on tillage operations, time and method of seed sowing, seed rate, irrigation, weed management, insect-pest control, and fertilization. The management practices are mostly recommended for both improved and local varieties of oilseeds. In some cases seed rate and fertilizer doses are different for improved and local varieties. However, different crop management technologies and their adoptions are discussed in the following sections.

4.5.1 Technology used in mustard cultivation

Land preparation includes ploughing, laddering and other operations needed to make the soil suitable for sowing seeds. The mustard farmers in the study areas ploughed their lands with the help of power tiller. The number of plowing and laddering varied from farm to farm and location to location. Only 18% mustard farmers provided recommended no. of ploughing (4-5 times). Most of them (77.2%) ploughed their lands 2-3 times which was below the recommendation. Therefore, land preparation had low level of adoption. The highest percentage of mustard farmers (96.7%) at Rajshahi district ploughed lands which was below the recommendation level (Table 4.9).

The recommended period of seed sowing is mid October to mid November. It is noted that 74.1% mustard farmers had sown seeds within recommended period and 25% farmers had sown seed within 1st & 2nd week of October. The highest percentages (98%) of farmers at Manikgonj district followed the recommended period of sowing. The time of seed sowing was mostly adopted because farmers found it convenient to sow it during the available range of time. Two types of sowing method were followed for mustard production. Most of the farmers (98%) followed broadcast method for sowing mustard seed which was recommended for it. The recommended seed rate for mustard is 6-7 kg/ha. About 86.1% respondent farmers used higher amount of seed than its recommendation (Table 4.9).

Two times irrigation, one is after 15-20 days of seed emergence and the other one is during flowering stage, is recommended for achieving higher productivity of mustard. Most of the sample farmers (72.8%) of Dinajpur district were found to irrigate their crop. About 97% farmers of Manikgonj district did not irrigate their crop because of rainfall that occurred in the early stage of production. The majority of mustard farmers (95.2%) did not weed their crop field. About 37% farmers used pesticides to control insects like aphid and cutworm. The highest number of farmers (58.9%) of Dinajpur district applied pesticides to control insects (Table 4.9).

Table 4.9 Percent of adoption of crop management technologies used in mustard cultivation

Technology	Manikgonj *(n= 180)*	Rajshahi *(n= 180)*	Dinajpur *(n= 180)*	All area *(n=540)*	Adoption level
Ploughing and laddering (No.)					
Recommended no. (4-5)	10.0 (18)	3.3 (6)	40.6 (73)	18.0 (97)	Low
Below recommendation (2-3)	90.0 (162)	96.7 (174)	45.0 (81)	77.2 (417)	
Above recommendation (>5)	--	--	14.4 (26)	4.8 (26)	
Seed sowing period					
*(Mid October-mid November)	98.3 (177)	90.0 (162)	33.9 (61)	74.1 (400)	High
Non-recommended period	1.7 (3)	10.0 (18)	66.1 (119)	25.9 (140)	
Seed sowing method					
Broadcasting	100.0 (180)	100.0 (180)	92.8 (167)	97.6 (527)	High
Line sowing	--	-	7.2 (13)	2.4 (13)	
Seed rate (kg/ha)					
Recommended rate (6-7)	13.3 (24)	5.6 (10)	10.6 (19)	9.8 (53)	Low
Below recommendation(1-5.4)	2.8 (5)	0.6 (1)	8.9 (16)	4.1 (22)	
Above recommendation (>7)	83.9 (151)	93.9 (169)	80.6 (145)	86.1 (465)	
No. of irrigation					
Recommended (2 times)	36.7 (66)	--	2.8 (5)	13.1 (71)	Low
Below recommendation	30.6 (55)	3.3 (6)	42.8 (77)	25.6 (138)	
Above recommendation	5.6 (10)	--	--	1.9 (10)	
Provide no irrigation	27.2 (49)	96.7 (174)	54.4 (98)	59.4 (321)	
No. of weeding					
Recommended (2 times)	--	--	--	--	Low
Below recommendation	10.6 (19)	3.9 (7)	--	4.8 (26)	
Above recommendation	--	--	--	--	
Provide no weeding	89.4 (161)	96.1 (173)	100 (180)	95.2 (514)	
Insect-pest control					
Do not use pesticides	73.9 (133)	75.0 (135)	41.1 (74)	63.3 (342)	--
Used pesticides	26.1 (47)	25.0 (45)	58.9 (106)	36.7 (198)	

Note: Figures in the parentheses indicate no. of farmers responded
*Indicate recommended period; Adoption level: 70-100% as high; 50-69% as medium; & <50% as low.

The recommended fertilizer doses are different for improved and Tori-7 variety mustard cultivation. The use of manure and fertilizers by sample farmers varied from location to location. Farmers' responses on the use of manure and fertilizer in improved and Tori-7 variety mustard cultivation are presented in Tables 4.10 and 4.11 respectively. The examination of these two tables reveals that mustard farmers often do not follow the recommendations for applying fertilizers. They tended to either use fertilizers in excess or in very small quantities. Almost all the respondent farmers applied urea, TSP, MoP, gypsum, and boric acid in lower quantity compared to recommended doses. Only zinc oxide was applied in excess quantity than its recommended dose. However, the levels of adoption of using manure and fertilizers were found to be low as they did not use recommended dose.

Table 4.10 Percent of adopters used manure and fertilizer in mustard cultivation

Particular	Manikgonj *(n=72)*	Rajshahi *(n=54)*	Dinajpur *(n=91)*	All area *(n=217)*	Adoption level
Cowdung (ton/ha)					
*8-10 ton/ha	13.2 (12)	1.4 (1)	3.7 (2)	6.9 (15)	Low
Below recommendation	38.5 (35)	16.7 (12)	37.4 (34)	37.3 (81)	
Above recommendation	26.4 (24)	--	--	11.1 (24)	
Non-users	1.4 (1)	75.9 (41)	60.4 (55)	44.7 (97)	
Urea (kg/ha)					
*250-300 kg/ha	7.0 (5)	--	2.1 (2)	3.2 (7)	Low
Below recommendation	86.1 (62)	98.1 (53)	90.1 (82)	90.8 (197)	
Above recommendation	7.0 (5)	1.8 (1)	5.4 (5)	5.1 (11)	
Non-users	--	--	2.2 (2)	0.9 (2)	
TSP (kg/ha)					
*170-180 kg/ha	4.2 (3)	--	1.1 (1)	1.8 (4)	Low
Below recommendation	41.7 (30)	42.6 (23)	61.5 (56)	50.2 (109)	
Above recommendation	34.7 (25)		18.7 (17)	19.3 (42)	
Non-users	19.4 (14)	57.4 (31)	18.7 (17)	28.6 (62)	
MoP (kg/ha)					
*85-100 kg/ha	5.6 (4)	5.5 (3)	19.8 (18)	11.5 (25)	Low
Below recommendation	37.5 (27)	66.7 (36)	40.7 (37)	46.1 (100)	
Above recommendation	12.5 (9)	9.3 (5)	39.6 (36)	23.0 (50)	
Non-users	44.4 (32)	18.5 (10)	--	19.4 (42)	
Gypsum (kg/ha)					
*150-180 kg/ha	--	5.6 (3)	4.3 (4)	2.8 (7)	Low
Below recommendation	33.3 (24)	35.2 (19)	29.7 (27)	32.3 (70)	
Above recommendation	6.9 (5)	3.7 (2)	8.8 (8)	6.9 (15)	
Non-users	59.7 (43)	55.6 (30)	57.1 (52)	57.6 (125)	
Zinc (kg/ha)					
*5-7 kg/ha	4.2 (3)	1.8 (1)	1.1 (1)	2.3 (5)	Low
Below recommendation	1.4 (1)	--	5.4 (5)	2.8 (6)	
Above recommendation	5.6 (4)	5.6 (3)	26.4 (24)	14.3 (31)	
Non-users	88.9 (64)	92.6 (50)	67.0 (61)	80.6 (175)	
Boron (kg/ha)					
*10-15 kg/ha	5.6 (4)	1.8 (1)	9.9 (9)	6.5 (14)	Low
Below recommendation	8.3 (6)	9.3 (5)	16.4 (15)	12.0 (26)	
Above recommendation	1.4 (1)	5.6 (3)	3.3 (3)	3.2 (7)	
Non-users	84.7 (61)	83.3 (45)	70.3 (64)	78.3 (170)	

Note: Figures in the parentheses indicate no. of farmers responded
*Recommended dose; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

Table 4.11 Percent of non-adopters used manure and fertilizer in mustard cultivation

Particular	Manikgonj *(n=108)*	Rajshahi *(n=126)*	Dinajpur *(n=89)*	All area *(n=323)*	Adoption level
Cowdung (ton/ha)					
*8-10 ton/ha	18.5 (20)	0.8 (1)	1.1 (1)	6.8 (22)	Low
Below recommendation	41.7 (45)	7.9 (10)	91.0 (81)	42.1 (136)	
Above recommendation	38.0 (41)	--	--	12.7 (41)	
Non-users	1.9 (2)	91.3 (115)	7.9 (7)	38.4 (124)	
Urea (kg/ha)					
*200-250 kg/ha	36.9 (43)	4.0 (5)	7.9 (7)	17.0 (55)	Low
Below recommendation	46.3 (50)	93.7 (118)	89.9 (80)	76.8 (248)	
Above recommendation	13.8 (15)	1.5 (2)	1.1 (1)	5.6 (18)	
Non-users	--	0.8 (1)	1.1 (1)	0.6 (2)	
TSP (kg/ha)					
*150-170 kg/ha	7.4 (8)	0.8 (1)	3.4 (3)	3.7 (12)	Low
Below recommendation	50.9 (55)	34.1 (43)	78.7 (70)	52.0 (168)	
Above recommendation	23.1 (25)	1.6 (2)	12.4 (11)	11.8 (38)	
Non-users	18.5 (20)	63.5 (80)	5.6 (5)	32.5 (105)	
MoP (kg/ha)					
*70-85 kg/ha	30.6 (33)	19.8 (25)	12.4 (11)	21.4 (69)	Low
Below recommendation	38.9 (42)	44.4 (56)	31.5 (28)	39.0 (126)	
Above recommendation	21.3 (23)	6.3 (8)	46.1 (41)	22.3 (72)	
Non-users	9.3 (10)	29.4 (37)	10.1 (9)	17.3 (56)	
Gypsum (kg/ha)					
*120-150 kg/ha	4.6 (5)	6.4 (8)	1.1 (1)	4.3 (14)	Low
Below recommendation	25.0 (27)	2.4 (3)	1.1 (1)	9.6 (31)	
Above recommendation	11.1(12)	7.9 (10)	2.2 (2)	7.4 (24)	
Non-users	59.3 (64)	83.3 (105)	95.5 (85)	78.6 (254)	
Zinc (kg/ha)					
*5-7 kg/ha	--	--	--	--	Low
Below recommendation	--	0.8 (1)	4.5 (4)	1.5 (5)	
Above recommendation	11.1 (12)	13.5 (17)	27.0 (24)	16.4 (53)	
Non-users	88.9 (96)	85.7 (108)	68.5 (61)	82.1 (265)	
Boron (kg/ha)					
*10-15 kg/ha	5.6 (6)	3.2 (4)	6.7 (6)	5.0 (16)	Low
Below recommendation	5.6 (6)	7.1 (9)	20.2 (18)	10.2 (33)	
Above recommendation	2.8 (3)	3.2 (4)	2.2 (2)	2.8 (9)	
Non-users	86.1 (93)	86.1 (109)	70.8 (63)	82.0 (265)	

Note: Figures in the parentheses indicate no. of farmers responded
*Recommended dose; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

4.5.2 Technology used in groundnut cultivation

The groundnut farmers in the study areas ploughed their lands with the help of power tiller. On an average, 59.1% groundnut farmers ploughed their land 4-5 times. The highest percentage (87.8%) of the Noakhali farmer ploughed their lands 4-5 times which is recommended for groundnut cultivation. Ploughing of land was medium level in groundnut cultivation.

Groundnut sowing started from the mid week of November and continued up to middle of January. The highest percentage (68%) of farmers had sown seeds during the first week of December to the last week of December. Majority of the farmers of Tangail district (95.6%)

had sown groundnut seeds during the recommended time span. The time of seed sowing was found at higher level of adoption. Almost all the farmers in the study areas followed line sowing method of sowing groundnut which is recommended for it. The recommended seed rate is 95 to 110 kg/ha. About half of the responded farmers used lower amount of seed and 38.9% used higher amount than its recommendation. Weeding was done mainly by utilizing human labour. More than 57% farmers performed weeding. Most of them did not use pesticides. Nearly 86% farmers did not apply pesticides to control insects. So, the study reveals that use of seed, irrigation, and weeding had low levels of adoption (Table 4.12).

Table 4.12 Percent of adoption of crop management technologies used in groundnut cultivation

Technology	Noakhali (n= 180)	Pabna (n= 180)	Tangail (n= 180)	All area (n= 540)	Adoption level
Plowing and laddering (No.)					
Recommended (4-5)	87.8 (158)	79.4 (143)	10.0 (18)	59.1 (319)	Medium
Below recommendation (2-3)	9.4 (17)	7.2 (13)	58.3 (105)	25.0 (135)	
Above recommendation (>5)	2.8 (5)	13.3 (24)	--	5.4 (29)	
Non-users	--	--	31.7 (57)	10.6 (57)	
Seed sowing time					
*Mid October-mid November		0.6 (1)	95.6 (172)	32.0 (173)	Low
Above recommendation	100 (180)	99.4 (179)	4.4 (8)	68.0 (367)	
Seed sowing method					
Broadcasting			2.8(5)	1.0 (5)	
*Line sowing	100 (180)	100.0 (180)	97.2 (175)	99.0 (535)	High
Seed rate (kg/ha)					
Recommended (95-110)	13.3 (24)	13.3 (24)	7.8 (14)	11.5 (62)	Low
Below recommendation (<95)	34.4 (62)	52.8 (95)	61.7 (111)	49.6 (268)	
Above recommendation (>110)	52.2 (94)	33.9 (61)	30.6 (55)	38.9 (210)	
Irrigation provide					
Not provided	96.1 (173)	95.0 (171)	91.7 (165)	94.3 (509)	
Provided	3.9 (7)	5.0 (9)	8.3 (15)	5.7 (31)	Low
Wedding					
Recommended (2 times)	4.4 (8)	8.9 (16)	2.8 (5)	5.4 (29)	Low
Below	63.3 (114)	60.6 (109)	15.6 (28)	46.5 (251)	
Above	10.6 (19)	3.3 (6)	2.2 (4)	5.4 (29)	
Not provided	21.7 (39)	27.2 (49)	79.4 (143)	42.8 (231)	Low
Insect-pest control					
Do not use pesticides	82.2 (148)	83.3 (150)	91.7 (165)	85.7 (463)	--
Used pesticides	17.8 (32)	16.7 (30)	8.3 (15)	14.3 (77)	

Note: Figures in the parentheses indicate no. of farmers responded
*Recommended dose; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

It is found from Table 4.13 that most of farmers often do not follow the recommendations during the application of fertilizers. They often either use fertilizers in excess or in very small quantities. Sometimes they do not use many fertilizers that are recommended for cultivation. In groundnut cultivation, majority of the respondent farmers did not apply TSP, DAP and gypsum. Again, most of them applied urea fertilizer in excess quantity and MoP fertilizer in lower quantity compared to their recommended doses. The lower adoption was mostly observed in fertilizer application.

Table 4.13 Percent of farmers used manure and fertilizer in groundnut cultivation

Particular	Noakhali *(n= 180)*	Pabna *(n= 180)*	Tangail *(n= 180)*	All area *(n= 540)*	Adoption level
Cowdung*					
Applied	6.7 (12)	--	--	2.2 (12)	--
Not applied	93.3 (168)	100 (180)	100 (180)	97.8 (528)	
Urea (kg/ha)					
Recommended (20-30)	8.3 (15)	2.8 (5)	2.8 (5)	4.6 (25)	Low
Below recommendation	0.6 (1)	1.1 (2)	1.7 (3)	1.1 (6)	
Above recommendation	45.6 (82)	59.4 (107)	41.1 (74)	48.7 (263)	
Not applied	45.6 (82)	36.7 (66)	54.4 (98)	45.6 (246)	Low
TSP (kg/ha)					
Recommended (150-170)	--	--	--	--	
Below recommendation	80.0 (144)	38.3 (69)	11.7 (21)	43.3 (234)	Low
Not applied	20.0 (36)	61.7 (111)	88.3 (159)	56.7 (306)	
MoP (kg/ha)					
Recommended (80-90)	3.3 (6)	1.7 (3)	--	1.7 (9)	Low
Below recommendation	45.6 (82)	34.4 (62)	10.0 (18)	30.0 (162)	
Above recommendation	5.6 (10)	3.9 (7)		3.1 (17)	
Not applied	45.6 (82)	60.0 (108)	90 (162)	65.2 (352)	
DAP*					
Applied	1.1 (2)	6.1 (11)	3.9 (7)	3.7 (20)	--
Not applied	98.9 (178)	93.9 (169)	96.1 (173)	96.3 (520)	
Gypsum (kg/ha)					
Recommended (160-180)	--	--	--	--	
Below recommendation	10.6 (19)	5.6 (10)	1.1 (2)	5.7 (31)	Low
Not applied					

Note: Figures in the parentheses indicate no. of farmers responded
*No recommended dose; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

4.5.3 Technology used in sesame cultivation

The existing levels of technology employed in the production of sesame are presented in Table 4.14. The sesame farmers ploughed their lands with the help of power tiller. Forty six percent farmers followed recommendation in ploughing their lands. All farmers followed broadcast method for sowing sesame seed. It was started from mid January and continued up to mid April. The time of seed sowing was highly adopted (96.5%) because farmers found it convenient to sow during the available range of time. The recommended seed rate for sesame is 7 to 7.5 kg/ha. But most of the farmers used either lower or higher amount of seed than the recommended rate. Majority of the sample farmers (61.5%) did not irrigate their crop, but most of them (96.9%) weeded their crop. Like irrigation, 62% sesame farmers did not use any pesticide to control insects. Therefore, the higher level of adoption was found in seed sowing period and method, whereas land preparation, seed rate, irrigation and weeding had low levels of adoption.

Table 4.14 Percent of adoption of crop management technologies used in sesame cultivation

Technology	Jessore *(n=180)*	Faridpur *(n=180)*	Comilla *(n=180)*	All area *(n=540)*	Adoption level
Plowing and laddering					
Recommended (4-5)	11.5 (62)	12.4 (67)	22.0 (119)	46.0 (248)	Low
Below recommendation (1-3)	65.6 (118)	61.7 (111)	32.8 (59)	53.3 (288)	
Above recommendation (>5)	--	1.1 (2)	1.1 (2)	0.7 (4)	
Seed sowing time					
*Mid February-mid April	91.7 (165)	98.3 (177)	100 (180)	96.5 (521)	High
Before recommendation	8.3 (15)	1.7 (3)	--	3.5 (19)	
Seed sowing method					
Line sowing	--	--	--	--	
*Broadcasting	100 (180)	100 (180)	100 (180)	100 (540)	High
Seed rate (kg/ha)					
Recommended (7-7.5)	38.9 (70)	26.7 (48)	16.7 (30)	27.4 (148)	Low
Below recommendation	45.6 (82)	55.6 (100)	11.1 (20)	37.4 (202)	
Above recommendation	15.6 (28)	17.8 (32)	72.2 (130)	35.2 (190)	
Irrigation provide					
Recommended (2 times)	5.0 (9)	8.3 (15)	32.2 (58)	15.2 (82)	Low
Below recommendation	10.0 (18)	18.3 (33)	36.7 (66)	21.7 (117)	
Above recommendation	0.6 (1)	0.6 (1)	1.7 (3)	0.9 (5)	
Not provided	84.4 (152)	72.8 (131)	29.4 (53)	62.2 (336)	
Weeding					
Recommended (2 times)	61.1 (110)	15.0 (27)	51.7 (93)	42.6 (230)	Low
Below recommendation	11.7 (21)	75.0 (135)	43.9 (79)	43.5 (235)	
Above recommendation	27.2 (49)	1.7 (3)	3.3 (6)	10.7 (58)	
Not weeded	--	8.3 (15)	1.1 (2)	3.1 (17)	
Insect-pest control					
Do not use pesticides	61.7 (111)	91.1 (164)	33.3 (60)	62.0 (335)	--
Used pesticides	38.3 (69)	8.9 (16)	66.7 (120)	38.0 (205)	

Note: Figures in the parentheses indicate no. of farmers responded
*Recommendation; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

Table 4.15 contains the percent responses of the oilseed farmers regarding manure and pesticide use. It was found that sesame farmers often did not follow recommendations for applying fertilizers. Most of them applied urea and TSP in lower quantity compared to their recommended doses. In the case of MoP application, more than 29% farmers used higher amounts compared to recommendation. Majority of the sesame farmers did not apply gypsum and DAP fertilizers.

Table 4.15 Percent of farmers used manure and fertilizer in sesame cultivation

Particular	Jessore *(n=180)*	Faridpur *(n=180)*	Comilla *(n=180)*	All area *(n=540)*	Adoption level
***Cowdung**					
Applied	36.7 (66)	2.2 (4)	10.6 (19)	16.5 (89)	
Not applied	63.3(114)	97.8 (176)	89.4 (161)	83.5 (451)	
Urea (kg/ha)					
Recommended (100-150)	22.8 (41)	5.6 (10)	20.0 (36)	16.1 (87)	Low
Below recommendation	63.3 (114)	40.0 (72)	58.3 (105)	53.9 (291)	
Above recommendation	4.4 (8)	0.6 (1)	12.2 (22)	5.7 (31)	
Non-users	9.4 (17)	53.9 (97)	9.4 (17)	24.3 (131)	
TSP (kg/ha)					
Recommended (130-150)	9.4 (17)	2.2 (4)	2.8 (5)	4.8 (26)	Low
Below recommendation	71.1 (128)	30.0 (54)	47.8 (86)	49.6 (268)	
Above recommendation	4.4 (8)	0.6 (1)	6.1 (11)	3.7 (20)	
Non-users	15.0 (27)	67.2 (121)	43.3 (78)	41.9 (226)	
MoP (kg/ha)					
Recommended (40-50)	11.7 (21)	3.3 (6)	5.6 (10)	6.9 (37)	Low
Below recommendation	12.8 (23)	10.6 (19)	4.4 (8)	9.3 (50)	
Above recommendation	48.9 (88)	11.1 (20)	27.2 (49)	29.1 (157)	
Non-users	26.7 (48)	75.0 (135)	62.8 (113)	54.8 (296)	
Gypsum (kg/ha)					
Recommended (100-110)	--	--	--	--	Low
Below recommendation	12.2 (22)	0.6 (1)	11.1 (20)	8.0 (43)	
Non-users	87.8 (158)	99.4 (179)	88.9 (160)	92.0 (497)	
***DAP**					
Applied	2.2 (4)	12.8 (23)	0.6 (1)	5.2 (28)	--
Not applied	97.8 (176)	87.2 (157)	99.4 (179)	58.3 (315)	

Note: Figures in the parentheses indicate no. of farmers responded
*No recommendation; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

4.5.4 Technology used in soybean cultivation

About 92% soybean farmers ploughed their lands 2-3 times that are much below the recommended number of ploughing. The time of seed sowing had moderate adoption because farmers planted soybean during the available range of time (mid December to mid January). Majority of the soybean farmers followed line sowing method for sowing soybean seeds which is recommended for it. The level of adoption of seed rate was found to be very low as because 67.5% farmers used higher amount of seed rather than its recommendation. The highest percentage (63.6%) of soybean farmers used pesticides to control insects and diseases. Generally farmers do not provide irrigation to their soybean crop (Table 4.16).

Only 15.6% farmers applied cowdung as manure in the study areas. They often have tendency not to follow the recommended dose of fertilizers application. They either used fertilizers in excess or in very small quantities. Therefore, the adoption picture of fertilizer application was opined to be very unpleasant in the study areas (Table 4.17).

Table 4.16 Percent of adoption of crop management technologies used in soybean cultivation

Technology	Laxmipur *(n= 180)*	Noakhali *(n= 180)*	All area *(n=360)*	Adoption level
Plowing and laddering (No.)				
Recommended (4-5)	1.7 (3)	14.4 (26)	8.1 (29)	Low
Below recommendation (2-3)	98.3 (177)	85.6 (154)	91.9 (331)	
Seed sowing time				
*Mid December - mid January	33.3 (60)	44.4 (80)	38.9 (140)	Low
Above	66.7 (120)	55.6 (100)	61.1 (220)	
Seed sowing method				
*Line	28.9 (52)	88.3 (159)	58.6 (211)	Medium
Broadcasting	71.1 (128)	11.7 (21)	41.4 (149)	
Seed rate (kg/ha)				
Recommended (50-60)	12.2 (22)	14.4 (26)	13.3 (48)	Low
Below recommendation (<50)	15.6 (28)	22.8 (41)	19.2 (69)	
Above recommendation (>60)	72.2 (130)	62.8 (113)	67.5 (243)	
Irrigation provide				
Recommended (2 time)	--	--	--	
Below recommendation	5.6 (10)	1.1 (2)	3.3 (12)	Low
Wedding				
Recommended (1 time)	43.9 (79)	32.8 (59)	38.3 (138)	Low
Above recommendation	32.8 (59)	47.2 (85)	40.0 (144)	
Insect-pest control				
Do not use pesticides	31.1 (56)	41.7 (75)	36.4 (131)	--
Used pesticides	68.9 (124)	58.3 (105)	63.6 (229)	

Note: Figures in the parentheses indicate no. of farmers responded
*Recommendation; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

Table 4.17 Percent of farmers used manure and fertilizer in soybean cultivation

Particular	Laxmipur *(n= 180)*	Noakhali *(n= 180)*	All area *(n=360)*	Adoption level
***Cowdung**				
Not applied	85.6 (154)	83.3 (150)	34.4 (124)	--
Applied	14.4 (26)	16.7 (30)	15.6 (56)	
Urea (kg/ha)				
Recommended (50-60)	7.8 (14)	6.7 (12)	7.2 (26)	Low
Below recommendation	24.4 (44)	32.8 (59)	28.6 (103)	
Above recommendation	51.1 (92)	45.6 (82)	48.3 (174)	
TSP (kg/ha)				
Recommended (150-170)	1.7 (3)	--	0.8 (3)	Low
Below recommendation	79.4 (143)	83.3 (150)	81.4 (293)	
MoP (kg/ha)				
Recommended (100-120)	2.8 (5)	2.2 (4)	2.5 (9)	Low
Below recommendation	42.8 (77)	43.9 (79)	43.3 (156)	
Gypsum (kg/ha)				
Recommended (80-115)	0.6 (1)	0.6 (1)	0.6 (2)	Low
Below recommendation	10.0 (18)	9.4 (17)	9.7 (35)	
***DAP**				
Not applied	96.1 (173)	95.6 (172)	45.8 (165)	--
Applied	3.9 (7)	4.4 (8)	4.2 (15)	

Note: Figures in the parentheses indicate no. of farmers responded
*No recommendation; Adoption level: 70-100% as high; 50-69% as medium; and <50% as low.

4.6 Determinants of Adoption of Improved Oilseed Varieties

The adoption of BARI released mustard varieties was likely to be influenced by different socio-economic factors. Table 4.18 shows that farm size, family labor, training on oilseed, influence of neighbouring farmers, influence of SAAO, cosmopoliteness, and extension contract had positive and significant influence on the adoption of improved mustard varieties in the study areas.

Table 4.18 Maximum likelihood estimates of variable determining adoption of improved mustard varieties among respondent farmers

Explanatory variable	Coefficient	Standard Error	z-statistic	Probability
Constant	-3.70295***	0.413278	-8.96	0.000
Farm size (decimal)	0.00045*	0.000252	1.80	0.072
Family labour (No./ha)	0.02763***	0.004501	6.14	0.000
Training on oilseed (No./life time)	0.09835	0.120697	0.81	0.415
Availability of improved seed (Score) (Scale,0-4; 0= not available, 4= plenty)	0.36302***	0.090219	4.02	0.000
Influence of neighbor (Score) (Scale,0-4; 0= no influence, 4= high influence)	0.07377	0.074082	1.00	0.319
Influence of SAAO (Score) (Scale,0-4; 0= no influence, 4= high influence)	0.40150***	0.069972	5.74	0.000
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	0.13839**	0.060797	2.28	0.023
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular contact)	0.03230**	0.015038	2.15	0.032

Note: Dependent variable = Improve variety adoption (Adopter = 1, Non-adopter = 0)
No. of observation = 537; LR chi-square (8) = 321.6; Log likelihood = -190.47736;
'***' '**' & '*' represent significant at 1%, 5% and 10% level respectively
Higher score value represents the higher probability of improved variety adoption

Marginal coefficient indicate that if farm size increased by 100% the probability of adopting improved mustard varieties increased at 0.017%. Again, if the number of family labor increased by 100% the probability of adopting improved mustard varieties would increase by 1.01%. The coefficients of seed availability, influences of SAAO, cosmopolitness, and extension contract are positive and significant. If these variables were increased by 100% the probability of adopting improved mustard varieties would be increased by 13.26%, 14.67%, 5.06% and 1.18% respectively (Table 4.19).

Table 4.19 Marginal effect of the variables determining adoption of improved mustard varieties among respondent farmers

Explanatory variable	Dy/dx	Standard Error	z-statistic	Probability
Farm size (decimal)	0.000165*	0.00009	1.80	0.071
Family labor (No./ha)	0.010094***	0.00167	6.04	0.000
Training on oilseed (No.)	0.035930	0.04414	0.81	0.416
Availability of HYV seed (Score)	0.132622***	0.03307	4.01	0.000
Influences of neighbor (Score)	0.026949	0.02699	1.00	0.318
Influences of SAAO (Score)	0.146682***	0.02669	5.50	0.000
Farmers' cosmopolitness (Score)	0.050557**	0.02218	2.28	0.023
Extension contract (Score)	0.011799**	0.00551	2.14	0.032

Note: '***' '**' & '*' represent significant at 1%, 5% and 10% level respectively

Table 4.20 shows that age and education of the farmer, availability of family labour, availability of improved groundnut seed, societal membership, cosmopolitness, and farmers' extension contract significantly influenced farmers to adopt improved groundnut varieties in the study areas.

The coefficient of age, education, family labour, availability of improved seed, societal membership, cosmopolitness, and extension contract are positive and significant. It implies that if these factors increased 100% the probability of adopting improved groundnut varieties would be increased by 0.15%, 0.69%, 0.13%, 17.54%, 8.25%, 5.95%, and 0.42% respectively (Table 4.21).

Table 4.20 Maximum likelihood estimates of variables determining adoption of improved groundnut varieties among respondent farmers

Explanatory variable	Coefficients	Standard Error	z-statistic	Probability
Constant	-8.099265***	0.813418	-9.96	0.000
Age (year)	0.014694**	0.006549	2.24	0.025
Education (Year of schooling)	0. 066531***	0.024671	2.70	0.007
Farm size (decimal)	0.000033	0.000239	0.14	0.890
Family labour (No./ha)	0.010857**	0.005092	2.13	0.033
Availability of improved seed (Score) (Scale,0-4; 0= not available, 4= plenty)	1.679903***	0.221698	7.58	0.000
Societal membership (wt. score) (Scale,0-3; 0= no membership , 3= executive)	0.174726**	0.077359	2.26	0.024
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	0.569352***	0.093161	6.11	0.000
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular)	0.040089**	0.019706	2.03	0.042

Note: Dependent variable = Improve variety adoption (Adopter = 1, Non-adopter = 0)
No. of observation = 540; LR chi-square (8) = 265.82; Log likelihood = -118.2775;
Pseudo R^2 = 0.529; '***' & '**' represent significant at 1% and 5% level respectively

Table 4.21 Marginal effect of the variables determining adoption of improved groundnut varieties among respondent farmers

Explanatory variable	Dy/dx	Standard Error	z-statistic	Probability
Age (year)	0.001535**	0.813418	2.21	0.027
Education (Year of schooling)	0.006948**	0.006549	2.56	0.011
Farm size (decimal)	0.000003	0.024671	0.14	0.890
Family labour (No./ha)	0.001309***	0.005092	2.01	0.045
Availability of improved seed (Score)	0.175446***	0.221698	5.75	0.000
Societal membership (Score)	0.082481**	0.077359	2.13	0.034
Cosmopolitness (Score)	0.059462***	0.093161	4.76	0.000
Extension contract (Score)	0.004187**	0.019706	1.93	0.054

Note: '***' &'**' represent significant at 1% and 5% level respectively

It is depicted from Table 4.22 that availability of family labour, availability of improved seed, cosmopolitness of the farmer, and contract with different extension sources had positive impact on the adoption of improved sesame varieties in the study areas.

The coefficients of family labour, availability of improved seed, cosmopolitness, and extension contract are positive and significant which imply that if these factors will increase 100% the probability of adopting improved sesame varieties would be increased by 0.01, 2.52, 0.63, and 0.09% respectively (Table 4.23).

Table 4.22 Maximum likelihood estimates of variable determining adoption of improved sesame varieties among respondent farmers

Explanatory variable	Coefficients	Standard Error	z-statistic	Probability
Constant	-14.77490***	2.521081	-5.86	0.000
Farm size (No./ha)	0.00008	0.000610	0.14	0.892
Family labor (No./family)	0.02023**	0.009209	2.20	0.028
Education (Year of schooling)	0.03110	0.036791	0.85	0.398
Training on agriculture (No./life time)	0.09891	0.121648	0.81	0.416
Training on oilseed (No./life time)	0.35446	0.660211	0.54	0.591
Availability of improved seed (Score) (Scale,0-4; 0= not available, 4= plenty)	4.87835***	0.932545	5.23	0.000
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	1.22388***	0.253079	4.84	0.000
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular)	0.16748***	0.057145	2.93	0.003

Note: Dependent variable = Improve variety adoption (Adopter = 1, Non-adopter = 0)
No. of observation = 540; LR chi-square (8) = 446.05; Log likelihood = -57.920995;
'***' and '**' represent significant at 1%, 5% and 10% level respectively

Table 4.23 Marginal effect of the variables determining adoption of improved sesame varieties among respondent farmers

Explanatory variable	Dy/dx	Standard Error	z-statistic	Probability
Farm size (No./ha)	0.0000428	0.00000	0.14	0.892
Family labor (No./family)	0.0001046	0.00015	0.69	0.493
Education (Year of schooling)	0.0001607	0.00026	0.61	0.539
Training on agriculture (Score)	0.0005112	0.00082	0.63	0.531
Training on oilseed (Score)	0.0018319	0.00431	0.42	0.671
Availability of improved seed (Score)	0.0252113	0.03182	0.79	0.428
Cosmopolitness (Score)	0.0063250	0.00821	0.77	0.441
Extension contract (Score)	0.0008655	0.00123	0.71	0.480

Different factors influence the adoption of BARI released improved soybean in the study areas. These variables were farm size, education, training on agriculture; training on oilseed, availability of BARI released seed, societal membership, cosmopolitness, and extension contract (Table 4.24).

The marginal coefficient of farm size is negatively significant at 1% level implying that higher the farm sizes lower the probability of adoption of improved BARI soybean variety in the study areas. The coefficients of other variables such as education, training on agriculture, training on oilseed, availability of BARI improved seed, cosmopolitness, and extension contract are positive and significant. It indicates that increase in any of the variable results in the increase of the probability of adopting BARI released soybean varieties in the study areas (Table 4.25).

Table 4.24 Maximum likelihood estimates of variable determining adoption of BARI released soybean variety among respondent farmers

Explanatory variable	Coefficient	Standard Error	z-statistic	Probability
Constant	-10.17920***	1.681248	-6.05	0.000
Farm size (decimal)	-0.00209***	0.000714	-2.93	0.003
Family labour (No./ha)	0.01465	0.009818	1.49	0.136
Education (year of schooling)	0.10575**	0.043881	2.41	0.016
Training on agriculture (No./life time)	0.19415**	0.097725	1.99	0.047
Training on oilseed (No./life time)	0.44895***	0.179981	2.49	0.013
Availability of improved seed (Score) (Scale,0-4; 0= not available, 4= plenty)	1.51910***	0.303193	5.01	0.000
Societal membership (wt. score) (Scale,0-3; 0= no membership , 3= executive)	0.21254**	0.102794	2.07	0.039
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	0.71278***	0.17558	4.06	0.000
Extension contract (wt. score) (Scale,0-4; 0= no contact, 4= regular contact)	0.14628***	0.042783	3.42	0.001

Note: Dependent variable = Improve variety adoption (Adopter = 1, Non-adopter = 0)
No. of observation =360; LR chi-square (8) = 223.88; Log likelihood= -43.659921;
'***' & '**' represent significant at 1% and 5% level respectively

Table 4.25 Marginal effect of the variables determining adoption of BARI released soybean varieties among respondent farmers

Explanatory variable	Dy/dx	Standard Error	z-statistic	Probability
Farm size (decimal)	-0.0000009	0.00001	-0.76	0.449
Family labour (No./ha)	0.0000624	0.00009	0.71	0.480
Education (year of schooling)	0.0004504	0.00060	0.75	0.454
Training on agriculture (No.)	0.0008269	0.00116	0.71	0.477
Training on oilseed (No.)	0.0019121	0.00247	0.77	0.439
Availability of BARI soybean seed	0.0064698	0.00797	0.81	0.417
Societal membership (Score)	0.0009052	0.00125	0.73	0.467
Cosmopolitness (Score)	0.0030357	0.00394	0.77	0.441
Extension contract (Score)	0.0006230	0.00082	0.76	0.447

It may be concluded that the levels of adoptions of improved oilseed varieties and crop management technologies at farm level are very poor. Majority of the respondent farmers use BARI old varieties along with other local varieties of oilseeds. The total oilseed area scenario at national level also shows the gloomy picture of improved variety adoption. Among mustard varieties, many farmers are found to be very much enthusiastic towards BARIMustard-14 and -15 varieties due to their short duration and high yielding characteristics. But, oilseed farmers in general are not found enthusiastic towards other improved varieties of groundnut, sesame, and soybean in the study areas.

Different socioeconomic factors have influenced farmers to cultivate improved varieties of oilseeds. The common factors that significantly influence oilseed farmers to adopt improved varieties of oilseeds are availability of improved seed, cosmopolitness, and extension contact.

The availability of family labour is also an important factor which has positive and significant impact on improved variety adoption (Table 4.26).

Table 4.26 Marginal effects of the variables determining adoption of improved oilseed varieties among respondent farmers

Explanatory variable	Mustard	Groundnut	Sesame	Soybean
Age (year)	--	0.001535**	--	--
Education (year of schooling)	--	0.006948**	0.0001607	0.0004504**
Farm size (decimal)	0.000165*	0.0000034	0.0000428	--
Family labour (No./ha)	0.010094***	0.001309***	0.0001046**	0.0000624
Training on oilseed (No.)	0.035930	--	0.0018319	0.0019121
Training on agriculture (No.)	--	--	0.0005112	0.0008269**
Availability of improved seed	0.132622***	0.175446***	0.0252113***	0.0064698***
Influences of neighbor (Score)	0.026949	--	--	--
Influences of SAAO (Score)	0.146682***	--	--	--
Farmers’ cosmopolitness	0.050557**	0.059462***	0.0063250***	0.0030357***
Extension contract (Score)	0.011799**	0.0041869**	0.0008655***	0.0006230***
Societal membership (Score)	--	0.082481**	--	0.0009052

Chapter V

PROFITABILITY AND COMPARATIVE ADVANTAGE OF OILSEED CULTIVATION

5.1 Introduction

The aim of analyzing costs and returns is to determine the amount of profit a producer is making from a particular commodity production within the given technology and investment. This is an important information in deciding on whether to make an investment. The profitability of a commodity production crucially depends on its prices, cost of production, and availability of technology.

In order to formulate suitable policy guidelines, policy-makers and research managers need overall information on the profitability of growing crops, its relative profitability, prevailing agricultural incentives structure, nature of price distortions, trading opportunities, and comparative advantages of growing crops. Since Bangladesh is a member of the World Trade Organization (WTO), comparative advantage may have a larger role in determining the trading status of Bangladesh with respect to a particular commodity in the future. Therefore, an attempt was made to analyze the status of both financial (private)[9] and economic (social)[10] profitability, relative profitability, and the comparative advantage of oilseed productions by using scarce resources.

5.2 Financial Profitability of Mustard Cultivation

Oilseed production requires different inputs, such as human labour, seed, fertilizer, manure, insecticide, irrigation, and land preparation tools. The average cost of cultivation of improved mustard was estimated to be Tk 51,246 which was 12.5% higher than the cost of producing BARI old mustard variety (Tori-7). This increased cost was for using the higher amount of labour, fertilizers, pesticides, irrigation, and land use (Appendix A-32). Again, more than 50% cost was spent for fixed inputs, such as land and family labour for both the varieties. Only the cost of seed was higher for Tori-7 variety cultivation which was due to the use of higher amount of seed compared to improved variety. The share of total cost was found to be the highest for land use (38.5-41.7%) followed by human labour (23.1-25.6%) and fertilizers (16-17.5%) among the cost items (Table 5.1).

The yield of BARI improved mustard varieties is much higher compared to BARI old variety (Tori-7) variety. The average yield of improved mustard was 1.64 t/ha which was significantly higher (31.7%) than the yield of old mustard variety (1.12 t/ha), and only 0.61%

---

[9] Financial profitability (FP) is based on calculation of market prices of inputs and outputs that farmers actually pay or receive for producing a crop, along with the quantities used of each. Farmers allocate land and other resources in the production of different crops on the basis of relative financial profitability.

[10] In many cases, FP differs from economic profitability (EP) because of distortions in the factor and product markets such as government taxes and subsidies, trade restrictions, monopoly elements in marketing, and segmentations in the capital market. EP involves deriving border prices of all inputs and outputs, and adjusting those prices by the economic costs of transportation and marketing.

lower than the potential yield of BARI Mustard-15 (Table 5.2). The yield of Tori-7 seems to be high in the study areas.

Table 5.1 Cost of mustard cultivation in the study areas

Particular	Improved		Tori-7		t-value
	Tk/ha	%	Tk/ha	%	
A. Variable cost (Tk)	23,496***	45.8	19,483	43.4	0.000
Hired labor	5,083***	9.9	3,689	8.2	0.000
Land preparation	4,549	8.9	4,431	9.9	0.179
Seed	631	1.2	677**	1.5	0.024
Fertilizers	8,989***	17.5	7,196	16.0	0.000
Manure	2,238	4.4	2,136	4.8	0.658
Pesticide	772***	1.5	426	0.9	0.000
Irrigation	1,045**	2.0	768	1.7	0.014
Interest on operating capital	194***	0.4	161	0.4	0.001
B. Fixed cost (Tk)	27,750***	54.2	25,365	56.6	0.000
Land use	19,697*	38.5	18,717	41.7	0.084
Family labor	8,053***	15.7	6,648	14.9	0.000
C. Total cost (A+B)	51,246***	100	44,848	100	0.000
D. Total cost (Tk/bigha)	6916	--	6052	--	--

Note: '***' '**' & '*' represent significant at 1%, 5% and 10% level respectively

The average net return of improved mustard variety was Tk 28,860 which was also significantly higher (74.4%) than BARI old mustard variety (Tori-7). This higher return was due to higher yield and high price of the produce. Miah and Alam (2008) found that the farmers who cultivated BARI Mustard received 58% higher net profit than Tori-7 variety. The rate of return (BCR) over total cost was higher than unity, implying that the productions of both improved and BARI old variety were profitable at farm level. The BCR of improved variety (1.56) is significantly higher (25.6%) compared to that of Tori-7 variety.

Table 5.2 Profitability of mustard cultivation (Tk/ha) in the study areas

Particular	Improved *(n=217)*	Tori-7 *(n=323)*	t-value
1. Seed yield (kg/ha)	1,641.26***	1,120.75	0.000
2. Price (Tk/kg)	46.50	43.60	0.000
3. Gross return (Tk/ha)	80,105***	52,241	0.000
Main product	76,319***	48,865	0.000
By-product	3,786***	3,376	0.000
4. Total variable cost (Tk/ha)	23,496***	19,483	0.000
5. Total cost (Tk/ha)	51,246***	44,848	0.000
6. Gross margin (Tk/ha) (3-4)	56,609***	32,758	0.000
7. Net return (Tk/ha) (3-5)	28,859***	7,393	0.000
8. Net return (Tk/bigha)	3,895***	998	0.000
9. Rate of return:			
Over variable cost (3÷4)	3.41***	2.68	0.000
Over total cost (3÷5)	1.56***	1.16	0.000

Note: '***' represent significant at 1% level respectively

Different economic studies also showed that the cultivation of oilseed is highly profitable. Islam et al. (2007) found mustard cultivation profitable, and estimated BCR as 2.25 over total cost. Miah and Alam (2008) estimated the net returns and BCR of HYV mustard production which were Tk 35,676/ha and 2.23 respectively. These returns were significantly higher than that of Tori-7 variety. Dey *et al*. (2013) analyzed the profitability of mustard production using primary data from Rajshahi, Pabna, Bogra, and Rangpur districts. Their estimated average net return and BCR were Tk 14,649 per hectare and 1.36 respectively.

Relative profitability of mustard: The respondent farmers in the study areas (i.e., Manikgonj, Tangail, and Dinajpur) mentioned the names of different crops that compete with mustard. It has mentioned earlier that the cultivation of mustard is profitable at farm level. But its overall profitability was not so encouraging to the farmers as compared to many other high value competing crops in the study areas. However, the profitability of improved mustard cultivation was very much encouraging and was higher than many other competing crops, such as cabbage, maize, onion, potato, and wheat (Table 5.3). Now the question arises, why mustard farmers cultivate Tori-7 variety? Farmers generally consider cash/variable costs in producing mustard and cultivate it for family consumption.

Table 5.3 Relative profitability of mustard cultivation in the study areas

Crop	Yield (t/ha)	Total Return (Tk/ha)	Cost of cultivation (Tk/ha)				Benefit cost ratio	
			Variable cost (VC)	Fixed cost (FC)	Total cost (TC)	Net return	Over VC	Over TC
Brinjal	6.15	92,991	45,569	9,060	54,629	38,362	2.04	1.70
Cabbage	6.49	109,267	61,215	9,060	70,275	38,992	1.78	1.55
Carrot	5.66	105,889	67,774	9,060	76,834	29,055	1.56	1.38
Cauliflower	6.33	107,772	55,631	9,060	64,691	43,081	1.94	1.67
Chili	1.95	136,157	62,583	8,941	71,524	64,633	2.18	1.90
Maize	7.36	114,568	63,256	18,538	81,793	32,775	1.81	1.40
Onion	10.51	172,066	110,451	15,819	126,271	45,795	1.56	1.36
Potato	11.01	151,684	82,500	19,074	101,574	50,110	1.84	1.49
Wheat	2.81	65,165	34,714	11,714	46,429	18,736	1.88	1.40
Lentil	1.15	64,929	33,811	7,675	41,486	23,443	1.92	1.57
Chickpea	1.16	68,805	14,901	9,465	24,366	44,439	4.62	2.82
Mustard:	1.38	66,173	21,490	26,558	48,047	18,126	3.05	1.36
Improved	1.64	80,105	23,496	27,750	51,246	28,859	3.41	1.56
Tori-7	1.12	52,241	19,483	25,365	44,848	7,393	2.68	1.16

Source: Field survey 2012; For pulses Matin et al. 2012

5.3 Financial Profitability of Groundnut Cultivation

The average costs of cultivation of BARI improved and BARI old variety (Dhaka No.-1) groundnut were Tk 62,048 and Tk 52,616 per hectare, respectively. The cost of improved groundnut cultivation was significantly higher (15.2%) than that of Dhaka No.-1 variety. Respondent farmers used different inputs in cultivating improved variety groundnut higher than that of Dhaka No.-1 variety (Appendix A-33). Among different cost items, human labour, land preparation, seed, fertilizers, and land use incurred significantly higher cost for improved groundnut cultivation. Again, 55-58% of the total cost was spent for fixed inputs for both types of varieties. Only the cost of pesticides was higher for cultivating Dhaka No.-1 variety compared to that of improved groundnut variety (Table 5.4).

The cultivation of groundnut was found to be the highest profitable crop in the study areas compared to the cultivation of other oilseed crops. Due to its higher profitability, a steady growth was observed both in the area and production of groundnut over the time. The average yield of improved groundnut was 2.40 t/ha which was 32.9% higher than that of Dhaka No.-1 variety, and 25% lower that the potential yield of BARI Groundnut-5 & -6.

Table 5.4 Cost of groundnut cultivation in the study areas

Cost heading	Improved variety		Dhaka No.-1		t_value
	Tk/ha	%	Tk/ha	%	
A. Variable cost (Tk)	36,028***	58.1	29,285	55.7	0.000
Hired labour	15,272**	24.6	13,521	25.7	0.015
Land preparation	6,616***	10.7	5,283	10.0	0.000
Seed	11,092***	17.9	8,116	15.4	0.000
Fertilizers	2,360***	3.8	1,687	3.2	0.011
Manure	135	0.2	100	0.2	0.441
Pesticides	108	0.2	180*	0.3	0.086
Irrigation	148	0.2	151	0.3	0.962
Interest on operating capital	297***	0.5	242	0.5	0.000
B. Fixed cost (Tk)	26,020*	41.9	23,331	44.3	0.001
Land use	9,730*	15.7	8,917	16.9	0.075
Family labour	15,948**	25.7	14,414	27.4	0.015
C. Total cost (A+B)	62,048***	100	52,616	100	0.000
D. Total cost (Tk/bigha)	8,374	--	7,101	--	--

Note: '***' '**' & '*' represent significant at 1%, 5% and 10% level, respectively

The farmers who cultivated improved groundnut received on an average Tk 84,200 as net return which was 76.8% higher than the farmers cultivating Dhaka No.-1 variety. This higher return was due to the higher yield and high price of improved groundnut. The rate of return (BCR) over total cost was significantly higher for adopters (2.36) than that of non-adopters (Table 5.5). Kawser (1993) estimated net return and BCR of groundnut cultivation which were Tk 2,030/ha and 1.11, respectively.

Table 5.5 Profitability of groundnut cultivation in the study area

Particular	Improved variety *(n=95)*	Dhaka No.-1 *(n=445)*	t-value
1. Nut yield (kg/ha)	2,398.98***	1,613.36	0.000
2. Price (Tk/kg)	59.97***	42.71	0.000
3. Gross return (Tk/ha)	146,248***	72,190	0.000
Main product	144,934***	71,152	0.000
By-product	1,314*	1,038	0.094
4. Total variable cost (Tk/ha)	36,028***	29,285	0.000
5. Total cost (Tk/ha)	62,048***	52,616	0.000
6. Gross margin (Tk/ha) (3-4)	110,220***	42,904	0.000
7. Net return (Tk/ha) (3-5)	84,200***	19,573	0.000
8. Net return (Tk//bigha)	11,363***	2,641	0.000
9. Rate of return			
Over variable cost (3÷4)	4.06***	2.47	0.000
Over total cost (3÷5)	2.36***	1.37	0.000

Note: '***' & '*' represents significant at 1% and 10% level, respectively

Relative profitability of groundnut: Irrespective of variety, the cultivation of groundnut is very much profitable to the farmers of the study areas. It is even more profitable than its different competitive crops, namely mungbean, brinjal, lentil, khesari, wheat, and onion. The rate of return (BCR) over total cost was the highest for improved groundnut production among all the competitive crops reported in the study areas (Table 5.6). Farmers are compelled to cultivate local variety of groundnut due to non-availability of improved variety.

Table 5.6 Relative profitability of groundnut cultivation in the study areas

Crop	Yield (t/ha)	Total return (Tk/ha)	Cost of cultivation (Tk/ha)				Benefit cost ratio	
			Variable cost (VC)	Fixed cost (FC)	Total cost (TC)	Net return	Over VC	Over TC
Blackgram	0.79	45,050	13,670	9,372	23,041	22,009	3.30	1.96
Chili	1.95	136,157	62,583	8,941	71,524	64,633	2.18	1.90
Mungbean	1.24	73,291	25,090	17,613	42,703	30,588	2.92	1.72
Brinjal	6.15	92,991	45,569	9,060	54,629	38,362	2.04	1.70
Lentil	1.15	64,929	33,811	7,675	41,486	23,443	1.92	1.57
Khesari	0.94	28,591	9,647	8,532	18,179	10,412	2.96	1.57
Wheat	2.81	65,165	34,714	11,714	46,429	18,736	1.88	1.40
Onion	10.51	172,066	110,451	15,819	126,271	45,795	1.56	1.36
Groundnut:	2.01	109,219	32,657	24,676	57,332	51,887	3.27	1.87
Improved	2.40	146,248	36,028	26,020	62,048	84,200	4.06	2.36
BARI old	1.61	72,190	29,285	23,331	52,616	19,574	2.47	1.37

Source: Field survey 2012; For pulses Matin et al. 2012

5.4 Financial Profitability of Sesame Cultivation

The respondent farmers in the study areas usually use higher inputs in cultivating improved variety sesame compared to that of BARI old variety Til-6 (Appendix A-34). The highest share of the total cost was for hired labour and land use in cultivating both improved and Til-6 varieties. The adopting farmers spent more on land preparation, fertilizer, and manure. However, the average cost of improved sesame cultivation was Tk 42,918/ha which was significantly higher (6.6%) than the cost incurred for cultivating Til-6 variety (Table 5.7).

Table 5.7 Cost of sesame production in the study areas

Cost heading	Improved variety		Old variety (Til-6)		t_value
	Tk/ha	%	Tk/ha	%	
A. Variable cost (Tk/ha)	24,527***	57.1	21,510	53.7	0.000
Hired labour	11,184	26.1	10,726	26.8	0.309
Land preparation	6,111***	14.2	5,722	14.3	0.009
Seed	452	1.1	460	1.1	0.505
Fertilizers	4,223***	9.8	3,061	7.6	0.000
Manure	633***	1.5	208	0.5	0.000
Pesticides	1,133	2.6	1,045	2.6	0.235
Irrigation	2,330	5.4	2,270	5.7	0.620
Int. on operating capital	203***	0.5	178	0.4	0.000
B. Fixed cost (Tk/ha)	18,390	42.9	18,556	46.3	0.681
Land use	8,474	19.7	8,544	21.3	0.480
Family labour	9,916	23.1	10,012	25.0	0.816
C. Total cost (A+B)	42,918***	100	40,066	100	0.000
D. Total cost (Tk/bigha)	5,792***	--	5,407	--	0.000

Note: '***' represents significant at 1% level, respectively

The average yields of improved and BARI old variety (Til-6) sesame were 1.46 t/ha and 1.14 t/ha, respectively. The yield of improved variety sesame was 21.9% higher than that of Til-6 variety, and 2.9% lower than the potential yield of BARI Sesame-4 variety.

The average net return received by adopting farmers was Tk 13,879 which was 71.01% higher than that of net return received by non-adopters. This higher return was mainly due to higher yield and high product price. The estimated rates of returns (BCRs) of improved and Til-6 variety sesame were 1.32 and 1.10 over total cost. The rates of returns scenario clearly indicated that the production of Til-6 variety sesame was marginally profitable to the farmers when all sorts of costs were taken into consideration (Table 5.8).

Table 5.8 Profitability of sesame cultivation in the study area

Particular	Improved variety *(n=116)*	Old variety (Til-6) *(n=424)*	t-value
1. Seed yield (kg/ha)	1,458.3***	1,140.90	0.000
2. Price (Tk/kg)	37.0	36.5	0.786
3. Gross return (Tk/ha)	56,796***	44,089	0.000
Main product	54,333***	41,643	0.000
By-product	2,463	2,446	0.875
4. Total variable cost (Tk/ha)	24,527***	21,510	0.000
5. Total cost (Tk/ha)	42,918***	40,066	0.000
6. Gross margin (3-4) (Tk/ha)	32,269***	22,579	0.000
7. Net return (3-5) (Tk/ha)	13,879***	4,023	0.000
8. Net return (Tk/bigha)	1,873***	543	0.000
9. Rate of return			
Over variable cost (3÷4)	2.32**	2.05	0.049
Over total cost (3÷5)	1.32***	1.10	0.000

Note: '***' and '**' represent 1% and 5% level of significance, respectively

Relative profitability of sesame: The respondent sesame farmers mentioned chili, jute, wheat, and *Aus* rice as the competing crops of sesame in the study areas. Table 5.9 represents the highest BCR for chili cultivation and the lowest for *Aus* rice. Irrespective of variety, the cultivation of sesame was not much profitable to the farmers as compared to its competing crops except *Aus* rice (Table 5.9). Sesame farmers were compelled to cultivate local variety due to non-availability of improved variety. The other causes of cultivating less remunerative crop sesame were home consumption, lower cost, and land suitability.

Table 5.9 Relative profitability of sesame cultivation in the study areas

Crop	Yield (t/ha)	Total Return (Tk/ha)	Cost of cultivation (Tk/ha)				Benefit cost ratio	
			Variable cost (VC)	Fixed cost (FC)	Total cost (TC)	Net return	Over VC	Over TC
Chili	1.95	136,157	62,583	8,941	71,524	64,633	2.18	1.90
Jute	2.05	73,643	37,263	8,529	45,792	27,851	1.98	1.61
Wheat	2.81	65,165	34,714	11,714	46,429	18,736	1.88	1.40
Aus rice	3.59	56,252	53,084	16,145	69,229	-12,977	1.06	0.81
Sesame:	1.30	50,443	23,019	18,473	41,492	8,951	2.19	1.21
Improved	1.46	56,796	24,527	18,390	42,918	13,878	2.32	1.32
BARI old	1.14	44,089	21,510	18,556	40,066	4,023	2.05	1.10

Source: Field survey 2012; For *Aus* rice BRRI 2012

5.5 Financial Profitability of Soybean Cultivation

The adopters of improved soybean used family labour, TSP, MoP, and pesticides significantly higher than that of non-adopters (Appendix A-35). The average cost of cultivation of BARI released soybean variety was Tk 44,410 per hectare, which was slightly higher (4.8%) than the cost of cultivating traditional variety (Sohag). More than 60% cost was spent for variable inputs and the rest was for fixed inputs. The adopting farmers spent significantly higher cost on land preparation, seed, and pesticides compared to that of non-adopters. The adopting soybean farmers used family labour significantly higher than that of non-adopting farmers (Table 5.10).

Table 5.10 Cost of soybean cultivation in the study areas

Particular	Improved variety		Sohag		t_value
	Tk/ha	%	Tk/ha	%	
A. Variable cost (Tk/ha)	26,669	60.1	26,369	62.3	0.726
Hired labour	10,475	23.6	11,272	26.7	0.172
Land preparation	6,577**	14.8	5,953	14.1	0.016
Seed	5,261**	11.8	4,674	11.1	0.014
Fertilizer	3,457	7.8	3,237	7.7	0.436
Manure	126	0.3	137	0.3	0.839
Pesticides	1,027*	2.3	1,224	2.9	0.063
Irrigation	1,764	4.0	1,717	4.1	0.899
Int. on operating capital	220	0.5	218	0.5	0.726
B. Fixed cost (Tk/ha)	17,741	39.9	15,925	37.7	0.127
Land use	8,779	19.8	8,878	21.0	0.909
Family labour	8,962***	20.2	7,047	16.7	0.000
C. Total cost (A+B)	44,410	100	42,294	100	0.114
D. Total cost (Tk/bigha)	5,993	--	5,708	--	0.125

Note: '***' '**' & '*' represent significant at 1%, 5% and 10% level, respectively

The average yields of BARI improved and BARI old variety soybean (Sohag) were more or less same in the study areas. The average yield of BARI improved variety soybean was 25.2% lower than its potential yields, and about 5% higher than the yield of Sohag variety (Table 5.11).

Table 5.11 Profitability of soybean cultivation in the study area

Particular	Improved *(n=56)*	Sohag *(n=304)*	t-value
1. Seed yield (kg/ha)	1,598.3	1,518.5	0.208
2. Price (Tk/kg)	29.6	30.3**	0.041
3. Gross return	48,171	46,605	0.431
Main product	47,475	46,107	0.490
By-product	696	498	0.188
4. Total variable cost	26,669	26,369	0.726
5. Total cost	44,410	42,294	0.114
6. Gross margin (3-4)	21,502	20,236	0.514
7. Net return (3-5)	3,761	4,311	0.777
8. Net return (Tk/bigha)	508	582	0.763
9. Rate of return			
Over variable cost (3÷4)	1.8	1.8	0.899
Over total cost (3÷5)	1.1	1.1	0.279

Note: '**' represents significant at 5% level

There was no much difference observed between the cultivation costs of two varieties. Therefore, the average net return and BCR for improved variety cultivation were more or less similar to the Sohag variety. However, non-adopting farmers received about 13% higher net return than that of adopting farmers, which was due to the high price of output and lower cost of cultivation. Due to higher cost of production, the BCR became very low (Table 5.11). Akter *et al*. (2010) found soybean as the second most profitable crop at Noakhali and Laxmipur districts. Their estimated gross margin and BCR (over variable cost) of its production were Tk 18,407 and 2.23, respectively.

Relative profitability of soybean: The respondent soybean farmers mentioned chili, mungbean, and groundnut as the competing crops of soybean in the study areas. The rates of returns (BCRs) estimated for competing crops were much higher than that of soybean (Table 5.12). Soybean cultivation is confined to two districts, namely Noakhali and Laxmipur. It was opined that farmers of these two districts cultivated this less remunerative crop mainly due to family tradition and good marketing facility.

Table 5.12 Relative profitability of soybean cultivation in the study areas

Crop	Yield (t/ha)	Total Return (Tk/ha)	Cost of cultivation (Tk/ha)				Benefit cost ratio	
			Variable cost (VC)	Fixed cost (FC)	Total cost (TC)	Net return	Over VC	Over TC
Chili	1.95	136,157	62,583	8,941	71,524	64,633	2.18	1.90
Mungbean	1.24	73,291	25,090	17,613	42,703	30,588	2.92	1.72
Groundnut	2.01	109,219	32,657	24,676	57,332	51,887	3.27	1.87
Soybean:	1.56	47,388	26,519	16,833	43,352	4,036	1.8	1.1
Improved	1.60	48,171	26,669	17,741	44,410	3,761	1.8	1.1
BARI old	1.52	46,605	26,369	15,925	42,294	4,311	1.8	1.1

Source: Field survey 2012; For mungbean Matin et al. 2012

5.6 Economic Profitability and Comparative Advantage of Oilseed Production

Economic profitability: It is stated in the preceding sections that the cultivation of oilseeds is profitable at farm level from financial point of view. An attempt was also made to assess oilseeds cultivation from economic point of view under import parity level in Bangladesh. It can be observed from Table 5.13 that the cultivation of oilseeds is also profitable. The highest net return (Tk 82,594/ton) under import parity level was calculated for groundnut followed by sesame (Tk 44,578/ton) and soybean (Tk 5,544/ton). The lowest net return (Tk 603/ton) was found in mustard production in Bangladesh. The rates of returns (BCRs) were also higher for groundnut (4.18) and lowest for mustard (1.02) production (Table 5.13).

Comparative advantage: It is an expression of the efficiency of using domestic resources to produce a particular product when measured against the possibilities of international trade. A country will reduce the production of those goods which can be imported at lower relative prices. Again, the country will lead to specialize in the production of those goods which can be produced at lower relative cost. In calculating comparative advantage of oilseeds production, farm gate prices of oilseeds were used as the domestic producer prices, while the c.i.f import prices of the respective oilseeds were considered the world prices. The respective world prices are available on internet (FAOStat).

Comparative advantage in producing oilseeds in the country was evaluated through calculation of their domestic resource costs (DRCs). The estimate of DRC greater than one implies that the country loses foreign exchange through domestic production (in the sense that it uses more domestic resources than it generates net value added to tradable goods and services), while DRC is less than one implies that the production is efficient and make positive contribution to domestic value addition. The estimated DRCs for selected oilseed crops were less than unity, which mean that the country had comparative advantage in producing oilseeds for import substitution. The comparative advantage of producing groundnut, sesame, and soybean was much higher than that of mustard production in Bangladesh. It implies that mustard production was not so advantageous in Bangladesh since the value of DRC is close to unity (Table 5.13). It is important to note that the area under oilseeds cultivation is decreasing over the years in spite of having comparative advantage. The reasons behind this decreasing trend are low relative profitability and lack of short duration improved varieties.

Table 5.13 Economic profitability and domestic resource cost (DRC) of different oilseeds production at import parity level in Bangladesh

(Value in Tk/ton)

Cost and return	Mustard	Groundnut	Sesame	Soybean
A. Cost of traded inputs*	7,945	1,257	3,561	3,115
B. Costs of non-traded inputs and domestic resources	25,754	24,739	27,733	27,029
Human labour	8,005	13,014	14,472	12,163
Mechanical power	2,772	2,758	4,191	4,116
Seed	385	4,624	310	3,292
Manure	1,364	56	434	79
Pesticides	470	45	777	643
Irrigation	637	62	1,598	1,104
Int. on operating capital	118	124	139	138
Land rent	12,003	4,056	5,812	5,494
C. Total input costs	33,699	25,996	31,294	30,144
D. Output price**	34,302	108,590	75,872	35,688
E. Net profit (D-C)	603	82,594	44,578	5,544
F. BCR (D/C)	1.02	4.18	2.42	1.18
G. Value added (Tradable) (D-A)	26,357	107,333	72,311	32,573
H**. DRC** (B/G)	**0.977**	**0.230**	**0.384**	**0.830**

Note: * Traded inputs included urea, TSP, MoP, and DAP; **Boarder price at farm gate
See also Appendix A-36 and A-37

The estimated DRC of mustard production in the present study is well supported by the study of Dey *et al.* (2013). They estimated nominal protection coefficient (NPC) and nominal rate of protection (NRP) for mustard production at import parity level for seven years (2005-2011). It was found that the border parity prices of mustard at producer level were higher during the last four years (2008-2011) as compared to the domestic producer prices of mustard production. This situation implied that mustard production remained in disadvantageous position in Bangladesh. However, the DRC of mustard production in this study was estimated irrespective of varieties. It would obviously be lower in the case of producing improved varieties of mustard. In that case, the local production of mustard will be cheaper which will emphasize the research towards generations of new mustard varieties and management technologies for the country.

Chapter VI

FACTORS OF PRODUCTION AND TECHNICAL EFFICIENCY OF OILSEEDS FARMERS

6.1 Introduction

Efficiency in economics is usually defined in terms of the optimal conditions (output/profit maximization or input/cost minimization) associated with the perfectly competitive market situations. Efficient enterprises are more likely to generate higher income and thus stand a better chance to surviving. Improvement in efficiency is particularly important for an enterprise in the periods of financial stress. The measurement of productive efficiency of a farm relative to other farms or to the best practice outcome has long been of interest to agricultural economists. From an applied perspective, measuring efficiency is important because this is the first step in a process that may lead to substantial resource savings.

Technological change and efficiency improvement are important sources of production growth in any economy. Technological change is defined as a shift in the frontier production function. Cobb-Douglas stochastic frontier production function specification provides an adequate representation of the production technology. It can be specified to estimate the level of technical efficiency. The model also allows the technical inefficiency, which occur by the random shocks outside the control of producers can affect output. Therefore, Cobb-Douglas stochastic frontier production function with yield as dependent variable was estimated in this study to generate farm specific efficiency indices for oilseeds production. The maximum likelihood estimates (MLEs) of the stochastic production frontier and technical inefficiency model show the efficient use of the available inputs in the oilseeds production. Farm specific technical efficiency estimated for different oilseeds production is discussed in the following subsequent sections.

6.2 Factors and Technical Efficiency in Mustard Production

6.2.1 Factors affecting mustard production

The maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic production frontier for mustard are presented in Table 6.1. The coefficients of the variables used in the frontier production function are the elasticity of average output with respect to the different inputs used in mustard production. The empirical result showed that, the sign and magnitudes of the estimated β coefficient in majority cases were consistent with prior expectation although some of them were insignificant.

Mustard production is likely to be influenced by different factors. The coefficients of human labour, organic fertilizers, urea, boron, irrigation, land rent, and variety were positive and significant, while that of seed was negative and significant. At 5% level of significance, the coefficients of human labour and land rent; at 10% level of significance, the coefficients of organic fertilizers, urea, boron, and irrigation; and at 1% level of significance, the coefficient of dummy for mustard variety was positive. It implied that human labour, land rent, organic fertilizer, urea, boron, irrigation, and improved variety had a significant and positive impact on the yield of mustard. The yield of mustard would increase by 0.118, 0.017, 0.001, 0.029, 0.004, 0.004, and 0.017% if farmers apply 1% additional human labour, land rent, organic fertilizer, urea, boron, and irrigation, respectively. Moreover, the coefficient of dummy for variety was found positive and highly significant at 1% level, implying that improved variety had highly significant effect on improving the productivity of mustard at farm level. More or less similar results were estimated for adopter and non-adopter mustard farmers. However, the level of significance of the coefficients of boron, irrigation, and land rent were higher for adopters than non-adopters (Table 6.1).

Irrespective of variety use, the use of human labour had positive and significant impact on the productivity of mustard at Manikgonj (intensive growing areas) and Rajshahi (medium growing areas) districts, whereas improved variety had highly significant impact on mustard yield in all the study areas. Positive and significant impacts of boron and land rent were found to be low for mustard growing district Dinajpur (Appendix A-38)

Table 6.1 Maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production functions for mustard in the study areas

(Per hectare)

Independent variable	Parameter	Adopter *(n=197)*	Non-adopter *(n=343)*	All farm (*n=540)*
Constant	β_0	6.81*** (0.630)	6.38*** (0.657)	6.27*** (0.445)
Human labour (man-day)	β_1	0.089* (0.057)	0.127* (0.065)	0.118** (0.045)
Land preparation cost (Tk)	β_2	0.017 (0.052)	0.006 (0.055)	0.029 (0.037)
Seed (kg)	β_3	-0.024 (0.036)	-0.069* (0.041)	-0.060** (0.028)
Organic fertilizers (kg)	β_4	0.003* (0.003)	0.002 (0.003)	0.001* (0.002)
Urea (kg)	β_5	0.037* (0.021)	0.037* (0.021)	0.029* (0.016)
TSP (kg)	β_6	0.0004 (0.007)	0.007 (0.009)	0.004 (0.006)
MoP (kg)	β_7	0.012* (0.007)	0.002 (0.007)	0.005 (0.005)
DAP (kg)	β_8	0.004 (0.006)	0.011 (0.008)	0.007 (0.005)
Gypsum (kg)	β_9	-0.001 (0.004)	0.0003 (0.005)	0.001 (0.003)
Zinc sulphate (kg)	β_{10}	-0.013 (0.011)	0.008 (0.012)	-0.001 (0.009)
Boron (kg)	β_{11}	0.022** (0.011)	0.011* (0.013)	0.004* (0.009)
Irrigation cost (Tk)	β_{12}	0.007** (0.003)	0.001* (0.003)	0.004* (0.002)
Pesticides cost (Tk)	β_{13}	0.0013 (0.003)	-0.002 (0.003)	-0.001 (0.002)
Land rent (Tk)	β_{14}	0.007** (0.031)	0.017* (0.031)	0.017** (0.022)
Dummy for soil type (1=Loamy, 0= otherwise)	β_{15}	-0.008 (0.020)	0.033 (0.022)	0.017 (0.016)
Dummy for variety (1= Improved, 0=otherwise)	β_{16}	-	-	0.031*** (0.018)

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

6.2.2 Factors affecting technical inefficiency in mustard production

The productivity of crop is not only influenced by different input variables, but also influenced by farmers' personal quality and the managerial capability. Table 6.2 depicts that the estimated coefficients of education, farming experience, cosmopolitness, and extension contact were negative and significant in the technical inefficiency model for mustard production, which implied that technical inefficiency decreases with the increase in farmers' education, farming experience, cosmopolitness, and extension contact. It may be concluded that farmers with higher education, more farming experience, cosmopolitness, and extension contact tend to be technically more efficient.

The estimated value of σ^2 (0.516) is large and significantly different from zero, which indicates a good fit and correctness of the specified distributional assumption. The estimated value of γ, which is the ratio of the variances of farm specific technical inefficiency to the total variance of output, is 0.983 and significant at 1% level, indicated that about 98% of the difference between the observed output and the maximum production frontier output is caused by differences in farmers levels of technical efficiency as opposed to the conventional random variability, i.e., there were significant technical inefficiency effects in the production of mustard.

Table 6.2 Maximum likelihood estimates of technical inefficiency models estimated for adopters and non-adopters of improved mustard in the study areas

Independent variable	Parameter	Adopter (n=197)	Non-adopter *(n=343)*	All farm (n=540)
Constant	δ_0	-1.406 (1.677)	-0.824 (1.481)	-1.922* (1.132)
Farm size (ha)	δ_1	0.108** (0.060)	0.199* (0.117)	0.259*** (0.073)
Proportion of family labor to total labor	δ_2	-0.145 (0.221)	0.599 (0.433)	0.269 (0.217)
Age (year)	δ_3	0.007 (0.004)	0.017 (0.008)	0.010 (0.005)
Education (year of schooling)	δ_4	-0.049** (0.043)	-0.098* (0.058)	-0.079*** (0.028)
Farming experience (year)	δ_5	-0.029* (0.020)	-0.108* (0.056)	-0.068** (0.019)
Training on oilseeds (no./life time)	δ_6	-0.013 (0.060)	0.044 (0.107)	0.006 (0.007)
Societal membership (wt. score) (Scale,0-3; 0= no membership , 3= executive)	δ_7	-0.009 (0.030)	-0.104 (0.069)	-0.073 (0.043)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	δ_8	-0.091* (0.065)	-0.051** (0.051)	-0.154*** (0.057)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_9	0.076 (0.130)	-0.049 (0.065)	0.156 (0.072)
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular)	δ_{10}	-0.001** (0.009)	-0.115* (0.066)	-0.063*** (0.022)
Variance parameters:				
Sigma-squared	σ^2	0.165* (0.100)	0.839* (0.487)	0.516*** (0.159)
Gamma	γ	0.974*** (0.014)	0.988*** (0.007)	0.983*** (0.006)
Log likelihood function		99.45	52.84	131.78

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

The coefficient of farm size was positive and significant in the technical inefficiency model for mustard production (Table 6.2) which implied that technical inefficiency increases with the increase in farm size. Islam (2002) found significant positive relationship of farmers' education and technical efficiency for aromatic and fine rice growers in Bangladesh. Sharif and Dhar (1996), Bravo-Ureta and Pinheiro (1997), Burki and Shah (1998), Seyoum *et al.* (1998), Chaudhry (2001), Ajibefun *et al.* (2002), and Khan and Alam (2003) also observed significant positive correlation with education and technical efficiency.

In Manikgonj district, technical inefficiency of the farmers significantly decreases with the increase in farm size, training in oilseed production, societal membership, cosmopolitness, innovativeness, and extension contact. The technical inefficiency of Rajshahi farmers significantly decreases with the increase of societal membership and cosmopolitness. Again, farmers with oilseed training and extension contact tend to be technically more efficient in Dinajpur district (Appendix A-39).

6.2.3 Technical efficiency of mustard farmers

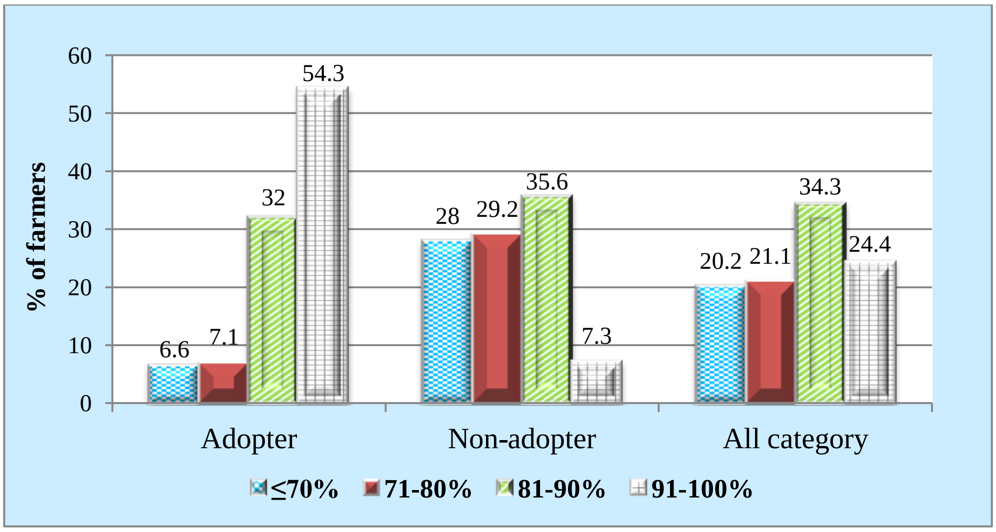
The estimated technical efficiencies of adopters, non-adopters, and all farms are presented in Table 6.3. The mean value of technical efficiency was 0.79 with a range from 0.27 to 0.96. This implied that, on average, the mustard producers in the study areas were producing mustard to about 79% of the potential (stochastic) frontier production levels, given the levels of their inputs and the technology currently being used. This also indicated that there existed an average level of technical inefficiency of 21%. The improved variety adopters in the study areas were technically more efficient (0.87) compared to that of non-adopters (0.75).

Table 6.3 Farm specific technical efficiencies of mustard producers in the study areas

Producer type	No. of farm	Technical efficiency			
		Mean	Minimum	Maximum	St. deviation
Adopter	147	0.87	0.38	0.96	0.10
Non-adopter	343	0.75	0.27	0.95	0.14
All type	540	0.79	0.27	0.96	0.14

The distribution of technical efficiency levels indicated that majority of the adopters (54.3%) had technical efficiency level 91-100% followed by 81-90%. For the non-adopters, about 36% farmers achieved technical efficiency levels ranged from 81 to 90% followed by 29.2% farmers technical efficiency levels 71-80% (Fig 6.1).

Figure 6.1 Percent of mustard farmers under different levels of technical efficiency



Irrespective of variety use, the highest mean technical efficiency (91%) was estimated for the farmers of intensive mustard growing district Manikgonj and the lowest (78%) for the low growing district Dinajpur (Table 6.4). One of the important reasons of attaining such level of efficiency was due to the level of improved variety adoption.

Table 6.4 Farm specific technical efficiencies of mustard farmers by study areas

Study area	No. of farm	Technical efficiency			
		Mean	Minimum	Maximum	St. deviation
Manikgonj	180	0.91	0.37	0.99	0.09
Rajshahi	180	0.89	0.42	0.98	0.10
Dinajpur	180	0.78	0.31	0.96	0.15

6.2.4 Yield of mustard under technical efficiency levels

The yields of mustard are examined under farm specific technical efficiency levels and presented in Tables 6.5 and 5.6. The highest level of yield of mustard was obtained by the farmers who had technical efficiency level 91-100% (1,744 kg/ha) followed by that of technical efficiency level of 81-90% (1,368 kg/ha) and 71-80% (1,158 kg/ha). The lowest level of yield (849 kg/ha) was obtained by the farmers who had the lowest levels of technical efficiency (≤70%). The farm specific efficiency estimated according to study areas further established the fact that technical efficiency and yield had a direct and positive correlation (Table 6.6).

Table 6.5 Yield of mustard as affected by different technical efficiency levels

Producer type	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Adopter	927	1,255	1,589	1,810	1,641
Non-adopter	838	1,144	1,254	1,465	1,121
All type	849	1,158	1,368	1,744	1,311

Table 6.6 Yield of mustard for different study areas as affected by different technical efficiency levels

Study area	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Manikgonj	763	1,086	1,236	1,614	1,463
Rajshahi	729	951	1,167	1,477	1,316
Dinajpur	719	1,015	1,330	1,557	1,153

6.3 Factors and Technical Efficiency in Groundnut Production

6.3.1 Factors affecting groundnut production

Groundnut production at farm level is influenced by different input variables. The maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic production frontier for groundnut are presented in Table 6.7. The coefficients of the variables in the frontier function are the elasticity of average output with respect to the different inputs used in groundnut production.

The empirical results indicated that the coefficients of land preparation, seed, organic fertilizers, TSP, dummy for groundnut variety, and dummy for soil type were positive and significant at different levels of confidence. It indicated that land preparation, seed, organic fertilizers, TSP, soil type, and improved variety had positive and significant impacts on groundnut production at farm level. The yield of groundnut would increase by 0.007, 0.056, 0.007, and 0.015% if groundnut farmers apply 1% additional land preparation, seed, organic fertilizers, and TSP respectively. Moreover, the coefficients of dummy variables land type and improved variety were found to be positive and highly significant at 1% level which meant that improved variety and loamy soil had significant positive impact on the productivity of groundnut in the study areas. More or less similar results regarding significant variables were found in the Cobb-Douglas stochastic frontier production function models estimated for adopters and non-adopters of groundnut variety in the study areas.

Table 6.7 Maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production function for groundnut in the study areas

(Per hectare)

Independent variable	Parameter	Adopter *(n=95)*	Non-adopter *(n=445)*	All farm *(n=540)*
Constant	β_0	8.20*** (0.982)	6.33*** (0.562)	6.60*** (0.489)
Human labour (man-day)	β_1	0.008 (0.014)	0.128 (0.096)	0.065 (0.089)
Land preparation cost (Tk)	β_2	0.008 * (0.014)	0.007* (0.004)	0.007** (0.003)
Seed (kg)	β_3	0.039** (0.026)	0.054** (0.031)	0.056** (0.025)
Organic fertilizers (kg)	β_4	0.008** (0.004)	0.006** (0.005)	0.007* (0.003)
Urea (kg)	β_5	-0.003 (0.004)	-0.004 (0.006)	-0.004 (0.006)
TSP (kg)	β_6	0.008* (0.009)	0.016** (0.008)	0.015** (0.006)
MoP (kg)	β_7	0.002 (0.007)	0.004 (0.008)	0.005 (0.007)
DAP (kg)	β_8	0.009 (0.009)	-0.008 (0.015)	-0.002 (0.010)
Gypsum (kg)	β_9	-0.018 (0.009	-0.008 (0.013)	-0.005 (0.011)
Irrigation cost (Tk)	β_{10}	-0.002 (0.005)	0.008 (0.007)	0.001 (0.005)
Pesticides cost (Tk)	β_{11}	0.001 (0.004)	0.003 (0.005)	0.003 (0.003)
Land rent (Tk/ha)	β_{12}	0.070 (0.038)	0.028 (0.026)	0.029 (0.023)
Dummy for soil type (1=Loam, 0= Otherwise)	β_{13}	0.014** (0.018)	0.024*** (0.023)	0.018*** (0.019)
Dummy for groundnut variety (1= Improved, 0=Otherwise)	β_{14}	--	--	0.298*** (0.026)

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

The Cobb-Douglas stochastic frontier production functions estimated according to study areas revealed that the yield of groundnut in Manikgonj district was significantly affected by improved variety and negatively affected by soil type. In Pabna, the positive and significant factors of groundnut production were seed and variety. Human labour, land preparation and variety played a positive and significant role in increasing groundnut yield in Tangail district (Appendix A-40).

6.3.2 Factors affecting technical inefficiency in groundnut production

Technical inefficiency in production is likely to be affected by different personal qualities and managerial capacities of the farmers. The coefficients of farm size, education, availability of HYV seed, and innovativeness were negative and significant in the technical inefficiency model for groundnut production which implied that technical inefficiency decreases with the increase in farmers' farm size, education, availability of HYV seed, and innovativeness. It may be expressed in other words that farmers with more farm size, higher education, innovativeness, and the higher availability of improved groundnut seed tend to be technically more efficient in groundnut production. More or less similar results regarding significant variables were observed in the inefficiency models estimated for adopters and non-adopters (Table 6.8).

The estimated value of σ^2 (0.032) is large and significantly different from zero, which indicates a good fit and correctness of the specified distributional assumption. The estimated value of γ is 0.25 and significant at 10% level, indicated that 25% of the difference between the observed output and the maximum production frontier output is caused by differences in farmers levels of technical efficiency as opposed to the conventional random variability, i.e., there were significant technical inefficiency effects in the production of groundnut.

Table 6.8 Maximum likelihood estimates of technical inefficiency model for groundnut in the study areas

Independent variable	Para-meter	Adopter *(n=95)*	Non-adopter *(n=445)*	All farm *(n=540)*
Constant	δ_0	-0.460 (0.554)	0.341 (0.223)	0.367*** (0.096)
Farm size (ha)	δ_1	-0.021* (0.014)	-0.022** (0.009)	-0.024** (0.006)
Proportion of family labour to total labour	δ_2	-0.021 (0.183)	0.032 (0.111)	0.032 (0.087)
Age (year)	δ_3	0.004 (0.002)	0.0004 (0.001)	0.001 (0.001)
Education (year of schooling)	δ_4	-0.006* (0.007)	-0.001** (0.003)	-0.001** (0.003)
Farming experience (year)	δ_5	0.007** (0.004)	0.001* (0.001)	0.002* (0.001)
Training on oilseeds (no./life time)	δ_6	-0.020 (0.037)	-0.021 (0.027)	-0.027 (0.018)
Availability of HYVseed (Score) (Scale,0-4; 0= not available, 4= plenty)	δ_7	-0.021* (0.036)	-0.211*** (0.072)	-0.284*** (0.031)
Dummy for society member (1=Member, 0= Otherwise)	δ_8	-0.031 (0.021)	0.018 (0.019)	0.019 (0.010)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	δ_9	0.086 (0.067)	-0.005 (0.012)	-0.008 (0.010)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_{10}	-0.041* (0.025)	-0.011** (0.022)	-0.014** (0.011)
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular)	δ_{11}	0.007 (0.004)	0.001 (0.005)	-0.001 (0.002)
Variance parameters:				
Sigma-squared	σ^2	0.007** (0.003)	0.032*** (0.003)	0.032*** (0.003)
Gamma	γ	0.481** (0.225)	0.019* (0.067)	0.250* (0.145)
Log likelihood function		122.48	134.7	198.23

Note: ***, ** and * indicate significant at 1, 5 and 10% level of probability respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

Area specific technical inefficiency of the groundnut farmers revealed that different factors influenced technical inefficiency at varying magnitudes. In Noakhali district, farm size, age, education, oilseed training, availability of HYV seed, cosmopolitness, and extension contact had significant impact on decreasing the technical inefficiency in groundnut production. Availability of HYV seed and innovativeness were the two factors that played significant role in reducing the inefficiency effects in groundnut production both in Pabna and Tangail districts (Appendix A-41).

6.3.3 Technical efficiency of groundnut farmers

The estimated farm specific technical efficiencies of adopters, non-adopters, and all farms are presented in Table 6.9. The average technical efficiency of groundnut farmers was 89% with a range from 68 to 99%. This implied that, on average, the respondent farmers in the study areas produced groundnut to about 89% of the potential (stochastic) frontier production levels using current levels of given inputs and technology. This also indicated that there existed an average level of technical inefficiency of 11% in the process of groundnut production. The technical efficiency was higher for improved variety cultivating farmers (96%) compared to that of non-adopting groundnut farmers in the study areas (88%).

The average highest technical efficiency (90%) was achieved by the groundnut farmers of moderate growing area Pabna mainly due to higher level of adoption of improved variety.

Again, the lowest technical efficiency (81%) was observed in the low growing area (Tangail) mainly due to lower level of adoption of improved groundnut varieties (Table 6.10).

Table 6.9 Farm specific technical efficiency of groundnut producer in the study areas

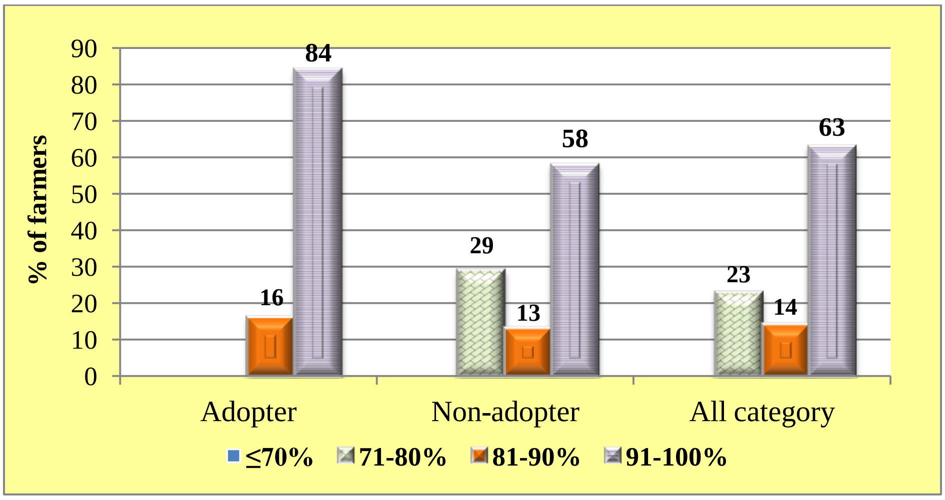
Producer type	No. of farm	Technical efficiency			
		Minimum	Maximum	Mean	St. deviation
Adopter	95	0.90	0.99	0.96	0.04
Non-adopter	445	0.67	0.98	0.88	0.09
All type	540	0.68	0.99	0.89	0.08

Table 6.10 Farm specific technical efficiency of groundnut producer in the study areas

Study area	No. of farm	Technical efficiency			
		Mean	Maximum	Minimum	St. deviation
Noakhali	180	0.87	0.99	0.52	0.12
Pabna	180	0.90	0.98	0.62	0.10
Tangail	180	0.81	0.99	0.52	0.12

The technical efficiencies of different groundnut farmers revealed that 84% of the improved groundnut cultivating farmers achieved technical efficiency level 91-100% followed by 16% farmers achieved technical efficiency level 81-90%. For non-adopters, the percent of farmers (58%) achieved technical efficiency level 91-100% was much lower than that of adopters. However, irrespective of producer types 63% respondent farmers had technical efficiency level 91-100% (Fig. 6.2).

Figure 6.2 Percent of groundnut farmers under different levels of technical efficiency



6.3.4 Yield of groundnut under technical efficiency levels

There is a direct and positive correlation between technical efficiency and crop productivity. Therefore, the yield of groundnut was examined under different levels of farm specific technical efficiency and the findings of this examination are presented in Table 6.11. The overall observation clearly depicts that the groundnut farmers with higher technical efficiency obtained the higher levels of yield in the study areas. The highest level of groundnut yield (1,963 kg/ha) was obtained by the farmers who had technical efficiency level 91-100% and the lowest level of yield (1,116 kg/ha) was obtained by the farmers who had technical efficiency level 70% or below.

Table 6.11 Yield of groundnut as affected by different levels of technical efficiency

Producer type	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Adopter	--	--	1,523	2,459	2,399
Non-adopter	1,116	1,307	1,339	1,803	1,613
All type	1,116	1,307	1,439	1,963	1,752

The highest average yield was found in Pabna district followed by Noakhali and Tangail districts. The overall observation further revealed that the groundnut farmers with higher technical efficiency obtained the higher levels of yield. The highest level of groundnut yield (2,170 kg/ha) was obtained by the farmers of Pabna district who had technical efficiency level 91-100% and the lowest level of yield (1,222 kg/ha) was obtained by the farmers of Noakhali district who had technical efficiency level 70% or below (Table 6.12).

Table 6.12 Yield of groundnut for different study areas as affected by different levels of technical efficiency

Study area	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Noakhali	1,222	1,303	1,746	2,086	1,834
Pabna	1,228	1,459	1,764	2,170	1,969
Tangail	1,421	1,447	1,456	1,485	1,451

6.4 Factors and Technical Efficiency in Sesame Production

6.4.1 Factors affecting sesame production

Different factors influence the yield of sesame at farm level. The maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic production frontier for sesame are presented in Table 6.13. The coefficients of the variables in the frontier production function are the elasticity of average output with respect to the different inputs used in sesame production. The sign and magnitudes of the estimated coefficients in majority cases were consistent with prior expectation although some of them were insignificant.

The empirical results of the Cobb-Douglas production function analysis revealed that the coefficients of human labour, urea, MoP, pesticides, land rent, dummy for soil type, and dummy for sesame variety were positive and significant at different levels, whereas the coefficient of land preparation was negative and highly significant at 1% level. It implied that human labour, urea, MoP, pesticides, land rent, loamy soil, and improved variety had significant and positive impacts on the yield of sesame. On the other hand, land preparation cost had negative impact on sesame yield. The yield of sesame would increase by 0.241, 0.002, 0.010, 0.001, and 0.096% if farmers use 1% additional human labour, urea, MoP, pesticides, and land rent respectively. Moreover, the improved variety of sesame had highly significant positive impact on the yield of sesame (Table 6.13).

Table 6.13 Maximum likelihood estimates of frontier production function model for sesame in the study areas

(in hectare)

Independent variable	Parameter	Adopter *(n=116)*	Non-adopter *(n=424)*	All farm *(n=540)*
Constant	β_0	3.638*** (0.801)	6.199*** (0.572)	5.870*** (0.437)
Human labour (man-day)	β_1	3.673*** (0.058)	0.215*** (0.045)	0.241*** (0.032)
Land preparation cost (Tk)	β_2	-0.083* (0.026)	-0.081** (0.027)	-0.076** (0.021)
Seed (kg)	β_3	0.015 (0.036)	0.003 (0.033)	0.001 (0.027)
Organic fertilizers (kg)	β_4	0.001 (0.002)	0.004 (0.003)	0.002 (0.002)
Urea (kg)	β_5	0.011** (0.006)	0.001* (0.005)	0.002** (0.004)
TSP (kg)	β_6	0.004 (0.006)	-0.003 (0.005)	-0.002 (0.004)
MoP (kg)	β_7	0.011* (0.004)	0.013** (0.005)	0.010** (0.004)
DAP (kg)	β_8	0.012 (0.010)	-0.010 (0.008)	-0.008 (0.006)
Gypsum (kg)	β_9	-0.002 (0.004)	-0.004 (0.007)	-0.003 (0.005)
Irrigation cost (Tk)	β_{10}	0.003 (0.002)	0.002 (0.002)	0.002 (0.001)
Pesticides cost (Tk)	β_{11}	0.003* (0.002)	0.001 (0.002)	0.001* (0.002)
Land rent (Tk/ha)	β_{12}	0.311*** (0.078)	0.074* (0.056)	0.096** (0.042)
Dummy for soil type (1=Loamy, 0= Otherwise)	β_{13}	0.003** (0.015)	0.011* (0.019)	0.002** (0.014)
Dummy for sesame variety (1=Improved, 0=Otherwise)	β_{14}	--	--	0.122*** (0.013)

Note: ***, ** and * indicate significant at 1%, 5% and 10% level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

The Cobb-Douglas stochastic frontier production functions estimated for different study areas showed that the productivity of sesame was significantly affected by improved variety and use of human labour in all the study areas. Again, the cost of land preparation had negative and significant impact on sesame yield in Faridpur and Comilla districts, whereas gypsum had negative impact on sesame yield in Jessore district (Appendix A-42).

6.4.2 Factors affecting technical inefficiency in sesame production

The sustainability of a technically efficient farm is generally more than that of a technically inefficient farm. Different characteristics and managerial qualities of the farmer also influence technical inefficiency in producing sesame. Table 6.14 depicted that farmer's education, training on oilseeds, availability of HYV seed, innovativeness, and extension contact significantly decreased the inefficiencies of sesame production. It may also be concluded that farmers with more higher education, more training, higher HYV seed availability, more innovativeness, and more extension contact tend to be technically more efficient. The farmers in the study areas generally use family labour more than that of hired labour in sesame cultivation. Therefore, the coefficient of the proportion of family labour to total was positive and highly significant at 1% level of probability, which implied that technical inefficiency increases with the increase in the use of family labour in sesame production.

The estimated value of σ^2 (0.168) is large and significantly different from zero, which indicates a good fit and correctness of the specified distributional assumption. The estimated value of γ is 0.950 and significant at 1% level, indicated that about 95% of the difference between the observed output and the maximum production frontier output is caused by differences in farmers levels of technical efficiency as opposed to the conventional random variability, i.e., there were significant technical inefficiency effects in the production of sesame.

Table 6.14 Maximum likelihood estimates of technical inefficiency model for sesame in the study areas

Independent variable	Para-meter	Adopter *(n=116)*	Non-adopter *(n=424)*	All farm *(n=540)*
Constant	δ_0	0.150*** (0.033)	-0.160 (0.785)	-0.419 (0.501)
Farm size (ha)	δ_1	-0.001 (0.005)	-0.160** (0.067)	-0.065 (0.036)
Proportion of family labour to total labor	δ_2	0.004 (0.044)	2.270*** (0.626)	1.646*** (0.277)
Age (year)	δ_3	0.001 (0.001)	0.007 (0.003)	-0.005 (0.002)
Education (year of schooling)	δ_4	-0.002* (0.001)	-0.040***(0.013)	-0.032*** (0.011)
Experience (year)	δ_5	0.002 (0.001)	0.007 (0.004)	0.003 (0.003)
Training on oilseeds (no./life time)	δ_6	-0.046* (0.031)	-0.178 (0.223)	-0.206** (0.128)
Availability of HYV seed (Score) (Scale,0-4; 0= not available, 4= plenty	δ_7	-0.024* (0.014)	-0.275***(0.181)	-0.212*** (0.119)
Dummy for society member (1=Member, 0= Otherwise)	δ_8	-0.021 (0.013)	-0.196 (0.086)	-0.145 (0.081)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	δ_9	0.004 (0.007)	0.078 (0.043)	0.039 (0.028)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_{10}	-0.001* (0.006)	-0.178***(0.060)	-0.099*** (0.033)
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular)	δ_{11}	-0.0001* (0.001)	-0.039***(0.016)	-0.027*** (0.009)
Variance parameters:				
Sigma-squared	σ^2	0.003*** (0.001)	0.205*** (0.046)	0.168*** (0.026)
Gamma	γ	0.998*** (0.306)	0.940*** (0.013)	0.950*** (0.009)
Log likelihood function		161.28	168.5	278.32

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

Area specific technical inefficiency of the sesame farmers depicted that different factors influenced technical inefficiency at varying magnitudes. Some common factors that had significant impact on decreasing the technical inefficiency in sesame production in all the study areas were education, oilseed training, availability of HYV seed, societal membership, and extension contact (Appendix A-43).

6.4.3 Technical efficiency of sesame farmers

The estimated technical efficiencies of improved sesame variety for adopters, non-adopters, and all farms are presented in Table 6.15. It was observed that the mean value of technical efficiency was 0.88 with a range from 0.31 to 0.98. This implied that, on average, the sesame farmers in the study areas were producing sesame to 88% of the potential (stochastic) frontier production levels, given the levels of their inputs, and the technology currently being used. This also indicated that the level of technical inefficiency existed in the process of sesame production was 12%. The technical efficiency was found higher for the adopters (0.97) than that of non-adopters (0.85).

Table 6.15 Farm specific technical efficiency of sesame producers in the study areas

Producer type	No. of farm	Technical efficiency			
		Minimum	Maximum	Mean	St. deviation
Adopter	116	0.85	0.97	0.94	0.05
Non-adopter	424	0.29	0.98	0.87	0.10
All type	540	0.31	0.98	0.88	0.11

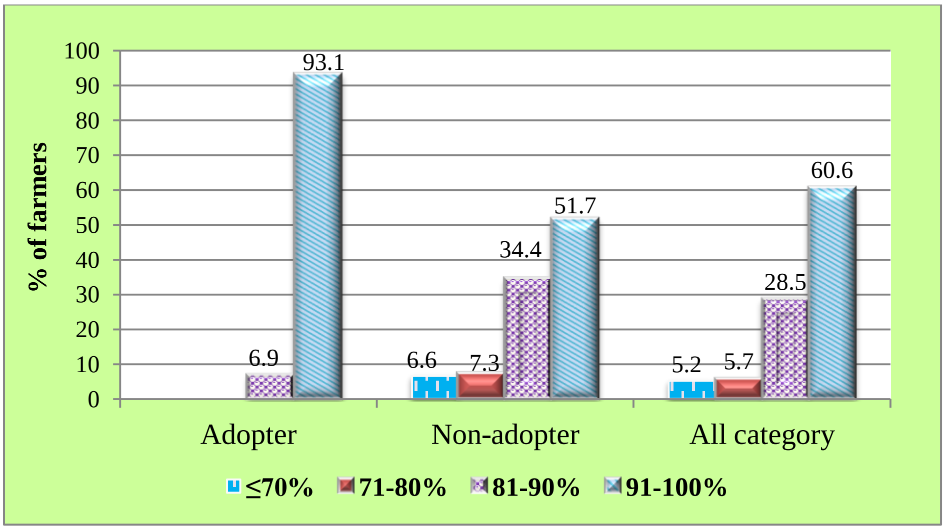
Table 6.16 revealed that there was a positive correlation between the intensity of growing sesame and technical efficiency of the farmers. It means that the farmers of intensive sesame growing area (Jessore) possessed the highest level of technical efficiency (92%) and the farmers of low sesame growing area (Comilla) obtained the lowest technical efficiency.

Table 6.16 Farm specific technical efficiency of sesame producers in the study areas

Study area	No. of farm	Technical efficiency			
		Mean	Maximum	Minimum	St. deviation
Jessore	180	0.92	0.98	0.38	0.08
Faridpur	180	0.88	0.98	0.45	0.10
Comilla	180	0.87	0.97	0.30	0.11

The level of technical efficiency of different sesame producers indicated that majority of the adopters (93.1%) had technical efficiency level 91-100% followed by technical efficiency level 81-90% which were attained by 6.9% of the sesame farmers. For the non-adopters, about 52% of the respondent farmers achieved technical efficiency level 91-100% and 34.4% of the farmers' efficiency level was 81-90% (Fig. 6.3).

Figure 6.3 Percent of sesame farmers under different levels of technical efficiency



6.4.4 Yield of sesame under technical efficiency levels

The yield of sesame was examined under different levels of farm specific technical efficiency. Generally, technically more efficient farms obtained higher levels of yield compared to less efficient farms. In sesame production, the highest level of yield (1,343 kg/ha) was obtained by the farmers who had technical efficiency level 91-100% followed by that of farmers whose technical efficiency level was 81-90%. The lowest level of yield (654 kg/ha) was obtained by the farmers who had lowest levels (≤70%) of technical efficiency (Table 6.17). This finding clearly indicated that there was a direct and positive correlation between technical efficiency and productivity. Similar types of observations were found in the case of area specific technical efficiency and sesame yield (Table 6.18)

Table 6.17 Yield of sesame as affected by different levels of technical efficiency

Producer type	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Adopter	-	-	1,280	1,471	1,458
Non-adopter	654	952	1,067	1,279	1,141
All type	654	952	1,078	1,343	1,209

Table 6.18 Yield of sesame as affected by different levels of technical efficiency by study area

Study area	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Jessore	652	1,001	1,164	1,427	1,328
Faridpur	641	965	1,050	1,275	1,140
Comilla	676	978	1,104	1,301	1,159

6.5 Factors and Technical Efficiency in Soybean Production

6.5.1 Factors affecting soybean production

The maximum likelihood estimates of the parameters of the Cobb-Douglas stochastic production frontier for soybean are presented in Table 6.19. The coefficients of the variables in the frontier production function are the elasticity of average output with respect to the different inputs used in soybean production. The sign and magnitudes of the estimated coefficients in most of the cases were consistent with prior expectation although some of them were insignificant.

The empirical results showed that the coefficients of human labour, urea, TSP, pesticides, soil type, and dummy for soybean variety were positive and significant. It indicated that human labour, urea, TSP, pesticides, loamy soil, and improved variety had significant and positive impacts on soybean production. Again, the negative sign of coefficient of land preparation was anticipated at 5% level of significance implying that if land preparation increases by 1%, the yield of soybean would be decreased by 0.092%. Therefore, the number of land preparation should be reduced to get better yield, since it had negative impact on production.

Table 6.19 Maximum likelihood estimates of frontier production function model for soybean in the study areas

(in hectare)

Independent variable	Parameter	Adopter *(n=56)*	Non-adopter *(n=304)*	All farm *(n=360)*
Constant	β_0	5.500*** (1.008)	7.770*** (0.394)	7.680*** (0.366)
Human labour (man-day)	β_1	0.617*** (0.193)	0.268*** (0.056)	0.286*** (0.050)
Land preparation (Tk)	β_2	-0.008 (0.130)	-0.083* (0.049)	-0.092** (0.042)
Seed (kg)	β_3	0.060 (0.136)	-0.020 (0.045)	-0.0001 (0.038)
Organic fertilizers (kg)	β_4	0.009 (0.017)	-0.001 (0.004)	-0.002 (0.004)
Urea (kg)	β_5	0.008* (0.023)	0.015* (0.008)	0.008** (0.007)
TSP (kg)	β_6	0.003** (0.026)	0.006* (0.009)	0.001* (0.008)
MoP (kg)	β_7	-0.022 (0.021)	0.009 (0.007)	0.001 (0.006)
DAP (kg)	β_8	--	-0.010 (0.014)	-0.008 (0.014)
Gypsum (kg)	β_9	0.024 (0.032)	-0.022 (0.014)	-0.002 (0.011)
Irrigation (Tk)	β_{10}	-0.037 (0.023)	0.009 (0.012)	0.0004 (0.010)
Pesticides (Tk)	β_{11}	0.004* (0.016)	0.006* (0.004)	0.006** (0.003)
Land rent (Tk)	β_{12}	-0.082 (0.073)	-0.052 (0.021)	-0.057 (0.018)
Dummy for soil type (1= Loam, 0 = Otherwise)	β_{13}	0.146 *(0.157)	0.076** (0.039)	0.084** (0.036)
Dummy for soybean variety (1=Improved, 0=Otherwise)	β_{14}	-	-	0.019 ** (0.032)

Note: ***, ** and * indicate significant at 1, 5 and 10% level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

6.5.2 Factors affecting technical inefficiency in soybean production

The signs on the δ parameter in the technical inefficiency effect model are expected to be negative. The coefficients of education, farming experience, HYV seed availability, and innovativeness were negative and significant in the technical inefficiency model for soybean production, which implied that technical inefficiency decreases with the increase in the aforesaid variables. In other words, farmers with higher education, more farming experience, availability of improved soybean seed in the study areas, and more innovativeness tend to be technically more efficient. Again, the coefficients of farm size and family labour were positive and significant at 10% and 5% levels, respectively which implied that technical inefficiency increases with the increase in farm size and use of family labour in the aggregate situation. That is, farmers with larger farm size and more usable family labourer are technically less efficient compared to the farmers with smaller farm size and hired labourer (Table 6.20).

The estimated value of σ^2 (0.423) is large and significantly different from zero, which indicates a good fit and correctness of the specified distributional assumption. The estimated value of γ is 0.985 and significant at 1% level, indicated that about 99% of the difference between the observed output and the maximum production frontier output is caused by differences in farmers levels of technical efficiency as opposed to the conventional random variability, i.e., there were significant technical inefficiency effects in the production of soybean (Table 6.20).

Table 6.20 Maximum likelihood estimates of technical inefficiency model for soybean in the study areas

Independent variable	Para-meter	Adopter *(n=56)*	Non-adopter *(n=304)*	All farm *(n=360)*
Constant	δ_0	-1.98*** (0.699)	-2.244 (1.556)	-2.080 (1.430)
Farm size (ha)	δ_1	0.160*** (0.050)	0.052 (0.064)	0.055* (0.058)
Proportion of family labour to total labour	δ_2	0.190* (0.231)	1.031** (0.438)	0.732** (0.318)
Age (year)	δ_3	0.002 (0.231)	0.001 (0.004)	0.002 (0.004)
Education (year of schooling)	δ_4	-0.027** (0.012)	-0.015* (0.019)	-0.015* (0.017)
Farming experience (Year)	δ_5	0.006 (0.009)	-0.041** (0.021)	-0.040* (0.018)
Training on oilseeds (no./life time)	δ_6	-0.142 (0.047)	-0.213 (0.145)	-0.178 (0.112)
Availability of HYVseed (Score) (Scale,0-4; 0= not available, 4= plenty	δ_7	-0.186* (0.097)	-0.237** (0.112)	-0.207** (0.100)
Dummy for society member (1= Member, 0 = Otherwise)	δ_8	0.038 (0.084)	-0.122 (0.150)	-0.027 (0.122)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently	δ_9	0.092 (0.045)	0.002 (0.050)	0.016 (0.050)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_{10}	-0.161** (0.058)	-0.135* (0.100)	-0.126*** (0.091)
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular	δ_{11}	-0.002 (0.011)	0.008 (0.022)	0.017 (0.017)
Variance parameters:				
Sigma-squared	σ^2	0.038*** (0.008)	0.479*** (0.186)	0.423*** (0.149)
Gamma	γ	0.057*** (0.017)	0.989*** (0.006)	0.985*** (0.006)
Log likelihood function		14.21	44.11	48.16

Note: ***, ** and * indicate significant at 1%, 5%, and 10% percent level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

6.5.3 Technical efficiency of soybean farmers

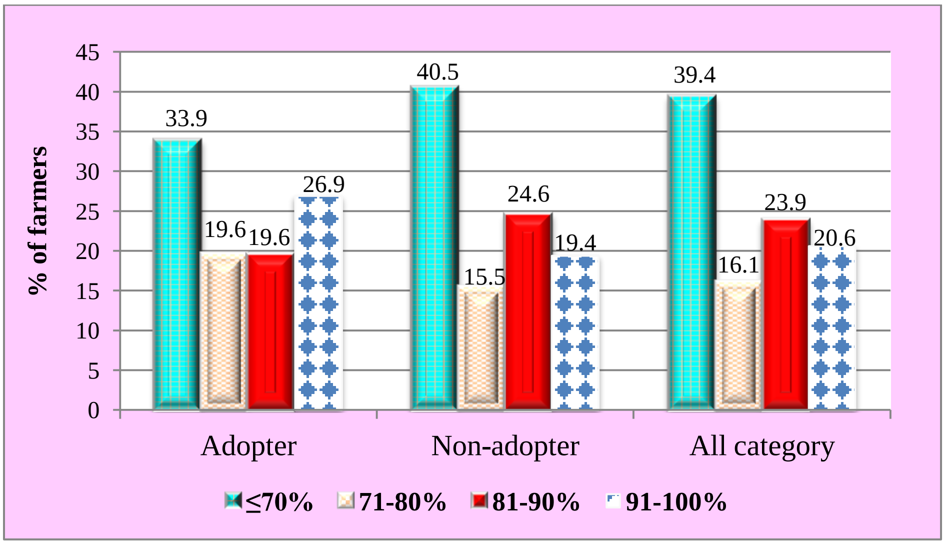
The technical efficiencies estimated for adopters, non-adopters, and overall farms are presented in Table 6.21. It was observed that the mean value of technical efficiency was 0.72 with a range from 0.15 to 0.97. This implied that, on average, the farmers in the study areas were producing soybean to about 72% of the potential (stochastic) frontier production levels, given the levels of their inputs and the technology currently being used. This also indicated that the level of technical inefficiency in soybean production was 28%, i.e., there is a scope to increase the soybean production by 28% without additional investment in inputs. The technical efficiency was higher for improved variety users (0.75) as compared to that of non-adopter (0.71).

Table 6.21 Farm specific technical efficiencies of soybean producers in the study areas

Producer type	No. of farm	Technical efficiency			
		Minimum	Maximum	Mean	St. deviation
Adopter	56	0.40	0.97	0.75	0.19
Non-adopter	304	0.15	0.97	0.71	0.17
All types	360	0.15	0.97	0.72	0.19

The technical efficiencies estimated for different soybean farmers were categorized into four levels, such as 0-70, 71-80, 81-90, and 91-100%. It was observed that 39.4% of the soybean farmers achieved technical efficiency level 0-70% followed by 33% farmers achieved 81-90% and 20.6% farmer's technical efficiency level 91-100%. More or less similar results were observed for non-adopting farmers. In the case of adopters, the same percent of farmers (19.6%) achieved technical efficiency levels 71-80% and 81-90% in the production of improved soybean in the study areas (Fig 6.4).

Figure 6.4 Percent of soybean farmers under different levels of technical efficiency



6.5.4 Yield of soybean under technical efficiency levels

As technical efficiency was defined as technically more efficient farms who obtained higher levels of yield of soybean. The yield of soybean was examined under different farm specific technical efficiency levels. It was found that the highest level of yield of soybean (2,078 k/ha) was obtained by the farmers who had technical efficiency level 91-100% and the lowest yield (1,054 kg/ha) was received by the farmers who had the lowest level of technical efficiency of 0-70% (Table 6.22). This further established the fact that there is a direct and positive correlation between technical efficiency of the farmer and crop yield.

Table 6.22 Yield of soybean as affected by different levels of technical efficiency

Producer type	Yield (kg/ha) as per technical efficiencies level				
	≤70%	*71-80%*	*81-90%*	*91-100%*	*All*
Adopter	1,142	1,561	1,832	2,107	1,598
Non-adopter	1,040	1,578	1,730	2,071	1,519
All type	1,054	1,575	1,819	2,078	1,531

Chapter VII

IMPACTS OF OILSEED RESEARCH AND DEVELOPMENT

7.1 Introduction

A number of high yielding varieties of different oilseeds along with their improved management technologies have been released for farm level use since 1976. The DAE has been involved in disseminating these technologies to the farmers through its countrywide networks. All these initiatives have made the productivity growth of oilseeds increasing to a great extent. Again, the farm level adoptions of these improved technologies have generated employment and additional income for the farmer, and save foreign exchange by producing more of these crops. It is important to state that the rate of adoption of BINA variety oilseeds was found very low than that of BARI released oilseeds variety. Therefore, much emphasis was given in this study on BARI variety in order to estimate the impact of research and development on oilseeds in Bangladesh.

7.2 Impact on Growth of Oilseed Area, Production and Yield

Three improved mustard varieties (i.e., BARI Mustard-6, -7, and -8) were first released in 1994 and the rest eight varieties were released between 2000 and 2009 (see Table 1.1) for farm level use. Besides, BINA also released eight improved mustard varieties between 1991 and 2011 for farm level use. However, a 3-year period was considered for the successful farm level adoption of an improved mustard variety[11]. Table 7.1 revealed that the productivity and production of mustard were significantly increased at national level due to the farm level adoption of improved mustard varieties and their improved cultural management practices, whereas the area under mustard decreased during post-adoption period (1998-2011). The coefficients of variations for area and production were also lower in the post-adoption period than that of pre-adoption period (1981-1997). It indicates that the area and production were more stable in the post-adoption period than that of pre-adoption period.

Table 7.1 Growth rates and structural break of area, production and yield of mustard between two periods

Period	Mean	Std. Dev	CV (%)	GR (%)	Structural break		
					Intercept	Slope	Total
A. Area (ha)							
1981-1997	283,135	74,084	26.17	4.25***	25.14***	40.42***	21.95***
1998-2011	269,858	53,925	19.98	-4.31***			
B. Production (t)							
1981-1997	189,041	50,510	26.71	4.33**	25.79***	41.84***	22.84***
1998-2011	217,592	30,925	14.21	2.16**			
C. Yield (t/ha)							
1981-1997	0.683	0.072	10.67	0.08**	5.57**	6.43**	3.22**
1998-2011	0.822	0.087	10.62	2.15***			

Note: *** and ** indicate significant at 1% and 5% levels, respectively

[11] The concerned scientists of BARI opined that an improved variety needs at least three years for its successful farm level adoption.

The results of chow test also depicted that highly significant structural breaks occurred in the area, production, and yield of mustard between pre- and post-adoption periods.

BARI so far released ten improved groundnut varieties between 1976 and 2010, and among these varieties, Dhaka No.-1 and -4 are very old and low yielders. The first improved groundnut variety (DG-2) was released in 1979 and the rest were released between 1987 and 2010 (see Table 1.3) for farm level use. BINA also released six improved groundnut varieties between 2000 and 2011 for farm level use. The results of chow test shown in Table 7.2 revealed that highly significant structural breaks happened in the production and yield of groundnut between pre- (1981-2001) and post-adoption period (2002-2011).

Like mustard, the productivity and production of groundnut were significantly increased at national level during 2002-2011 due to the farm level adoption of improved groundnut varieties and their improved cultural management practices, whereas groundnut area decreased during post-adoption period. The coefficients of variations for area and production were also lower in the post-adoption period compared to that of pre-adoption period (Table 7.2). It indicated that the area and production of groundnut were more stable in the post-adoption period than that of pre-adoption period.

Table 7.2 Growth rates and structural break of area, production and yield of groundnut between two periods

Period	Mean	Std. Dev	CV (%)	GR (%)	Structural break		
					Intercept	Slope	Total
D. Area (ha)							
1981-2001	31,157	7,533	24.17	2.83***	0.55	0.01	6.95**
2002-2011	30,089	2,649	8.80	2.35***			
E. Production (t)							
1981-2001	34,999	9,084	25.96	3.15***	8.42***	5.79**	6.05***
2002-2011	41,885	8,201	19.57	6.38***			
F. Yield (t/ha)							
1981-2001	1.12	0.063	5.62	0.31	38.97***	50.98***	30.69***
2002-2011	1.38	0.178	12.91	4.03***			

Note: *** and ** indicate significant at 1% and 5% levels, respectively

It was mentioned earlier that Til-6 is a highly adopted BARI old variety of sesame. Up to now, BARI released two improved sesame varieties in 2001 and one variety in 2009 for farm level use. BINA also released three improved varieties between 2004 and 2013. The adoption impact was not magnificent for sesame. The growth rates of area, production, and yield were negative during post-adoption period (2005-2011), whereas these were positive in the pre-adoption period (1981-2004). Significant structural break was found only in the yield of sesame during post-adoption period. However, the productivity was increased due to adoption of improved sesame variety (Table 7.3).

Due to unavailability of time series data and very low adoption of improved soybean variety at farm level, the analyses of growth rates and chow test for identifying structural break in area, production, and yield had not been taken into consideration.

Table 7.3 Growth rates and structural break of area, production and yield of sesame between two periods

Period	Mean	Std. Dev	CV (%)	GR (%)	Structural break		
					Intercept	Slope	Total
G. Area (ha)							
1981-2004	58,742	24,872	42.34	1.42	0.00	0.06	1.88
2005-2011	33,719	4,289	12.71	-2.40			
H. Production (t)							
1981-2004	34,629	15,050	43.46	2.12	0.31	0.43	0.50
2005-2011	31,501	4,834	15.34	-4.08			
I. Yield (t/ha)							
1981-2004	0.237	0.014	6.23	0.704***	4.31**	1.98	17.72***
2005-2011	0.383	0.072	19.05	-1.680			

Note: *** and ** indicate significant at 1% and 5% levels, respectively

7.3 Impact on Income from Oilseed Production

The adoption of improved oilseeds varieties made a lucrative impact on farmers' income in the study areas. The farmers who cultivated improved varieties of oilseeds received higher monetary benefits in most of the cases. Table 7.4 showed that improved mustard variety cultivating farmers got 53.8% and 290.4% higher gross and net incomes, respectively. Almost similar benefits were also received by improved variety groundnut and sesame cultivating farmers in the study areas. The gross income received from improved soybean cultivation was slightly higher, but net income was 12.8% lower than that of income from BARI old variety cultivation. Less adoption of improved variety and overall good performance of BARI old varieties were the main reasons for achieving good monetary benefit.

Table 7.4 Income from the production of different oilseed varieties

Oilseed crop	Variety	Gross income (Tk/ha)	Total cost (Tk/ha)	Net income (Tk/ha)
Mustard	Improved	80,105 (53.3)***	51,245 (14.3)***	28,860 (290.4)***
	BARI old	52,241	44,848	7,393
Groundnut	Improved	146,248 (102.6)***	62,048 (17.9)***	84,200 (330.2)***
	BARI old	72,190	52,616	19,574
Sesame	Improved	56,796 (28.8)***	42,918 (7.1)***	13,878 (245.0)***
	BARI old	44,089	40,066	4,023
Soybean	Improved	48,171(3.4)	44,410 (5.0)	3,761(-12.8)
	BARI old	46,605	42,294	4,311

Note: '***' indicates mean difference is significant at 1% level
Figures in the parentheses are percent higher than corresponding varieties

7.4 Returns to Investment in Oilseed R&D

Bangladesh government has invested a lot of money on the R&D of oilseeds mainly through the Oilseed Research Centre of BARI and BINA since independence for increasing oilseed production. BARI and BINA have released a good number of improved varieties of oilseeds and some of them are being cultivated in the farmers' fields. DAE has contributed to disseminate these improved varieties among farmers. Therefore, an attempt was made to estimate the output of R&D of oilseeds in Bangladesh using economic surplus model.

7.4.1 Adoption status and area under improved variety

The adoption of improved variety is an important factor by which the volume of change in economic surplus is determined. The more the adoption of improved variety over traditional one, higher the change in surplus will be. Apart from this, it gives us feedback as to why and how well an improved variety is being accepted by the farmers. The adoption rates of improved varieties of mustard, groundnut, sesame, and soybean for three years (2009-2011) were estimated using primary data from 64 districts. The adoption rates of the remaining years were estimated by taking expert opinions (Table 7.5).

Table 7.5 Adoption status and areas under improved varieties of oilseeds in Bangladesh

Year	% of area replaced by improved varieties over old ones				Area coverage (ha) of improved varieties replacing old ones			
	Mustard	Groundnut	Sesame	Soybean	Mustard	Groundnut	Sesame	Soybean
1997-98	6.0	-	-	-	20,626	-	-	-
1998-99	6.0	-	-	-	20,648	-	-	-
1999-00	8.0	-	-	-	26,313	-	-	-
2000-01	8.0	-	-	-	25,416	-	-	-
2001-02	10.0	5.00	-	-	30,306	1,424	-	-
2002-03	12.0	7.00	-	-	35,707	1,867	-	-
2003-04	15.0	7.00	-	-	41,885	1,823	-	-
2004-05	18.0	8.00	5.0	-	43,478	2,308	1,946	-
2005-06	20.0	8.00	7.0	8.0	43,363	2,354	2,147	3,249
2006-07	21.0	9.00	8.0	10.0	44,214	3,030	2,883	3,923
2007-08	22.0	9.00	9.0	12.0	51,414	2,798	1,051	4,727
2008-09	23.9	8.95	6.4	14.5	55,931	2,802	2,109	5,828
2009-10	29.4	12.18	12.5	50.9	51,357	4,093	4,446	20,716
2010-11	30.0	9.05	11.2	21.6	6,920	2,875	3,891	8,955
2011-12	35.0	12.00	13.0	30.0	6,666	3,606	2,850	12,630
GR (%)	13.1***	6.74***	11.9***	24.82**	-2.11	8.51***	9.09	25.72**

Note: Adoption rates for three years (2009-2011) were estimated using 64 districts DAE data. Adoption rates of the remaining years were estimated through expert opinions. See also Appendix A-38.
'***' and '**' represent significant at 1% and 5% level of confidence, respectively

The first improved varieties of mustard, groundnut, sesame, and soybean were released for farm level use in 1994-95, 1998-99, 2001-02, and 2002-03 respectively. For the adoption of any new variety to a certain level requires at least three years (FGD, 2013). The area covered by improved varieties of mustard was 6% during 1997-98 and then gradually increased to 35% in 2011-12. The annual rate of adoption of improved variety mustard was 13.09%, but due to less area planted to mustard throughout the country during 2010/11-2011/12, the annual growth rate became negative. Again, 5, 5, and 8% of the total groundnut, sesame, and soybeans areas were planted with improved varieties during 2001-02, 2004-05, and 2005-06 respectively. Then the adoptions of these varieties gradually increased to 12, 13, and 30% in 2011-12. The annual rates of adoption of improved varieties of groundnut, sesame, and soybean were 6.74, 11.95, and 24.82% respectively (Table 7.5).

7.4.2 Yield advantage of improved varieties of oilseeds over old varieties

This is an important factor to determine the economic surplus. The higher yield advantage always ensures higher level of economic surplus. The yields of the improved varieties of mustard, groundnut, sesame, and soybean were much higher compared to their corresponding BARI old varieties. The farm level yield data revealed that the adopters of improved mustard, groundnut, sesame, and soybean received on an average 46.39, 48.73, 27.78, and 5.20% higher yield than that of non-adopters (Table 7.6).

Table 7.6 Yield advantages of improved varieties of oilseeds over old ones

Oilseed crop	Yield of old variety (t/ha)	Yield of improved variety (t/ha)	Yield difference (t/ha)	Yield advantage (%)
Mustard	1.121	1.641	0.520	46.39
Groundnut	1.613	2.399	0.786	48.73
Sesame	1.141	1.458	0.317	27.78
Soybean	1.519	1.598	0.079	5.20

7.4.3 Supply shifter and additional oilseed production

The supply shifter (k) identifies the amount of production that can be attributed to the varietal improvement research in each year (i.e., the shift in the supply curve). The more the value of supply shifter, the more is the shift in the supply curve, resulting higher benefit to the society. The supply shifter is the outcome of the simultaneous force of the percentage of improved variety adoption and its yield advantage. It was calculated using the formula discussed in methodology section. It was found that the rate of shift gradually increased. The shifter accounted for the yield advantage of improved oilseed varieties over the BARI old oilseeds varieties. The supply shifter of mustard was found to be 0.019 for the year 1997-98, meaning that about 2% more mustard production was made during 1997-98 because of farmers' adoption of improved varieties of mustard. Due to the adoption of improved varieties, the total amount of additional production of mustard, groundnut, sesame, and soybean were estimated at 140.53, 14.36, 4.95, and 4.81 thousand metric ton respectively (Table 7.7).

Table 7.7 Supply shifter (k) and amount of additional oilseed production in different years due to improved variety adoption

Year	Supply shifter (k)				Additional production (ton)			
	Mustard	Groundnut	Sesame	Soybean	Mustard	Groundnut	Sesame	Soybean
1997-98	0.019	-	-	-	4819	-	-	-
1998-99	0.019	-	-	-	4798	-	-	-
1999-00	0.025	-	-	-	6227	-	-	-
2000-01	0.025	-	-	-	5942	-	-	-
2001-02	0.032	0.016	-	-	7448	477	-	-
2002-03	0.038	0.023	-	-	8283	788	-	-
2003-04	0.048	0.023	-	-	10107	784	-	-
2004-05	0.057	0.026	0.011	-	10908	1011	410	-
2005-06	0.063	0.026	0.015	0.004	11558	987	588	246
2006-07	0.067	0.029	0.017	0.005	12655	1331	496	289
2007-08	0.070	0.029	0.020	0.006	15955	1284	541	355
2008-09	0.076	0.029	0.014	0.007	15406	1349	398	416
2009-10	0.093	0.040	0.027	0.025	14066	2139	872	1738
2010-11	0.095	0.030	0.024	0.011	5982	1742	753	725
2011-12	0.111	0.039	0.028	0.015	6376	2468	891	1039
Total	-	-	-	-	140530	14360	4949	4808

7.4.4 Research and extension expenditure

The total expenditures of the development of improved oilseeds varieties, and the extension of these improved varieties to the farmers' fields included the costs incurred by different institutes, such as ORC of BARI, BINA, BARC, and DAE (Table 7.8). These institutional costs included infrastructure, salaries & wages, vehicles, repair & maintenance, research & development, training, higher education, etc. DAE expenditure for the dissemination of oilseed technologies was estimated based on the percentage of oilseeds cropped area relative to total cropped area (for detailed information, see methodology section). For the analysis, the current total expenditures were converted to 2011-12 constant prices (inflated price) using the national CPI Index. The total cost for R&D of oilseeds was estimated at Tk 2,461.69 million during the period from 1992-93 to 2011-12. The highest share of the total cost was for DAE (84.12%) followed by BARI (14.34%).

Table 7.8 Expenditures for oilseed research and development in Bangladesh

(Figures in Taka)

Year	ORC, BARI (current price)	BINA (current price)	BARC (current price)	DAE (current price)	Total Expenditure (current price)	Total Expenditure (Base:2011-12=100)
1992-93	7754625	15973	1434943	34267234	43472775	154707384
1993-94	7745999	4510	851361	38831330	47433200	163958521
1994-95	8045249	3428	240383	35030542	43319602	137043980
1995-96	7464001	5225	182712	40213301	47865239	141529388
1996-97	8028000	13517	278493	43429552	51749562	147602858
1997-98	10082250	23635	720456	45620889	56447230	145745494
1998-99	2253155	24310	756480	43792928	46826873	110623371
1999-00	2312010	31443	794302	43346580	46484335	106958893
2000-01	4992431	40668	834017	43569283	49436399	112176989
2001-02	2064001	52600	875719	44225560	47217880	105420585
2002-03	4427325	68033	919503	45746164	51161025	110427423
2003-04	2414250	87993	965480	45523078	48990801	98891403
2004-05	4178250	113810	1013755	43334319	48640134	90984164
2005-06	6042375	119501	1064440	47903479	55129795	95694836
2006-07	6489000	125476	1117665	50640587	58372728	93711235
2007-08	15924150	131750	1173548	52019342	69248790	99025869
2008-09	19874624	138338	1099270	125976012	147088244	196222311
2009-10	26031056	146637	1119445	123593820	150890958	185483661
2010-11	13840326	158368	1338033	66862097	82198824	88547694
2011-12	22034353	171038	1228739	53498774	76932904	76932904
Total	**181,997,430**	**1,476,253**	**18,008,744**	**106,742,4871**	**1,268,907,298**	**2,461,688,961**
% share	14.34	0.12	1.42	84.12	100.0	

7.4.5 Economic returns to oilseeds R&D

The efficiency of resource allocation to R&D for oilseeds improvements was assessed through NPV, BCR, and IRR under both closed and small open-economy market condition. The return to investment in R&D of sesame was estimated under closed economy market situation, since no international trade was present for sesame during the study period. Small open-economy market situation was considered for the rest oilseed crops, namely mustard, groundnut, and soybean. Under small open-economy, the producers' benefits were much higher compared to consumers' benefits, since the elasticity of demand for oilseeds was very high. The opposite scenario was found in the closed-economy situation, because the elasticity of demand for oilseeds was low. In estimating economic benefits, related costs incurred by different organizations were taken into consideration.

The total changes in consumers' and producers' surplus were estimated at Tk 281.80 million and Tk 6,704.88 million, respectively from oilseeds R&D during 1997-98 to 2011-12. Producers' surplus was about 2279.3% higher than that of consumers' surplus, because the elasticity of demand for oilseeds was very high under small-open economy market. The estimated total surplus/benefits ranged from Tk 246.10 million in 1997-98 to Tk 491.03 million in 2011-12, and the total surplus accrued as Tk 6,986.68 million from the oilseeds R&D in Bangladesh. Besides, the total net benefits (NPV) obtained from oilseeds R&D was Tk 4,769.04 million for the year 1992-93 to 2011-12. The NPV indicates the total social benefit for a country, and it was found negative up to 1996-97 and then it was positive. It means that the country did not receive any benefit from oilseeds R&D up to that period. After that the country as a whole benefited with a big amount and found increasing trend up to 2011-12. Using the base parameters, the IRR of the oilseeds R&D was estimated to be 24%, implying one Taka invested in R&D gave returns on an average Taka 1.24 annually from the date of investment until 2011-12. The benefit cost ratio (BCR) of the project is estimated at 3.15 implying that one taka investment returned 3.15 taka over the period (Table 7.9).

Table 7.9 Distribution of financial benefits and costs of oilseeds R&D in Bangladesh

(Base: 2011-12 = 100 Tk)

Year	Change in consumer surplus (Taka)	Change in producer surplus (Taka)	Change in total surplus (Taka)	Research and extension costs (Taka)	Net benefit (Taka)
A	*B*	*C*	*D = B+C*	*E*	*F = D-E*
1992-93	0	0	0	105,763,671	-105,763,671
1993-94	0	0	0	116,155,185	-116,155,185
1994-95	0	0	0	94,982,205	-94,982,205
1995-96	0	0	0	101,045,204	-101,045,204
1996-97	0	0	0	120,365,890	-120,365,890
1997-98	0	246,103,789	246,103,789	118,935,701	127,168,088
1998-99	0	216,467,424	216,467,424	99,915,862	116,551,562
1999-00	0	269,006,357	269,006,357	106,958,893	162,047,464
2000-01	0	222,677,183	222,677,183	112,176,988	110,500,195
2001-02	0	285,145,190	285,145,190	105,420,584	179,724,606
2002-03	0	326,470,137	326,470,137	110,427,421	216,042,716
2003-04	0	459,611,115	459,611,115	98,891,403	360,719,712
2004-05	20,891,610	409,238,855	430,130,466	90,984,163	339,146,303
2005-06	28,941,516	437,854,633	466,796,149	95,694,837	371,101,312
2006-07	28,935,240	579,083,343	608,018,583	93,711,236	514,307,347
2007-08	39,256,718	966,459,852	1,005,716,570	99,025,870	906,690,700
2008-09	18,796,987	774,613,705	793,410,692	196,222,309	597,188,383
2009-10	49,378,061	750,606,866	799,984,927	185,483,663	614,501,264
2010-11	39,369,829	326,741,349	366,111,178	88,547,694	277,563,484
2011-12	56,227,322	434,800,366	491,027,688	76,932,902	414,094,786
Total	**281,797,284**	**6,704,880,163**	**6,986,677,447**	**2,217,641,681**	**4,769,035,766**

Note: See also Appendix A-39

Results: Net present value (NPV) = Tk. 4769.036 Million
Benefit-cost ratio (BCR) = 3.15
Internal rate of return (IRR) = 24%

A sensitivity analysis was undertaken under various assumptions on the adoption of improved varieties of oilseeds and the R&D expenditures (Table 7.10). The estimated NPV, BCR, and IRR of the oilseeds development program ranged from Tk 4,070.01 to Tk 5,468.15 million, 22 to 26%, and 2.84 to 3.50 respectively. However, it is clearly apparent that the investment on oilseed R&D was a good effort.

Table 7.10 Sensitivity analysis on the benefits of oilseed R&D in Bangladesh

Scenario	NPV (Million taka)	BCR	IRR (%)
Base parameters	4769.036	3.15	24
Adoption increased by 10%	5468.145	3.47	26
Adoption decreased by 10%	4070.007	2.84	22
Expenditure increased by 10%	4547.272	2.86	22
Expenditure decreased by 10%	4990.800	3.50	26

7.4.6 Foreign exchange savings

A considerable amount of oilseeds are imported in Bangladesh every year to meet the internal demand of its increasing population. Bangladesh Bank (2012) stated that in 2011-12, the values of total imports of oilseeds and edible oils were Tk 14,200 million (US$182.05 million) and Tk 130,510 million (US$1,673.21 million) respectively. Thus, the increased production attributed to adoption of improved varieties of oilseeds (see Table 7.7) saved foreign exchange amounting US$ 97.105 million during the period from 1997-98 to 2011-12 (Table 7.11).

Table 7.11 Foreign exchange savings due to adoption of improved varieties of oilseeds in Bangladesh

Year	Mustard *(Base: 2011-12 =100)*		Groundnut *(Base: 2011-12 =100)*		Soybean *(Base: 2011-12 =100)*		Total Savings ($)
	Price ($/ton)	Savings ($)	Price ($/ton)	Savings ($)	Price ($/ton)	Savings ($)	
1997-98	683.19	3,292,299	--	--	--	--	3,292,299
1998-99	546.40	2,621,615	--	--	--	--	2,621,615
1999-00	534.22	3,326,559	--	--	--	--	3,326,559
2000-01	481.78	2,862,731	--	--	--	--	2,862,731
2001-02	554.97	4,133,399	1,232.8	588,023	--	--	4,721,422
2002-03	555.00	4,597,038	1,002.1	789,684	--	--	5,386,722
2003-04	505.25	5,106,545	1,386.0	1,086,617	--	--	6,193,162
2004-05	581.78	6,346,065	1,419.5	1,435,125	--	--	7,781,190
2005-06	616.75	7,128,403	1,190.0	1,174,549	477.02	117,346	8,420,298
2006-07	506.34	6,407,749	802.7	1,068,390	446.19	128,948	7,605,087
2007-08	571.79	9,122,847	1,072.5	1,377,091	440.48	156,372	10,656,310
2008-09	642.10	9,892,231	1,334.1	1,799,627	461.23	191,873	11,883,731
2009-10	534.73	7,521,463	1,075.6	2,300,706	401.97	698,618	10,520,787
2010-11	652.81	3,905,087	1,010.5	1,760,202	361.95	262,415	5,927,704
2011-12	521.00	3,321,896	907.0	2,238,476	332.00	344,948	5,905,320
Total		**79,585,927**		**15,618,490**		**1,900,520**	**97,104,937**

Note: Import prices of oilseeds are taken from FAOstat. See also Appendix A-40

7.5 Impact on Employment Generation

The adoptions of improved oilseed varieties at farm level have created a lot of additional employments for the farmers as well as for the society. It was estimated that the per hectare cultivation of an improved mustard, groundnut, sesame, and soybean variety created an additional employment of 12.7, 11.6, 15.4, and 6.1 man-days for the respondent farmers, respectively (Appendix A-41). The additional labour mainly required for harvesting and threshing the increased production of oilseeds. The national level employments created due to improved variety adoption were estimated based on the above estimates and varietal adoption rates, and presented in Table 7.12. During 2011-12, a total of 1.414 million man-days of additional farm labour valuing Taka 353.56 million were generated due to cultivation of improved varieties of oilseeds. The number of additional employment created by improved mustard was much higher compared to that of other oilseeds which was due to higher area coverage and adoption.

Table 7.12 Additional employment created at national level due to improve variety adoption

(Man-days)

Year	Mustard	Groundnut	Sesame	Soybean	All oilseeds
1998	261,952	--	--	--	261,952
1999	262,228	--	--	--	262,228
2000	334,171	--	--	--	334,171
2001	322,788	--	--	--	322,788
2002	384,887	16,514	--	--	401,401
2003	453,473	21,654	--	--	475,128
2004	531,942	21,142	--	--	553,084
2005	552,171	26,775	29,971	--	608,916
2006	550,707	27,305	33,071	19,821	630,904
2007	561,522	35,147	44,404	23,931	665,005
2008	652,956	32,455	16,185	28,833	730,429
2009	710,319	32,506	32,473	35,553	810,850
2010	652,234	47,476	68,466	126,367	894,543
2011	961,437	39,988	59,921	54,554	1,115,901
2012	1,227,309	43,394	66,466	77,080	1,414,249
Total	**8,420,098**	**344,356**	**350,958**	**366,138**	**9,481,549**

7.6 Impact on Livelihood Development

A livelihood is a means of making a living. It encompasses people's capabilities, assets, income, and activities required to secure the necessities of life (http://www.ifrc.org). In another words, livelihood is defined as a set of activities, involving securing water, food, fodder, medicine, shelter, clothing, and the capacity to acquire above necessities working either individually or as a group by using endowments for meeting the requirements of a household (http://en.wikipedia.org/wiki/Livelihood). Livelihood development is a broad issue usually which depends on the wider economic development of the society. In this section, the scenario of livelihood development through adopting improved oilseeds varieties will give a glimpse of the livelihood development of a respondent household.

A total of 13 socio-economic indicators were used to measure the impact of improved oilseed variety adoption on the livelihood of adopting households. The results of the present study in this regard depicted that the livelihood status of the adopting households was better to some extent than that of non-adopting households (Table 7.13). Among thirteen indicators, the highest percentage of the adopting households owned assets and having social standard much higher compared to that of non-adopting households. Obviously, there were some positive impacts of cultivating improved oilseeds on the livelihoods of its adopters.

Table 7.13 Livelihood status of adopter and non-adopter households in the study areas

(Figures in percent)

Particulars	Mustard		Groundnut		Sesame		Soybean	
	Adopter (n=197)	N-adopter (n=343)	Adopter (n=95)	N-adopter (n=445)	Adopter (n=116)	N-adopter (n=424)	Adopter (n=56)	N-adopter (n=304)
1. Housing status								
Concrete building	3.6	7.9	5.3	1.4	10.3	4.5	--	1.3
Brick wall-tin roof	58.9	45.5	26.3	7.0	26.7	17.0	3.6	5.3
Tin wall-Tin roof	11.2	11.1	60.0	81.8	35.3	62.0	75.0	80.9
Earthen wall-Tin roof	21.3	16.9	--	0.5	16.4	10.9	--	--
Bamboo wall-Tin roof	1.0	1.8	8.4	7.9	3.5	3.3	19.6	11.2
Katcha (straw roof)	6.6	19.5	--	1.6	7.8	2.4	1.8	1.3
2. Motorcycle	23.4	18.4	20.0	9.2	6.9	5.7	32.1	5.9
3. Bicycle	74.6	70.3	69.5	57.1	58.6	45.1	69.6	37.2
4. Hand tube well	93.9	93.6	90.5	85.2	98.3	94.8	91.1	75.7
5. Water pump	12.2	6.1	10.5	5.4	6.0	4.0	5.4	1.0
6. Electricity	81.2	78.4	71.6	42.5	75.9	75.2	62.5	29.9
7. Television	71.1	62.1	53.7	27.4	58.6	46.0	53.6	18.8
8. Gas	1.0	0.9	2.1	0.5	1.7	1.4	--	--
9. Land phone	3.1	1.2	1.1	0.5	2.6	--	--	0.7
10. Mobile phone	85.3	77.6	73.7	70.6	66.4	65.1	83.9	60.9
11. Sanitation status	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Flush toilet	2.6	3.8	2.1	1.6	2.6	1.9	--	0.7
Sanitary toilet	75.6	74.6	62.1	54.8	75.8	66.5	62.5	87.8
Temporary toilet	21.8	21.6	35.8	43.6	21.6	31.6	37.5	11.5
12. Expenditure (Tk/month)	**9118**	**8516**	**11175**	**10371**	**9200**	**9480**	**12193**	**10669**
Food	6153	5850	6953	7019	6451	6667	8446	7271
Education	1295	1180	2159	1398	926	909	1214	1148
Transportation	829	697	981	875	772	841	1120	942
Treatment	841	789	1083	1078	1051	1063	1413	1308
13. Doctor's visit								
Specialist	4.1	7.0	1.1	0.2	1.7	--	1.8	1.3
MBBS	54.8	56.0	42.1	58.7	80.2	77.1	62.5	71.7
Village doctor	70.1	74.9	90.5	93.5	98.3	97.9	96.4	99.3
Quack	--	1.2	2.1	2.5	--	0.5	--	--

Chapter VIII

CONSTRAINTS AND OPPORTUNITIES IN OILSEEDS RESEARCH AND DEVELOPMENT

8.1 Introduction

A strengths, weaknesses, opportunities, and threats (SWOT) analysis has been conducted and is presented in this section to explore the constraints and investment opportunities with respect to Research and Development (R&D) of oilseeds in Bangladesh.

8.2 Strengths

8.2.1 Research capability

BARI, BINA, and different agricultural universities (e.g., BAU, BSMRAU, etc.) have sufficient staff and adequate technical capacity to develop improve oilseed varieties that can be grown under various biotic and abiotic stress conditions. The scientists continue their efforts in evolving new varieties with short duration, new cropping patterns, crop and soil management technologies, and in providing farmers' training in association with DAE.

8.2.2 Availability of inputs

The Government of Bangladesh has taken a number of steps to increase the supply of different inputs, especially fertilizer and electricity (for irrigation) at farm level. It also formulates farmer's friendly agricultural credit policy, provides 100 hours free supplementary irrigation, supports for accelerated mechanization of agriculture, and facilitates surface water irrigation for the farmers (Ahmed, 2010). However, oilseed farmers will directly or indirectly be benefited through this government programme.

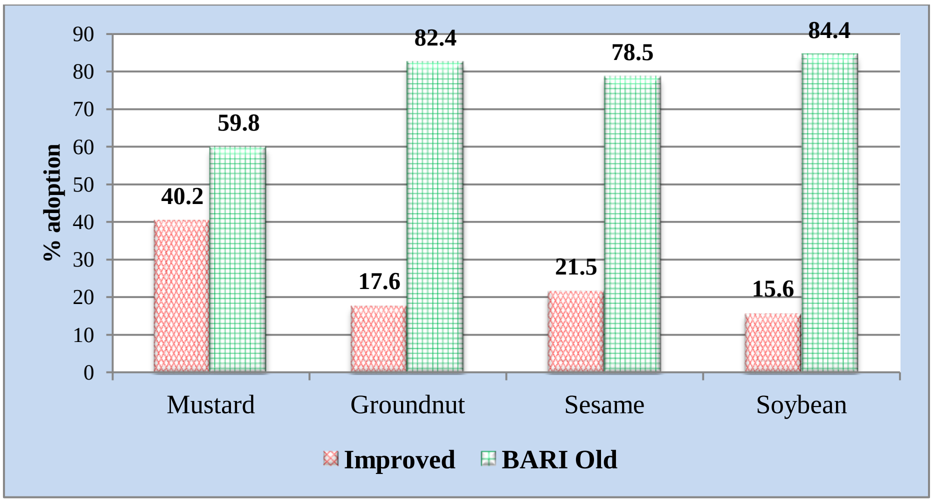
8.2.3 Availability of good varieties

BARI and BINA have so far developed 24 varieties of improved mustard, 16 varieties of improved groundnut, 7 varieties of improved sesame, and 8 varieties of improved soybean which are available to some extent for cultivation. Many of these varieties are very short duration and can be fitted extensively used cropping pattern *T.Aman- winter crops- Boro rice*. These varieties are being cultivated to some extent throughout the country (Fig 8.1). The availability of BARI and BINA varieties at local markets is playing an important role in the expansion of oilseed cultivation in Bangladesh.

8.2.4 Higher productivity of oilseeds

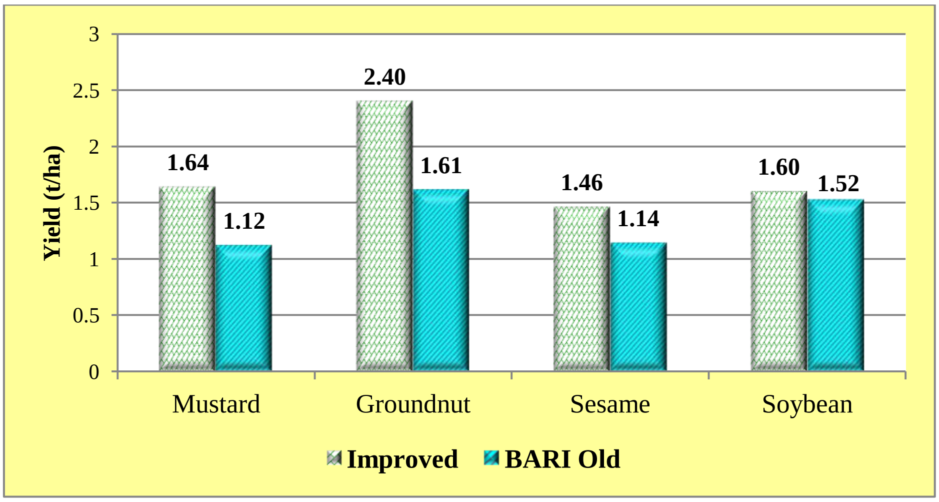
Higher productivity is one of the major strengths of BARI and BINA released oilseed varieties in Bangladesh. The yield advantage of improved varieties of oilseeds ranged from 5-49% (Fig 8.2).

Figure 8.1 Overall adoptions of improved oilseeds at farm levels, 2012



Source: field survey, 2012

Figure 8.2 Yield advantages of improved oilseeds at farm levels, 2012



Source: field survey, 2012

8.2.5 Higher profitability

The profitability of improved oilseed cultivation is much higher than that of its traditional variety. It was also reported that the profitability of improved mustard cultivation was higher compared to its competing crops like cabbage, carrot, maize, onion, potato, and wheat (see Table 5.3). Again, the profitability of improved groundnut cultivation was much higher than that of its competing crops, such as pulses, chilli, brinjal, wheat and onion (see Table 5.6). Sesame cultivation is also more remunerative than *Aus* rice cultivation (see Table 5.9).

8.2.6 Farmers' higher interest

Due to its higher profitability and existing/ assured markets farmers are interested to cultivate oilseed crops in future. The respondent farmers were asked to mention the possibility of expanding their cultivated area for improved oilseed crops. In the case of adopters, the highest percentage (92.63%) of groundnut farmers and the lowest (51.78%) percentage of mustard farmers showed their interest to increase oilseed cultivation in the next year. In the case of non-adopters, soybean farmers showed the highest (85.53%) and mustard farmers showed the lowest (46.65%) level of interest to expand their cultivable area (Table 8.1).

Table 8.1 Willingness of farmers to increase oilseed cultivation in the next year

(Figures in %)

Particulars	Mustard	Groundnut	Sesame	Soybean
A. Adaptor	*n=197*	*n=95*	*n=116*	*n= 56*
1. Increase	51.78	92.63	77.59	85.71
2. Not increase	47.72	3.16	17.24	7.14
3. Decrease	0.51	4.21	5.17	7.14
B. Non- adaptor	*n=343*	*n=445*	*n=424*	*n= 304*
1. Increase	46.65	81.12	80.90	85.53
2. Not increase	51.60	16.18	14.62	7.89
3. Decrease	1.75	2.70	4.48	6.58
C. All category	*n=540*	*n=540*	*n=540*	*n=360*
1. Increase	48.52	83.15	80.19	85.56
2. Not increase	50.19	14.07	15.19	7.78
3. Decrease	1.30	2.78	4.63	6.67

Oilseed farmers mentioned various reasons behind their eagerness to increase oilseed cultivation in future. The highest percentage of farmers mentioned higher yield and good price of the produces as the reasons for increasing oilseed cultivation in the next year. The other reasons were low cost but high profit, easy cultivation, needs less labour, and available lands for oilseed cultivation (Table 8.2).

Table 8.2 Reasons for increasing oilseed cultivation in the next year

Reasons	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*
1. Higher yield and good product price	38.9	87.0	77.4	86.7
2. Low cost, but high profit	34.1	33.7	18.5	--
3. Easy cultivation and needs less labour	14.6	12.8	30.9	6.4
4. Availability of cultivable land	3.9	18.3	4.4	8.1
5. Others*	3.1	--	--	0.3

*Creates new cropping patterns, invest mustard income on *Boro* cultivation, less attack of insects, due to early soil moisture, and family consumption.

8.2.7 Availability of extension facilities

Bangladesh Government has a strong agricultural extension network (DAE) throughout the country for disbursing agricultural inputs to the farmers. A total of 63 Multi Location Test (MLT) sites under the On-Farm Research Division (OFRD) of BARI are available which can play a crucial role in diffusing improved varieties and production technologies of oilseeds at farm level.

8.3 Weaknesses

The weaknesses involved in oilseed cultivation are related to input, production, post-harvest management, market access, and enabling environment. All these issues are briefly discussed below.

8.3.1 Lack of adoption of improved varieties

BARI and BINA has developed a good number of improved oilseed varieties, but unfortunately few of them are currently available in the farmers' fields. Most of the farmers used BARI released old varieties or local cultivars of oilseeds. The concerned scientists and policy makers have no information or very shallow knowledge about the adoption rate and total area coverage of improved varieties. Most of the BARI released old varieties and some improved varieties of oilseeds are long duration which cannot be fitted successfully in the cropping pattern *T.Aman* –Oilsees- *Boro* rice (FGD, 2013).

8.3.2 Lack of availability of improved varieties

There is a good demand for improved and short-duration oilseed varieties throughout the country. But the non-availability of such oilseed varieties compels farmers to use local or traditional varieties of oilseeds. Hybrid of oilseeds generally requires long duration for cultivation which is unexpected in our cropping patterns. Therefore, the lacking of short-duration hybrids of oilseeds is also a constraint to expand oilseed areas in Bangladesh. Again, the existing seed companies or NGOs closely working with farmers are not interested from business point of view to produce and market improved seeds of oilseeds. They usually wanted more profit from their business (Table 8.3).

8.3.3 Non-availability of short-duration variety

Short-duration rice variety, especially *T. Aman* or *Boro* rice is very much important for the expansion of oilseeds cultivation over the country. Most of the mustard farmers opined that they wanted to cultivate *Boro* rice just after harvesting of oilseed crops. The gap between *T.Aman* and *Boro* rice cultivation is very low (80-90 days). Therefore, they need short duration variety of mustard, groundnut, and soybean so that they can successfully cultivate *Boro* rice. They also need short duration varieties of *T.Aman* and *Boro* rice. But, due to the un-availability of short-duration oilseed as well as rice varieties (i.e., BINAdhan-7, BRRIdhan-33), farmers cannot cultivate mustard at their desired level. The highest 40.8% soybean farmers followed by 39.8% groundnut, 26.9% mustard, and 22.2% sesame farmers encountered lack of short duration varieties of oilseeds and rice as a crucial problem (Table 8.3).

8.3.4 Insects and diseases infestation

With the expansion of modern variety adoption, pest management to 'seed to seed' is getting increasing importance. Infestations of different insects and diseases were reported to be the problems of oilseed cultivation. The important insects were pod borer, jessed, stem borer, leaf eater, leaf hopper, cater pillar, and hoq moth. The highest 55.8% soybean farmers mentioned insect infestation problem which followed by groundnut (43%), sesame (37.8%), and mustard (19.4%) farmers.

Oilseed farmers also found various symptoms of different diseases during oilseed cultivation. The symptoms were black spots on leaf and siliqua (pod), leaf becomes yellow or curl or white, white spot on leaf, flowers fall off, and plant becomes dry. About 20% groundnut farmers and 13.9% mustard farmers encountered this disease problem during cultivation (Table 8.3).

8.3.5 Lack of cash and access to financial institutions

Most of the farmers of our country are poor. Cultivation of oilseeds generally needs low cost compared to the costs incurred for cultivating other crops. But this cost was also burden to many small and marginal farmers. They do not have enough access to state owned financial institutions due to complicated rules and regulations. Therefore, lack of cash money and lack of access to finance leads to inferior input purchase and improper post-harvest management resulting in low income. Sometimes they borrow money from informal sources at very high interest rates. They have to sell oilseeds quickly after harvest at lower price to repay the loan. The highest percentage of soybean farmers (38.9%) followed by sesame and groundnut farmers in the study areas raised this as a major problem (Table 8.3).

8.3.6 Unsuitable weather

Unsuitable weather is very much damaging to oilseeds, especially mustard crop. More than 12% mustard growing farmers, 7.2% sesame farmers, and 4.2% soybean farmers faced this problem (Table 8.3).

8.3.7 Attack by birds and animals

Oilseed farmers in the study areas also faced the problems of birds and foxes. Foxes generally take soil away from the soil beds which is harmful to groundnut production. On the other side, birds like pigeon, crow, and *Shalik* were reported to be harmful to mustard and sesame crops (Table 8.3).

Table 8.3 Problems and constraints to oilseed production in the study areas

Problems and constraints	**Mustard** *(n=540)*	**Groundnut** *(n=540)*	**Sesame** *(n=540)*	**Soybean** *(n=360)*
1. Lack of short duration improved variety (oilseeds & rice)	26.9	39.8	22.2	40.8
2. Incidence of insects*	19.4	43.0	37.8	55.8
3. Infestation of diseases**	13.9	19.6	--	1.9
4. Foggy/unsuitable weather	12.4	2.2	7.2	4.2
5. Higher production cost	9.8	18.5	22.8	38.9
6. Lack of cash/access to credit	1.7	25.9	8.9	32.2
7. Damage by birds and foxes	8.1	6.3	9.4	--
8. Lack of irrigation and its high price	2.0	2.6	1.3	0.8
9. Scarcity of power tiller	0.7	4.1	1.7	7.5
10. Lack of technical knowledge	3.3	3.7	0.6	--
11. Scarcity of labour and its high price	--	1.7	1.5	--
12. Other problems***	2.8	19.6	6.9	28.9

Note: *Pod borer, jessed, stem borer, leaf eater, leaf hopper, cater pillar, and hoq moth.

**Alternaria leaf spot, white mould on leaf, leaf becomes yellow in color, flowers are fallen off, leaf becomes white, and plant dried.

***Problems related to adulteration of fertilizers, water logging, salinity, storage, nodule formation in the stem, and lack of suitable cultivable land.

8.3.8 Lack of irrigation and its high price

Some oilseed farmers were lacking adequate irrigation facilities. The areas with adequate irrigation facilities during oilseed cultivation were suffering from high prices of irrigation. The load shedding of electricity, the high price of diesel, high labour prices, low water aquifers, low discharge of water, etc. make irrigation cost very high to the farmers (Table 8.3).

8.3.9 Lack of availability of power tiller

Most of the tillage operations in the study areas are done by power tiller (PT). The well-off farmers generally buy PT for their own use as well as use as custom hiring basis. In the peak period of cultivation (generally winter season), some small and marginal oilseed farmers could not plough their lands timely due to lack of availability of PT (Table 8.3).

8.3.10 Lack of proper technical knowledge

Although technical knowledge on planting time, seed rate, plant spacing, fertilization, irrigation plays a significant role in getting higher yield, many farmers still are not aware of the improved methods of oilseed cultivation leading to lower yield. Oilseed farmers cultivate oilseeds based on their experience because they have no formal training on oilseed cultivation. Lack in oilseed related technical knowledge dissemination to oilseed farmers is also a problem (Table 8.3).

8.3.11 Lack of cultivable land for small holders

Most of the farmers of Bangladesh are small holders. They cannot expand their oilseed production, even if they have the investment capacity and opportunity only because of the lack of enough cultivable land. The land and property rights are also not in favour of small farmers.

8.3.12 Adulteration in fertilizers

It is currently a common problem in Bangladesh. Oilseed farmers mentioned that they could not get good response of the application of balanced fertilizer dose because of adulteration. This problem increase production cost and decreases yield (Table 8.3). The Soil Resource Development Institute (SRDI) carried out thorough laboratory tests on 17 different brands of fertilizers in its laboratories across the country in 2011. Of these, 14 brands were found to be highly adulterated. The percentages of fertilizers which were adulterated were urea 2%, TSP 25%, DAP 21%, SSP 33%, MoP 11%, mixed fertilizer (NPKS) 80%, zinc sulphate 80%, SoP 30%, boron 40%, magnesium sulphate 14%, gypsum 21%, organic 47%, and other fertilizers 29% (Khan, 2012).

8.3.13 Lack of storage facilities

This is one of the major reasons for quality deterioration. Small-scale producers do not have enough storage space to store oilseeds in their homestead. Most of them are exposed to bad weather and other destructive forces. On the other hand, there are no warehousing facilities in the producing areas where they can store their produces for the time being. Therefore, lack of storage facility compels farmers to sell oilseeds just after harvesting and as a results those is a low chance for farmers to benefit from higher prices at later time (Table 8.3).

8.3.14 Lack of stress tolerant varieties

Many areas of Bangladesh are prone to various biotic and abiotic stresses. The prominent abiotic stresses are heat, drought, water logging, and excess moisture. The water logging problem is mainly associated with *Kharif-1* oilseed production. The farmers who have low lying land normally face loss due to damages of water logged oilseed plants. But, Bangladesh does not have suitable stress tolerant oilseed varieties.

8.3.15 Marketing problem

A small number of oilseed farmers also mentioned some marketing problems in the study areas. The major problem of oilseed marketing was opined to be the lack of transports facilities. Due to this problem, they sometimes are compelled to sell their produces at farm gate and at the local market at a low price. Sometimes, they could not take advantage of the higher prices prevailing at the distant markets due to lack of transportation and the higher cost of transports. The other problems were higher marketing charges demanded by lease holders, lower price of the produces, and inadequate marketing facility (Table 8.4).

Table 8.4 Problems of oilseed marketing in the study areas

Problem	Mustard *(n= 540)*	Groundnut *(n= 540)*	Sesame *(n= 540)*	Soybean *(n= 360)*
1. Lack of transports facility	9.3	15.4	0.6	3.3
2. High market charges	5.6	14.6	1.9	2.2
3. Low price of produces	1.3	3.7	1.3	--
4. Inadequate marketing facility	5.7	--	--	--

8.3.16 Lack of awareness

Most farmers generally use both purchased and own produced seeds of oilseeds. They have to trust seed sellers regarding quality which sometimes lead them buy poor quality seed. Such lacking of awareness regarding identification and the usage of quality seeds leads them to purchase low quality seeds and as a result, the productivity declines.

The present study revealed that some oilseed farmers will not be interested to increase their oilseed area due to various reasons (Table 8.5). The important reasons were reported to be the scarcity of cultivable lands as they need to grow other crops. A very small percentage of farmers mentioned higher cost of production as a barrier to expand oilseed cultivation. This reason seems to be illogical, because most farmers mentioned that oilseed cultivation requires lower cost compared to the costs required for cultivating other crops. About 10.2% mustard farmers and 1.7% sesame farmers pointed out that oilseed cultivation was less profitable compared to that of maize, onion, carrot, and vegetables cultivation. Some farmers did not want to increase mustard cultivation because of *Boro* rice cultivation and lack of short duration improved variety.

Table 8.5 Reasons for not increasing oilseed cultivation in the next year

Reasons	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*
1. Scarcity of cultivable lands	19.6	9.3	8.1	1.1
2. Less profitable than other crops	10.2	0.2	1.7	--
3. Higher cost of production	2.6	4.6	3.1	5.8
4. Other reasons*	9.0	0.6	0.4	0.3

*Delay in *Boro* rice production, lack of short duration variety seed, foggy weather, decrease soil fertility due to use same cropping pattern repeatedly, increase rice cultivation, and lack of irrigation facility.

8.3.17 Lack of post-harvest processing

Mustard farmers usually face problem of crushing mustard for edible oil, because oil crushing machines or devices are not available at each Union or Upazila levels. Besides, high transport cost for crushing mustard does not allow subsistence farmers crushing mustard for household consumption or even for sale (FGD, 2013).

8.4 Opportunities

The imports of edible oils and oilseeds are increasing year after year to fulfil the increasing demand of Bangladesh. The country has ample opportunities to increase both area and productivity of oilseeds significantly since it has short-duration improved varieties, suitable soil conditions, topography, and huge demand for oilseeds. Also at the production and post-harvest processing levels, there is some potential for mechanical interventions that might add value to current oilseed production processes, and allow poor farmers to earn more from oilseed cultivation.

8.4.1 Land suitability

Suitable land for growing a variety of crops including oilseeds is a gift of nature in Bangladesh. Most of the areas of Bangladesh are suitable for rice and oilseeds cultivation. Oilseeds, especially sesame and groundnut can be grown successfully in *Char* lands, where the cultivations of these two oilseed crops are found to be more profitable than the cultivation of other crops including rice.

8.4.2 Dissemination of promising oilseed varieties

Technology related to oilseed cultivation has been changed to some extent due to the efforts of BARI and BINA scientists. BARI has developed some good varieties of mustard for farm level cultivation. Among these varieties, BARImustard-14 and -15 are reported to be very much promising. These two varieties are good yielder (1.4-1.6 t/ha) and short-duration (75-85 days). BINA has also developed three improved varieties of mustard (i.e. Agrani, Binasarisha-3 & -4) which also contain high yielding (1.75-2.50 t/ha) and short-duration (83-85 days) qualities. The production of mustard can be increased manifolds without increasing its area, but replacing Tori-7 and *Maghi Sarisa* with these high yielding varieties. Among short duration varieties, BARI Jhingha Badam, BINAchinabadam-2, and BINAchinabadam-3 are potential varieties for farm level cultivation. BARI/BINA has also developed improved varieties of sesame that need to be disseminated.

8.4.3 Establish better linkage between extension agent and farmers

Farmers should be provided with the up-to-date information regarding oilseeds cultivation. Agricultural extension agent can play a crucial role in this regard. Current extension contact between farmers and extension agent is not up to the mark. The situation can be improved by taking proper steps. The state authority may take some departmental initiatives for giving right time promotion to the devoted extension workers, providing reward and additional yearly increment to dutiful personnel, and ensuring punishment through demotion and held-up yearly increment for inefficient workers.

8.4.4 Availability of lands under oilseeds cultivation

Huge potential lies in locations, such as the areas under current fallow after *T.Aman* harvest, *Char* areas, low-lying areas, dried-up riverbeds, and saline areas of Bangladesh, where oilseeds can be grown successfully. A study showed that Bangladesh has accessible land of 0.82 and 0.85 million hectares in *Char* and saline area, respectively for cultivating different crops including oilseeds (Banik *et al*., 2011). In different parts of Bangladesh (e.g. Comilla, Manikgonj, Sherpur, Jamalpur, Netrokona, Tangail, Dinajpur, etc.), a huge amount of lands are kept fallow after *T.Aman* harvest. These current fallow lands can be easily used by growing short-duration improved mustard. *Char* areas and dried-up riverbeds can also be utilized by growing different crops including different oilseeds. A report showed that the landless and marginal farmers of northern districts achieved bumper production of various crops, such as pumpkin, maize, vegetables, groundnut, sesame, mustard, *china*, *kawn*, pulses, wheat, and watermelon on the *Char* and dried-up riverbeds (Financial Express, 2012). The major cropping pattern found in most of the coastal areas is *T.Aman*-Fallow-Fallow. Salt tolerant groundnut varieties can be grown in these coastal areas successfully. However, if the aforesaid potential areas can be brought under oilseeds cultivation, the country can fulfil its increasing demand by producing huge amount of oilseeds.

8.4.5 Value addition and capturing

There are ample opportunities to create value addition through promoting mustard oil and various food items based on sesame and groundnut in case of assured markets. There is also a good demand for soya foods in the urban markets. Therefore, promotion of the production and consumption of different types of soybean-based products can create value addition at both producer and national levels.

8.4.6 Improved post-harvest management practices

Improve post-harvest management practices are very much important especially for the seeds of groundnut, sesame and soybean. Many oilseed farmers experience low yield due to poor storage of seeds and lack of knowledge on post-harvest practices. Providing adequate knowledge on post-harvest management practices to the farmers and creation of adequate storage facility both can play an important role in this aspect (FGD, 2013).

8.4.7 Private sector involvement

Private sectors in Bangladesh are generally interested in business with hybrid seeds of different crops (e.g. maize, wheat, rice, vegetables, etc.). Currently, ACI Seed and CCDB have extended their hands to promote BARImustard 14 & 15 varieties among their stakeholders. Besides, the oilseed scientists of BARI opined that higher demand for branded mustard oil is being created by the expansion of manufacturing capacities of the private oil mills in the country (FGD, 2013). Therefore, there are ample opportunities for private sectors for doing business with different improved varieties and products of oilseeds.

8.4.8 Introduction of mechanized seeder and raised bed technology

There is an ample scope of introducing mechanized seeder and raised bed technology in oilseed, especially soybean, groundnut and sesame production to increase the yield. The turnaround period between *T. Aman* rice and oilseed crops is very short. After ploughing the land, farmers can use mechanized seeder for sowing soybean, sesame, and groundnut seed quickly. The system of sowing seeds on raised bed is relatively new in Bangladesh and is very much useful for sesame and groundnut cultivation (FGD, 2013).

8.4.9 Promoting contract farming

Groundnut is being used as an important ingredient of *Chanachur* in many food products companies. The companies are (1) Bombay Sweets and Co. Ltd, (2) Pran Foods Ltd, (3) Square Consumers Products Ltd, (4) Thai Food Products, (5) BD Foods Ltd, (6) Banoful and Co. Ltd, (7) Ispahani Foods Ltd, (8) Mahin Food Products, etc. Mustard oils are marketed in different brand names by different companies in Bangladesh. The associated companies are (1) Pran Agro Ltd, (2) Annapurna Oil Mills, (3) Square Consumer Products Ltd, (4) Bangladesh Edible Oil Ltd, (5) Dipa Food Products Ltd, and (6) Sajeeb Corporation. Soybean is being used by some companies for preparing soya foods. Besides, the cultivation of groundnut requires a higher amount of cash (Tk 57,332/ha) compared to other oilseed crops. Hence, there is an opportunity for the state authorities to promote contract farming systems.

This will enable farmers to link with traders/companies who can provide them with technical knowledge regarding oilseeds production, access to larger buyers, and credit to buy inputs (FGD, 2013).

8.4.10 Provision of technical knowledge

Adoption of crop production technologies (discussed in *Chapter IV)* clearly reveals that many farmers are still not aware of the improved production technologies of oilseeds. Training can play an important role in strengthening farmers' capacity in this regards. For instance, a study on maize showed that trained farmers can receive more than 1.0 t/ha of additional maize yield compared to non trained farmers (CIMMYT, 2006). Hence, there is an opportunity to disseminate technical knowledge to the oilseed farmers through short-term training programmes, especially in the intensive oilseeds growing areas for better performance.

8.4.11 Dissemination of best production practices

BARI and BINA have developed complete production technologies for different oilseeds production at farm level that can be demonstrated through DAE both at public and private sector for comparison (FGD, 2013). This initiative obviously makes farmers enthusiastic toward higher oilseeds production.

8.5 Threats

8.5.1 Climate variability

Climate change could have a significant impact on different crop production including oilseeds in Bangladesh. Due to the greenhouse effect, the temperature and rainfall pattern are observed to be very irregular in Bangladesh which is harmful for mustard and soybean production. Water logging is a problem for sesame cultivation. Flash flood occurred in April-May in the coastal region is a problem for groundnut cultivation. Therefore, weather variability could have detrimental effects on the yields of oilseeds. Besides, Bangladesh is also facing a problem of salinity due to climate change which also hinders oilseeds area expansion (FGD, 2013).

8.5.2 High competition with other crops

Most of the farmers in Bangladesh are poor and the main cereal food items for them are rice and wheat. They are always interested mainly to grow rice in their field. Most of the farmers grow *Boro* rice in the winter season. Nevertheless, a variety of high value crops are also grown in the winter season. As a result, oilseeds have to face serious competition with these high value crops in terms of crop choice by the farmers.

8.6 Facility Demanded by Respondent Farmers

The respondent farmers mentioned some facilities that need to be created for them to expand their oilseed area in the near future. All of their needs are displayed in Table 8.6.

The availability of cultivable land is very much important for growing or expanding the area for oilseeds. The highest 20.4% mustard farmers followed by 7.8% groundnut farmers, and 6.5% sesame farmers wanted to expand their cultivation for the next year, if they can manage more cultivable lands through lease or mortgage. Soybean farmers did not demand much for available cultivable lands.

Many farmers demanded short duration *T.Aman* rice variety, so that they can harvest *T.Aman* rice early and can cultivate oilseeds in between *T.Aman* and *Boro* rice cultivation. A good number of oilseed growers mentioned the need of short duration improved oilseed varieties in the study areas.

Good quality seeds, fertilizers, and pesticides are important inputs for producing any kind of crop profitably. Therefore, these inputs should be made available to the farmers at lower price. The perusal of Table 8.6 is that the percent of oilseed farmers ranged from 4.3% to 12% requested government to reduce the existing price of inputs.

Table 8.6 Facilities demanded by respondent farmers for increasing oilseed cultivation

Facility	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*
1. Availability of cultivable lands	20.4	7.8	6.5	1.7
2. Improved short duration varieties	17.0	12.8	5.6	10.6
3. Ensuring low price of inputs	12.0	5.9	4.3	7.8
4. Credit facility with easy terms	5.7	5.7	3.1	5.6
5. Adequate irrigation facility	2.6	2.8	0.7	0.8
6. Ensuring fair price of their produces	5.2	--	0.9	--
7. Hand-on training on oilseed cultivation	3.7	4.4	3.5	8.6
8. Reducing labour scarcity problem	2.0	--	1.9	1.4
9. Other facilities*	7.4	3.7	2.8	2.5

* Short duration variety of *T.Aman* rice, cooperation from extension personnel, low-cost of plough, removal of water logging problem, crop threshing machine, and storage facility

Some oilseed farmers wanted easy access to institutional credit facilities with easy terms and conditions since the rate of interest of non-institutional credit is very high.

Irrigation is an important input for crop production. It helps increasing crop productivity to a great extent. Most of the study areas are facilitated with irrigation. But oilseed farmers often are constrained by the frequent load shedding of electricity that hamper their crop production. Nevertheless, some farmers till do not have adequate irrigation facility. Therefore, they have demanded this facility in the study areas.

Product price is very much important to the oilseed farmers for higher production. Some of adopter and non-adopter mustard and sesame farmers opined that they could not receive good price of their produces.

It is noted that a small percentage of oilseed adopter and non-adopter farmers approached for providing hand-on training on oilseed production. Farmers also proposed some other facilities, such as short duration variety of *T.Aman* rice; cooperation from extension personnel; crop threshing machine; low cost of plough; removal of water logging problem; and storage facility (Table 43).

Chapter IX

CONCLUSIONS AND POLICY IMPLICATIONS

9.1 Conclusions

The acute shortage of edible oils has been prevailing in Bangladesh during last several decades. The expenditure on edible oils and oilseeds imports has been increasing over the year to meet the country's demand. But, oilseeds area has been decreasing due to various economic and technical reasons. Adoptions of improved technologies have also created additional income and employment for the farmers and saved foreign exchange for the country through producing more of these crops replacing local varieties in the country. But, a large number of farmers are still reluctant to adopt these improved oilseeds technologies. Therefore, the present study has been conducted to assess the technological adoption and profitability of oilseed cultivation at farm level, and to estimate the outputs of R&D in Bangladesh.

The levels of adoptions of the improved oilseed varieties and their production technologies are very low. Improved mustard varieties are well adopted at farm level compared to groundnut, sesame, and soybean varieties. The lion's share of total oilseed areas is planted to BARI old or local varieties of oilseeds. Different socioeconomic factors have influenced farmers to adopt improved oilseed varieties. Family labour, availability of improved seed, farmers' cosmopolitness, and extension contract significantly influence farmers to adopt improved variety.

Irrespective of variety, oilseed cultivation at farm level is to some extent remunerative to its growers. But, the productivity and profitability of improved oilseeds are significantly higher than that of BARI old and local varieties of oilseeds. The highest profitability is observed in groundnut cultivation followed by mustard, sesame, and soybean. Unfortunately, the overall profitability of mustard, sesame, and soybean production is lower than most of their competing crops, like brinjal, cabbage, cauliflower, carrot, chilli, potato, wheat, pulses, and jute. However, the domestic production of oilseeds is more profitable than their importation from foreign countries.

Oilseed production at farm level is influenced by various factors at different magnitudes. Improved variety, human labour, organic fertilizer, urea, TSP, soil type, and pest control have positive and significant influences on the yield of oilseeds. The study also revealed that farmers with higher education, more farming experience, frequent extension contact, improved seed, and more innovativeness tend to be technically more efficient than other farmers. Farm-specific technical efficiency depicts that the respondent farmers could produce oilseeds to 68-88% of the potential (stochastic) frontier production levels, given the levels of inputs and technologies currently being used. The average technical efficiency of the farmers is higher for intensive growing areas as compared to low growing areas.

The adoptions of improved oilseed technologies at farm level have made significant positive impacts on productivity growth, employment generation, farmers' income, livelihoods, and foreign exchange savings through producing more of these crops. Ex-post evaluation of the past investment on oilseeds R&D revealed an IRR to be 24%. The estimated IRR seems to be low due to lower adoption of improved. Under various assumptions, the IRR ranged from 22 to 26% and BCR from 2.84 to 3.5. The amounts of NPV and foreign exchange savings due to R&D of oilseeds for the period from 1997/98 to 2011/12 are Tk 4,769.04 million and US$ 97.11 million respectively. Therefore, the investment on R&D of oilseeds is found to be encouraging in Bangladesh.

The constraints to oilseed cultivation and expand its area are climate variability, high competition with other crops, non-availability of short-duration variety, low adoption of improved varieties, and insects & diseases infestation. Again, the potential strengths and opportunities behind the R&D of oilseeds are research capability, availability of good varieties with higher yield, farmers' higher profit, farmers' interest toward adoption, availability of extension facilities, potential areas under cultivation, and increasing private sector involvement in oilseed related business. In order to increase oilseed production, constraints to oilseed cultivation should be minimized and exploit the existing strengths and opportunities behind the R&D of oilseed in Bangladesh.

Based on the findings of the study, different steps and measures discussed in the recommendation section should be taken into consideration to enhance oilseed production throughout the country.

9.2 Recommendations and Policy Interventions

In drawing recommendations, the facilities demanded by the respondent farmers and the findings of the present study are taken into consideration. However, the following steps and policy interventions are recommended for improving the performance of the oilseed sector in Bangladesh.

9.2.1 Dissemination of existing improved rice and oilseed varieties

Rapeseed and mustard is the principal oil crop in Bangladesh, which occupied a lion share of the oilseeds area. Again, the main mustard based cropping pattern in the country is *T.Aman*-Mustard-*Boro*. Therefore, immediate steps should be taken by BRRI, BINA, and BARI in order to develop more short duration varieties of rice and oilseeds. Nevertheless, the seed production programme of short duration and high yielding varieties of *T.Aman* (BINAdhan-7) and mustard (i.e. BARI Mustard-14, BARI Mustard-15, Binasarisha-4) should be strengthened and disseminated these varieties to the farmer throughout the country. The promising areas for disseminating these varieties are Manikgonj, Faridpur, Tangail, Jessore, Rajshahi, Jamalpur, Kustia, Bogra, and Dinajpur districts which together covered about 73% of the total mustard areas.

Short duration (110-150 days) and high yielding (2-3 t/ha) groundnut varieties are Jhingha Badam, BARI Groundnut-5, and BARI Groundnut-6 and these varieties should be disseminated in Noakhali, Faridpur, Dinajpur, Pabna, Dhaka, Kishoregonj, and Rangpur districts through pilot production program. These promising districts occupied about 72% groundnut areas of the country.

The promising areas of sesame cultivation are Jessore, Pabna, Dhaka, Faridpur, Khulna, Tangail, Dinajpur, Kustia, and Rajshahi districts which together covered about 83% of the total sesame areas of Bangladesh. BARI Sesame-4, BINAtil-1, BINAtil-2, and BINAtil-3 are short duration (85-95 days) and high yielding (1.25-1.80 t/ha) varieties of sesame. Therefore, demonstration program should be taken to disseminate these varieties in the aforesaid districts.

The potential districts of soybean cultivation are Noakhali, Laxmipur, Comilla, and Mymensingh where 100% soybeans are cultivated for the country. BARI Soybean-6, BINAsoybean-1, and BINAsoybean-2 are high yielding (1.6-2.8 t/ha) and short duration (90-110 days). These varieties may be disseminated in the aforesaid districts.

9.2.2 Availability of improved seeds of oilseeds and rice

Availability of quality seeds at farm level is one of the pre-requisites of the adoption of improved oilseed varieties. So, the seeds of improved oilseed varieties should be made locally available to the farmers. In order to make improved seed available to the farmers, existing pilot production programme, and block farming of improved oilseeds should be strengthened and extended to oilseed growing areas. Besides, Government should encourage BADC and private seed companies to produce sufficient quantities of improved variety seeds of oilseeds and supply those seeds to interested farmers at reasonable price. Government may also encourage adopter farmers to store improved variety seed and disseminate those to the enthusiastic farmers.

9.2.3 Strengthening existing extension services

It is found that the farmers with more extension contact are technically efficient and have a tendency to adopt improved oilseed varieties. Therefore, the intensity of current extension contact or visit between extension personnel and farmers should be increased for getting up-to-date knowledge and information regarding production technology and new varieties of oilseeds. The authority should take administrative measures (right time promotion, reward for good deeds, demotion for negligence in duties, etc.) so that the present extension system of the country provides technological information more effectively and efficiently at farm level.

9.2.4 Bringing potential areas under oilseed cultivation

A good potential lies in the locations like the areas under current fallow after *T.Aman* harvest, *Char* areas, low-lying areas, dried-up riverbeds, and coastal areas of Bangladesh, where different types of oilseeds can be grown successfully for meeting the increasing demand of the country. Therefore, Government through its concerned departments should take appropriate steps to bring potential areas under oilseeds cultivation.

9.2.5 Involving private sectors to oilseed production and value addition

There are ample opportunities to create value addition, employment generation, and expand agri-business activities through promoting oilseed-based food products, seed production, and storage facility development throughout the country. Therefore, Government should encourage and facilitate private sectors to involve in producing improved seeds, preparing oilseed-based food products, storage, and post-harvest processing in Bangladesh. The facilities to be provided for private sector may be credit with low interest rate, supplying breeder seed, and other administrative measures that help making a bridge between farmers and private sector.

9.2.6 Strengthening oilseed research and development

The main task of oilseeds technology generation in Bangladesh should be shouldered by BARI and BINA. Short duration and stress tolerant improved oilseed varieties are pre-requisites for expanding the oilseed cultivation throughout the country. Besides, the production of improved oilseeds would be highly efficient for import substitution. Therefore, more intensive research should be undertaken to develop short duration and stress tolerant oilseed varieties, and necessary steps should be taken by the government for disseminating these improved seeds to the interested farmers.

9.2.7 Conducting regular training programme

The low productivity is one of the major problems of most oilseed crops. Farmers can't even harvest the potential yields of oilseeds and receive low financial benefit from oilseed cultivation due to low adoption of the recommended crop management technologies. Therefore, farmers should be more aware of the benefits of improved oilseed technologies. Training is an important tool that enhances up-to-date knowledge and skill of the farmers. Regular training programme on oilseed production and other technologies should be organized for farmers, extension workers, and private seed companies for the efficient use of inputs and production technologies at farm level.

9.2.8 Providing institutional credit facilities

Farmers need cash money at the time of cultivation. So, institutional credit facilities should be made available at the right time to the farmers for increasing the volume of production. Some oilseed farmers wanted easy access to institutional credit facilities with easy terms and conditions, since the rate of interest of non-institutional credit is very high.

9.2.9 Availability of production inputs at reasonable prices

Fertilizer, pesticides, and irrigation are important inputs for profitable crop production. In the study areas, oilseed farmers are facing several problems associated with these three inputs. The major problems are non-availability of quality inputs and their high prices. Therefore, Government should provide more subsidies on the production and distribution of these important inputs, and make them available at local markets with reasonable price. Alternatively, Government may offer more subsidies to small and marginal category farmers compared to the large farmers, so that they can purchase and use these inputs properly.

9.2.10 Strengthening international collaboration

Collaboration with international research institutes (e.g., ICRISAT, ICARDA, etc.) and donor agencies is very much important for oilseed R&D in Bangladesh. International collaboration for oilseed R&D is virtually absent in Bangladesh. Therefore, international collaboration should be given priority and encouraged for increasing investment in the R&D of oilseeds. It will certainly encourage scientists in many ways to develop suitable oilseed technologies.

9.3 Areas of future studies

Besides varietal improvement research of oilseeds, the following socio-economic studies related to oilseeds production, consumption, and marketing need to be implemented.

1. Assessment of demand and supply of oilseeds in Bangladesh.
2. In-depth value chain analysis of oilseeds in Bangladesh.
3. Economic impacts of climate change on the productivity of major oilseeds in Bangladesh.

References

Ahmed, C. Q. K. M. 2010. Agriculture in Bangladesh: Present position, problems, prospects and policy. Ministry of Agriculture, Dhaka, Bangladesh. www.bpatc.org.bd/handouts/ *Agriculture_ Bangladesh.ppt*

Aigner, D.J.; C.A.K. Lovell and P. J. Schmidt. 1977. Formulation and estimation of stochastic frontier production function models, *Journal of Econometrics*, 6(1):21-37.

Ajibefun, I. A.; G. E. Battese and A. G. Daramola. 2002. Determinants of technical efficiency in smallholder food crop farming: Application of stochastic frontier production function. *Quarterly Journal of International Agriculture*. 41 (3): 225-240.

Akino, M. and Y. Hayami. 1975. Efficiency and equity in public research: rice breeding in Japan's economic development. *American Journal of Agricultural Economics,* 57:1-10.

Akter, M.; M. A. M. Miah; M. M. H. Khurram; M.S. Rahman; and Q. M. Alam. 2010. Economic feasibility of soybean production in some selected areas of Bangladesh. *Bangladesh Journal of Agricultural Research, 35(4): 561-571*.

Akter, M.; Miah, M. A. M.; Rahman, M. S.; and Khurram, M. M. H. 2010. Adoption and relative profitability of groundnut (*Arachis hypogaea* L.) cultivation in char areas of Bangladesh. *Bangladesh J. of agri.* 2010, 35 (1): 85-95.

Akter, N. and Jaim, W.H.M. 2002. Changes in the major food grains production in Bangladesh and their sources during the period from 1979/80 to1998/99. *Bangladesh J. Agric. Econs.* XXV(1): 1-16. June, 2002.

Ali, M. A. and M. A. Chaudhry. 1990. Inter-regional farm efficiency in Pakistan's Punjab: a frontier production function study. *Journal of Agricultural Economics,* 71(2):303-310.

Ali, Nawab. 1996. Indian Soybean Industry- Recent trend and development, In: Alex Buchanan, Ed. 1996. Proceedings of the 2nd International Soybean Processing and Utilization Conference: 8-13 January, 1996, Bangkok, Thailand. Funny publishing limited partnership, Bangkok, Thailand.

Alston, J.M., G.W. Norton and P.G. Pardey. 1995. *Science Under Scarcity: Principles and Practice for Agricultural Research*. Evaluation and Priority setting. Cornell University Press, Ithaca. pp.237.

Bangladesh Bank, 2012. *Monthly Economic Trends*, December, 2012. Statistics Department, Bangladesh Bank, Head Office, Dhaka, Bangladesh.

Banik, B. R.; Amiruzzaman, M.; Rahman, M. M. and Khaldun, A. B. M. 2011. Maize improvement in Bangladesh, Conference Paper, Presented in 11th Asian Maize Conference, Beijing, China.

Banu, S. P.; M. J. Hossain and M. S. Alam. 2013. *BARI Developed Crop Varieties*. Research Wing, Bangladesh Agricultural Research Institute, Gazipur. Publisher: Bengal Com-Print, 685, Green road, Panthapath, Dhaka-1205.

BBS, 2011. *Yearbook of Agricultural Statistics of Bangladesh*. Bangladesh Bureau of Statistics, Statistics and Information Division, Ministry of Planning, Dhaka, Bangladesh.

BBS, 2012. *Statistical Yearbook of Bangladesh*. Bangladesh Bureau of Statistics, Statistics and Information Division, Ministry of Planning, Dhaka, Bangladesh.

BNNC, 1984. Nutrition Policy and Programme for Bangladesh, Bangladesh National Nutrition Council, 19/1 Rasulbagh, Mohakhali, Dhaka. P.70-79

Bravo-Ureta, B. E. and A. E. Pinheiro. 1997. Technical, economic, and allocative efficiency in peasant farming: Evidence from the Dominican Republic. *The Developing Economics,* 35 (1):48-67.

Bravo-Ureta, B. E. and L. Rieger. 1991. Dairy farm efficiency measurement using stochastic frontiers and neoclassical duality. *American Journal of Agricultural Economics,* 73(2):421-428.

Bravo-Ureta, B. E. and R. E. Evenson. 1994. Efficiency in agricultural production: the case of peasant farmers in Eastern Paraguay. *Agricultural Economics*, 10(1):27-37.

Burki, A. A. and H. N. Shah. 1998. Stochastic frontier and technical efficiency of farms in irrigated areas of Pakistan's Punjab. *The Pakistan Development Review*, 37 (3):275-291.

Chaudhry, G. M. 2001. Technical efficiency analysis of Pakistan agriculture with special reference to chemical fertilizer use. *Asia-Pacific Journal of Rural Development*, 11 (1): 15-25.

CIMMYT. 2006. Maize whole family training. In: *Food Security in Bangladesh: Improving Wheat, Maize and Papaya Production and Impacts of Arsenic Contamination*. Project Annual Report for 2005-2006. pp. 31-44.

Coelli, T. and G. Battese. 1996. Identification of factors which influence the technical inefficiency of Indian farmers. *Australian Journal of Agricultural Economics,* 40(2): 103-128.

Cooper, W. W. and S. C. Kumbhakar. 1995. DEA and stochastic frontier analysis in the1978 Chinese economic reforms. *Socio-economic Planning Science*. 29:85-112.

Currie, J.M., J.A. Murphy and A. Schmitz. 1971. The concept of economic surplus and its use in economic analysis. *Economic Journal* 18:741-798.

DAE, 2013. Department of Agricultural Extension (DAE), Ministry of Agriculture, Khamarbari, Farmgate, Dhaka.

Deb, U.K.; Bantilan, M.C.S.; Evenson, R.E. and Roy, A.D. 2004. Productivity impacts of improved sorghum cultivars. Pages 203-222 *in* Sorghum genetic enhancement: research process, dissemination and impacts (Bantilan MCS, Deb UK, Gowda CLL, Reddy BVS, Obilana AB and Evenson RE, eds.). Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Dey. N. C.; S.K. Bala; A.K.M.S. Islam; and M. A. Rashid. 2013. Sustainability of Groundwater Use for Irrigation in Northwest Bangladesh. Report submitted to National Food Policy Capacity Strengthening Programme (NFPCSP), Food Planning and Monitoring Unit (FPMU), Ministry of Food, FAO-Bangladesh, Dhaka.

FAO, 2008. *Production Yearbook*, Food and Agricultural Organization, Rome, Italy.

Farrell, M. J. 1957. Measurement of production efficiency, *Journal of Royal Statistical Society*, Series A, 120: 253-290.

FGD, 2013. Focused group discussion with extension personnel of different upazilas and the scientists of Oilseed Research Centre, BARI, Gazipur.

Financial Express, 2012. Char land brought under crops cultivation in Gaibandha, 6 December, 2012; Crop harvest ends in dried-up riverbeds, *Chars* lands, 4 June 2012. http://www. thefinancialexpress-bd.com/index.php?news_id=131726&date=2012-06-04.

Gardiner, J.C., J. H. Sanders, and T. G. Barker. 1986. An economic evaluation of the Purdue soft red winter wheat program. Department of Agricultural Economics, Agricultural Experimental Station, Purdue University, West Lafayette, Pakistan.

Hassan, M. K. and M.A.M. Miah, 2003. Impact of rapeseed & mustard research and extension in Bangladesh. *Bangladesh J. Agril. Res.* 28 (1): 15-31.

Hazell, Peter B.R. 1982. Instability of Indian food grain production. Research Report 30, Washington, D.C, International Food Policy Research Institute (IPFRI).

Hazell, Peter B.R. 1985. Sources of increased variability in World cereal production since the 1960s. *Journal of Agricultural Economics*, 36: 145-159.

Hossain, M.A.; Parveen, S.; and Miah, M.A.M. 1997. Adoption of recommended package of technology for uttara brinjal: a farm level study in Bangladesh. *Bangladesh Journal of Extension Education*, Vol-9 (Special issue, 1994-97): 99-104.

Islam, M. R. 2002. Determinants of production of and demand for rice in Bangladesh: A comparative study of aromatic and coarse varieties. Ph. D. dissertation, Department of Agricultural Economics, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

Islam, Q.M.S.; M.A.M. Miah, and Q.M. Alam, 2007. Economic analysis of BARI masur and mustard cultivation in selected areas of Bangladesh: A comparative study. Annual report 2006-07, Agricultural Economics Division, BARI, Gazipur. pp105-106.

Islam, Q.M.S; Miah, M. A. M.; Rahman, M.S.; and Hossain, M.S. 2013. Adoption of BARI mung varieties and its constraints to higher production in southern region of Bangladesh. *Bangladesh J. Agricultural Research*, 38(1): 85-96, March 2013.

Kakali, M. and Basu, P. 2006. Measurement of growth trend: An econometric study of food grains production in west. *Bangladesh J. Agric. Econ. 3 (3):44-55.*

Kawser, M. K. 1993. A Comparative analysis of sweet potato and groundnut cultivation in a selected area of Kishoregonj district with special reference to small farmers. An unpublished M.S. thesis submitted to the Department of Agricultural Economic, BAU, Mymensingh.

Khan, M. A. and M. F. Alam. 2003. Technical efficiency of the hatchery operators in fish seed production farms in two selected areas of Bangladesh. *Bangladesh Journal of Agricultural Economics*, 26 (1&2): 55-70.

Khan, A. R. 2012. Adulterated fertilizers flood markets. http://arrkhan.blogspot.com/2012/10/ adulterated-fertilizers-flood-markets.html

Mallik, M. S. A. 2013. Quality seed production of oilseed crops: An overview. Paper presented in the workshop on '*Modern Techniques for Quality Seed Production of Oilseed Crops'*. Oilseed Research Centre, Bangladesh Agricultural Research Institute, Gazipur, October 02, 2013.

Meeusen, W. and J. Van den Broeck. 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 18(2):435-444.

Miah, M.A.M.; M.S. Akter and M.A. Bakr 2004. Status of pulses varieties adoption in Bangladesh: A farm level study. *Bangladesh Journal of Agricultural Economics*, XXVII (2): 107-122.

Miah, M. A. M. and Q.M. Alam, 2008. Adoption and relative profitability of mustard production in Bangladesh. Annual research report (2007-08) of Oil Seed Research Centre, BARI, Joydebpur, Gazipur.

Miah, M. A. M.; Alam Q. M.; Sarker, A.; and Aktar, M. S. 2009. Socio-economic Impact of Pulse Research in Some Selected Areas of Bangladesh. *Asia Pacific Journal of Rural Development*, *19(2):115-141*, December, 2009.

Nagy, J. G. and W. H. Furtan. 1978. Economic costs and returns from crop development research: the case of rapeseed breeding in Canada. *Canadian J. Agril. Econ.*, 26 (1): 1-14.

Nagy, J. G, and M. F. Alam. 2000. The impact of agricultural research in bangladesh: estimating returns to agricultural research. Project Report submitted to BARC, Dhaka and International Fertilizer Development Centre, Muscle Shoals, Alabama.

Norton, G. 1993. *Analysis of Agricultural Research Priorities in Bangladesh*, Discussion Paper No. 93-07, ISNAR, The Hague.

Schmidt, P. and C. A. Lovell. 1979. Estimating technical and allocative inefficiency relative to stochastic production and cost frontiers. *Journal of Econometrics*, 9(3): 343-366.

Seyoum, E. T.; G. E. Battese and E. M. Fleming. 1998. Technical efficiency and productivity of maize producers in eastern Ethiopia: a study of farmers within and outside the Sasakawa-Global 2000 project. *Agricultural Economics*, 19 (3):341-348.

SFYP, 2011. Sixth Five Year Plan (FY2011-FY2015). Planning Commission, Ministry of Planning, Government of the People's Republic of Bangladesh, Agargaon, Dhaka.

Sharif, N. R. and A. A. Dar. 1996. Stochastic frontiers and technical efficiency distributions: an analysis based on rice farming data for Bangladesh. *Canadian Journal of Economics*, 29 (Special issue): 582-586.

Sharma, K. R.; P. S. Leung and H. M. Zaleski. 1999. Technical, allocative and economic efficiency in swine production in Hawaii: a comparison of parametric and nonparametric approaches. *Agricultural Economics,* 20 (10): 23-35.

Singh, A.J. and Byerlee, D. 1990. Relative variability in wheat yields across countries and over time. *Journal of Agricultural Economics* 41(1):21-32.

Siju, T. and Kombairaju, S. 2001. Rice production in Tamil Nadu: A trend & decomposition analysis. *Agric. Situation in India*, 58(4): 143-145.

Weber, A. and Sievers, M. 1985. Observations on the geography of wheat production instability. *Quarterly Journal of International Agriculture* 24(3):201-211.

A-1: Area, production and yield of rapeseed and mustard in Bangladesh, 1989-2012

Year	Area ('000' ha)	Production ('000' ton)	Yield (t/ha)
1989	335.73	163.93	0.49
1990	338.55	217.41	0.64
1991	339.27	227.53	0.67
1992	313.84	220.74	0.70
1993	308.79	218.00	0.71
1994	336.69	239.08	0.71
1995	307.58	218.73	0.71
1996	336.13	245.89	0.73
1997	336.24	249.36	0.74
1998	343.77	253.64	0.74
1999	344.13	252.52	0.73
2000	328.91	249.08	0.76
2001	317.70	237.66	0.75
2002	303.06	232.74	0.77
2003	297.55	217.98	0.73
2004	279.23	210.57	0.75
2005	241.54	191.38	0.79
2006	216.81	183.47	0.85
2007	210.54	188.88	0.90
2008	233.70	227.93	0.98
2009	234.02	202.72	0.87
2010	174.68	151.25	0.87
2011	252.35	246.49	0.98
2012	276.11	262.00	0.95

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-2: Division wise area, production and yield of rapeseed and mustard in Bangladesh, 1989-2012

Year	Barisal			Chittagong			Dhaka		
	Area (ha)	**Prod. (ton)**	**Yield (t/ha)**	**Area (ha)**	**Prod. (ton)**	**Yield (t/ha)**	**Area (ha)**	**Prod. (ton)**	**Yield (t/ha)**
1989	7763.6	2596	0.334	52894.7	39057	0.738	130718.2	46870	0.359
1990	8299.6	3195	0.385	55512.1	40465	0.729	131902.8	75000	0.569
1991	10404.9	4845	0.466	54289.5	40225	0.741	132649.8	78190	0.589
1992	8451.4	3705	0.438	53732.8	39955	0.744	126749.0	82950	0.654
1993	8570.9	3640	0.425	48910.9	38710	0.791	126587.0	83300	0.658
1994	9226.7	3935	0.426	51554.7	32745	0.635	132157.9	89565	0.678
1995	8344.1	3430	0.411	47852.2	29015	0.606	126269.2	88065	0.697
1996	8862.3	3710	0.419	52265.2	33445	0.640	131783.4	92575	0.702
1997	8832.0	4015	0.455	52089.1	33955	0.652	131797.6	94145	0.714
1998	8684.2	4000	0.461	52415.0	33580	0.641	131862.3	91490	0.694
1999	8977.7	4125	0.459	52281.4	32315	0.618	131882.6	91460	0.693
2000	9004.0	4035	0.448	52095.1	36365	0.698	116876.5	84435	0.722
2001	8979.8	4150	0.462	52332.0	36485	0.697	107876.5	76325	0.708
2002	7048.6	3160	0.448	52182.2	36595	0.701	104070.9	74230	0.713
2003	6981.8	3150	0.451	51870.4	36720	0.708	102647.8	69580	0.678
2004	5973.7	2790	0.467	53008.1	39190	0.739	91297.6	65690	0.720
2005	5884.6	2685	0.456	17433.2	15010	0.861	88593.1	66815	0.754
2006	5578.9	2660	0.477	12678.1	10905	0.860	85536.4	66420	0.777
2007	3074.9	1455	0.473	11157.9	9395	0.842	96651.8	80830	0.836
2008	1151.0	479	0.416	11141.7	10667	0.957	116142.1	102605	0.883
2009	1183.8	596	0.503	8660.7	8764	1.012	113413.8	89639	0.790
2010	1174.9	669	0.569	5448.6	4449	0.817	98270.0	56724	0.577
2011	1389.5	774	0.557	10193.9	10009	0.982	114317.0	100332	0.878
2012	1500.8	875	0.583	11024.7	10674	0.968	114774.3	105981	0.923

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-2: ***Continued …………………………..***

Year	Khulna			Rajshahi		
	Area (ha)	**Production (ton)**	**Yield (t/ha)**	**Area (ha)**	**Production (ton)**	**Yield (t/ha)**
1989	55078.5	33555	0.609	53361.9	18100	0.339
1990	56570.9	38845	0.687	51876.5	37220	0.717
1991	57334.0	40985	0.715	50206.5	40080	0.798
1992	49629.6	36150	0.728	43688.3	36375	0.833
1993	49536.4	35215	0.711	43682.2	35715	0.818
1994	57228.7	43965	0.768	50585.0	41815	0.827
1995	49757.1	36610	0.736	43761.1	38615	0.882
1996	57348.2	44645	0.778	50706.5	45095	0.889
1997	57332.0	45110	0.787	50779.4	45410	0.894
1998	64574.9	51730	0.801	50755.1	45630	0.899
1999	64698.4	51955	0.803	50447.4	45170	0.895
2000	65305.7	52170	0.799	50566.8	43665	0.864
2001	63388.7	50600	0.798	50787.4	40735	0.802
2002	63062.8	57680	0.915	46767.2	36100	0.772
2003	62708.5	50435	0.804	45192.3	35290	0.781
2004	59680.2	46675	0.782	44546.6	34590	0.776
2005	61394.7	51050	0.832	44625.5	34825	0.780
2006	45830.0	42020	0.917	48366.4	44650	0.923
2007	34726.7	37050	1.067	50817.8	47765	0.940
2008	34849.8	36833	1.057	56164.4	54828	0.976
2009	34603.2	32815	0.948	29451.0	57045	1.937
2010	11115.0	7538	0.678	44483.0	50623	1.138
2011	42431.2	44025	1.038	69096.4	76728	1.110
2012	46759.2	50492	1.080	98559.0	88099	0.894

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-2: ***Continued …………………………..***

Year	Sylhet			Rangpur		
	Area (ha)	Production (ton)	Yield (t/ha)	Area (ha)	Production (ton)	Yield (t/ha)
1989	7761.9	5138	0.662	28148.6	18618	0.661
1990	7892.7	5265	0.667	26496.0	17420	0.657
1991	8072.9	5505	0.682	26313.8	17700	0.673
1992	8168.0	5425	0.664	23421.1	16180	0.691
1993	8117.4	5555	0.684	23382.6	15865	0.678
1994	8198.4	6035	0.736	27742.9	20020	0.722
1995	8107.3	5965	0.736	23491.9	17025	0.725
1996	7453.4	5900	0.792	27706.5	20525	0.741
1997	7659.9	6005	0.784	27747.0	20715	0.747
1998	7613.4	5880	0.772	27864.4	21330	0.765
1999	7781.4	6140	0.789	28050.6	21350	0.761
2000	7961.5	6775	0.851	27099.2	21635	0.798
2001	8048.6	7085	0.880	26291.5	22280	0.847
2002	8006.1	7185	0.897	21923.1	17790	0.811
2003	7785.4	6595	0.847	20368.4	16210	0.796
2004	6698.4	5455	0.814	18030.4	16180	0.897
2005	6348.2	4980	0.784	17265.2	16010	0.927
2006	3026.3	2460	0.813	15797.6	14350	0.908
2007	1583.0	1510	0.954	12532.4	10875	0.868
2008	1275.3	1297	1.017	12974.9	11221	0.865
2009	1232.8	1387	1.125	13976.1	12471	0.892
2010	1048.6	1281	1.222	4540.9	3819	0.841
2011	1239.7	1482	1.195	13678.1	13500	0.987
2012	1243.1	1531	1.232	13530.4	14035	1.037

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-3: Area, production and yield of groundnut in Bangladesh, 1989-2012

Year	Area ('000' ha)	Production ('000' ton)	Yield (t/ha)
1989	38.19	44.78	1.17
1990	38.60	41.07	1.06
1991	38.50	41.22	1.07
1992	39.02	41.91	1.07
1993	35.77	39.34	1.10
1994	35.50	41.26	1.16
1995	35.71	39.28	1.10
1996	35.55	40.34	1.13
1997	34.64	39.53	1.14
1998	34.73	39.54	1.14
1999	34.80	38.76	1.11
2000	33.93	42.21	1.24
2001	28.99	31.84	1.10
2002	28.47	29.84	1.05
2003	26.67	34.24	1.28
2004	26.04	34.08	1.31
2005	28.85	38.88	1.35
2006	29.42	37.98	1.29
2007	33.67	45.91	1.36
2008	31.09	44.27	1.42
2009	31.31	46.53	1.49
2010	33.60	53.47	1.59
2011	38.09	58.07	1.52
2012	30.05	53.65	1.79

Source: Various issues of BBS

A-4: Division wise area, production and yield of groundnut in Bangladesh, 1989-2012

Year	Barisal			Chittagong			Dhaka		
	Area (ha)	Prod. (ton)	Yield (t/ha)	Area (ha)	Prod. (ton)	Yield (t/ha)	Area (ha)	Prod. (ton)	Yield (t/ha)
1989	3076.5	3403	1.106	15127.9	18246	1.206	12084.6	14885	1.232
1990	2666.0	3715	1.393	15238.9	12455	0.817	12182.2	15975	1.311
1991	3178.1	2645	0.832	14334.0	14710	1.026	13170.0	15690	1.191
1992	3147.8	2715	0.863	14307.7	13940	0.974	13174.1	16190	1.229
1993	3340.1	2840	0.850	11979.8	12230	1.021	12611.3	14135	1.121
1994	3538.5	3165	0.894	12111.3	13242	1.093	11204.5	12815	1.144
1995	3576.9	2230	0.623	12105.3	14055	1.161	11350.2	12560	1.107
1996	3496.0	3510	1.004	12000.0	13837	1.153	11623.5	12440	1.070
1997	3319.8	3705	1.116	12785.4	14500	1.134	11404.9	12275	1.076
1998	3417.0	3580	1.048	12789.5	14760	1.154	11368.4	12285	1.081
1999	3787.4	3555	0.939	12884.6	14955	1.161	11020.2	11295	1.025
2000	3803.6	3655	0.961	11690.3	13695	1.171	11234.8	15860	1.412
2001	2921.1	2885	0.988	10718.6	12960	1.209	10340.1	10510	1.016
2002	2915.0	2875	0.986	10716.6	13285	1.240	9896.8	8335	0.842
2003	2698.4	2520	0.934	10437.2	13430	1.287	8830.0	11985	1.357
2004	2686.2	2595	0.966	10378.5	13770	1.327	7730.8	10980	1.420
2005	2945.3	2480	0.842	9682.2	13125	1.356	9664.0	13170	1.363
2006	2755.1	2475	0.898	5062.8	11995	2.369	10621.5	12345	1.162
2007	2153.8	2230	1.035	9380.6	12515	1.334	11155.9	14730	1.320
2008	2234.8	3684	1.648	9263.2	12274	1.325	11429.6	15868	1.388
2009	1692.3	2646	1.564	9282.6	13304	1.433	9921.5	14316	1.443
2010	1840.9	9526	5.175	11220.6	16374	1.459	10957.9	18667	1.704
2011	1962.3	3269	1.666	9964.0	16568	1.663	10679.4	18968	1.776
2012	1959.5	3426	1.748	9158.7	13562	1.481	10119.8	22572	2.230

Source: Various issues of BBS

A-4: ***Continued …………………………..***

Year	Khulna			Rajshahi		
	Area (ha)	**Production (ton)**	**Yield (t/ha)**	**Area (ha)**	**Production (ton)**	**Yield (t/ha)**
1989	827.1	902	1.091	1632.0	2921	1.790
1990	512.1	580	1.132	1587.0	2600	1.638
1991	542.5	600	1.106	1544.5	3055	1.978
1992	585.0	525	0.897	1726.7	2355	1.364
1993	540.5	525	0.971	1736.8	3665	2.110
1994	481.8	455	0.944	2443.3	5160	2.112
1995	512.1	490	0.957	2463.6	3700	1.502
1996	548.6	570	1.039	2334.0	3760	1.611
1997	558.7	525	0.940	2121.5	3110	1.466
1998	489.9	500	1.021	2137.7	3115	1.457
1999	429.1	465	1.084	2032.4	2985	1.469
2000	413.0	425	1.029	2099.2	3050	1.453
2001	259.1	280	1.081	2089.1	2955	1.415
2002	220.6	270	1.224	2131.6	2995	1.405
2003	380.6	545	1.432	1884.6	2740	1.454
2004	797.6	1240	1.555	1834.0	2370	1.292
2005	1581.0	3105	1.964	2445.3	3275	1.339
2006	1206.5	2915	2.416	2530.4	3575	1.413
2007	1682.2	3105	1.846	3273.3	4200	1.283
2008	1070.4	1557	1.455	2980.6	3989	1.338
2009	1001.6	1473	1.471	3084.2	5259	1.705
2010	2255.5	2231	0.989	2589.1	3639	1.406
2011	991.9	2114	2.131	1943.3	2948	1.517
2012	998.8	2088	2.091	2000.0	1999	1.000

Source: Various issues of BBS

A-4: ***Continued …………………………***

Year	Sylhet			Rangpur		
	Area (ha)	Production (ton)	Yield (t/ha)	Area (ha)	Production (ton)	Yield (t/ha)
1989	1339.3	1112	0.830	4107.3	3718	0.905
1990	1485.8	1615	1.087	4113.4	4125	1.003
1991	1506.1	1740	1.155	4386.6	5092	1.161
1992	1445.3	1590	1.100	4637.7	4595	0.991
1993	1443.3	1710	1.185	4113.4	4230	1.028
1994	1447.4	1705	1.178	4277.3	4715	1.102
1995	1443.3	1675	1.161	4153.8	4440	1.069
1996	1419.0	1655	1.166	4131.6	4570	1.106
1997	1305.7	1935	1.482	3141.7	3475	1.106
1998	1323.9	1715	1.295	3202.4	3585	1.119
1999	1323.9	1725	1.303	3358.3	3775	1.124
2000	1327.9	1755	1.322	3358.3	3770	1.123
2001	1330.0	1835	1.380	1327.9	410	0.309
2002	1305.7	1700	1.302	1285.4	375	0.292
2003	1190.3	1590	1.336	1247.0	1430	1.147
2004	1072.9	1385	1.291	1536.4	1735	1.129
2005	1064.8	1630	1.531	1469.6	2095	1.426
2006	1076.9	1965	1.825	2121.5	2710	1.277
2007	1585.0	2715	1.713	4435.2	6415	1.446
2008	1165.2	1903	1.633	4204.0	6689	1.591
2009	1181.0	1810	1.533	5147.0	7725	1.501
2010	1191.5	1924	1.615	4934.4	7470	1.514
2011	1192.3	1966	1.649	5036.0	7831	1.555
2012	731.2	1177	1.610	5119.0	7828	1.529

Source: Various issues of BBS

A-5: Area, production and yield of sesame in Bangladesh, 1989-2012

Year	Area ('000' ha)	Production ('000' ton)	Yield (t/ha)
1989	90.82	50.93	0.56
1990	86.42	49.29	0.57
1991	83.12	48.61	0.58
1992	80.60	45.32	0.56
1993	82.52	49.53	0.60
1994	79.79	48.44	0.61
1995	80.12	49.60	0.62
1996	79.71	48.75	0.61
1997	79.72	48.93	0.61
1998	79.69	49.03	0.62
1999	36.14	20.88	0.58
2000	37.22	22.01	0.59
2001	37.01	22.12	0.60
2002	36.68	22.18	0.60
2003	39.03	24.44	0.63
2004	39.02	25.49	0.65
2005	38.92	37.26	0.96
2006	30.68	39.23	1.28
2007	36.04	29.18	0.81
2008	11.68	27.04	2.32
2009	32.95	28.46	0.86
2010	35.57	32.31	0.91
2011	34.74	31.36	0.90
2012	35.67	32.95	0.92

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-6: Division wise area, production and yield of sesame in Bangladesh, 1989-2012

Year	Barisal			Chittagong			Dhaka		
	Area (ha)	Prod. (ton)	Yield (t/ha)	Area (ha)	Prod. (ton)	Yield (t/ha)	Area (ha)	Prod. (ton)	Yield (t/ha)
1989	13056.3	8674	0.664	19373.3	10979	0.567	34735.6	18915	0.545
1990	12087.0	6515	0.539	16724.7	12160	0.727	32334.0	18195	0.563
1991	12558.7	7465	0.594	20107.3	12175	0.606	30977.7	17730	0.572
1992	11747.0	6470	0.551	19508.1	12250	0.628	29708.5	15575	0.524
1993	11631.6	6875	0.591	20471.7	12790	0.625	29514.2	18085	0.613
1994	11159.9	7480	0.670	20603.2	13115	0.637	30014.2	17305	0.577
1995	11178.1	7715	0.690	20423.1	13251	0.649	30467.6	18050	0.592
1996	11283.4	7455	0.661	20504.0	13042	0.636	30028.3	17970	0.598
1997	11238.9	7600	0.676	20491.9	13042	0.636	29973.7	17865	0.596
1998	11244.9	7610	0.677	20534.4	13180	0.642	29832.0	17715	0.594
1999	1151.8	660	0.573	7791.5	4880	0.626	2919.0	1600	0.548
2000	1141.7	715	0.626	7807.7	5055	0.647	3133.6	2015	0.643
2001	1141.7	680	0.596	7603.2	4700	0.618	3178.1	2235	0.703
2002	1220.6	725	0.594	7664.0	4895	0.639	2967.6	2230	0.751
2003	1026.3	605	0.589	7641.7	5125	0.671	2815.8	1705	0.606
2004	987.9	570	0.577	7247.0	5215	0.720	2844.1	1830	0.643
2005	1062.8	635	0.598	7350.2	5400	0.735	2807.7	1745	0.622
2006	1546.6	900	0.582	2945.3	1990	0.676	4083.0	3365	0.824
2007	611.3	430	0.703	3394.7	2540	0.748	8076.9	6355	0.787
2008	4171.7	739	0.177	3440.1	2220	0.645	8304.9	6316	0.761
2009	1221.5	1040	0.851	3330.0	2684	0.806	8858.7	7318	0.826
2010	1238.9	1132	0.914	3344.9	3335	0.997	5092.7	4687	0.920
2011	902.0	847	0.939	3253.4	2975	0.914	9939.7	9165	0.922
2012	765.3	760	0.993	3215.7	3128	0.973	10512.2	10196	0.970

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-6: ***Continued …………………………..***

Year	Khulna			Rajshahi		
	Area (ha)	Production (ton)	Yield (t/ha)	Area (ha)	Production (ton)	Yield (t/ha)
1989	8755.9	4433	0.506	8503.6	4664	0.548
1990	8475.7	4890	0.577	7888.7	4770	0.605
1991	7858.3	4240	0.540	5498.0	3465	0.630
1992	7791.5	4375	0.562	5635.6	3385	0.601
1993	7874.5	4595	0.584	6202.4	3580	0.577
1994	6795.5	4250	0.625	5536.4	3370	0.609
1995	6880.6	4260	0.619	5514.2	3300	0.598
1996	6878.5	4135	0.601	5441.3	3165	0.582
1997	6777.3	4095	0.604	5572.9	3255	0.584
1998	6686.2	4100	0.613	5522.3	3255	0.589
1999	10180.2	6360	0.625	3277.3	2020	0.616
2000	10451.4	5675	0.543	3607.3	2155	0.597
2001	10455.5	5750	0.550	3627.5	2255	0.622
2002	10684.2	5605	0.525	3342.1	2075	0.621
2003	10520.2	6160	0.586	3556.7	2240	0.630
2004	10553.4	7080	0.671	4287.4	2760	0.644
2005	8680.2	16600	1.912	5338.1	3470	0.650
2006	7747.0	23240	3.000	7048.6	4810	0.682
2007	9965.6	8400	0.843	9998.0	8805	0.881
2008	10128.3	8925	0.881	7596.4	6758	0.890
2009	10175.7	9257	0.910	6753.0	6008	0.890
2010	7423.9	9763	1.315	7434.8	6585	0.886
2011	10514.6	9877	0.939	7203.2	6174	0.857
2012	10636.5	10197	0.959	7435.9	6258	0.842

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-6: ***Continued …………………………..***

Year	Sylhet			Rangpur		
	Area (ha)	**Production (ton)**	**Yield (t/ha)**	**Area (ha)**	**Production (ton)**	**Yield (t/ha)**
1989	352.2	168	0.477	6043.7	3092	0.512
1990	392.7	160	0.407	5605.3	2600	0.464
1991	421.1	170	0.404	5702.4	2785	0.488
1992	415.0	160	0.386	5789.5	3100	0.535
1993	402.8	165	0.410	6425.1	3445	0.536
1994	396.8	155	0.391	5287.4	2765	0.523
1995	242.9	90	0.371	5819.8	2930	0.503
1996	186.2	80	0.430	5392.7	2905	0.539
1997	218.6	115	0.526	5451.4	2955	0.542
1998	226.7	120	0.529	5639.7	3050	0.541
1999	12.1	5	0.412	10684.2	5350	0.501
2000	12.1	5	0.412	11062.8	6385	0.577
2001	14.2	5	0.353	10985.8	6495	0.591
2002	16.2	5	0.309	10783.4	6645	0.616
2003	12.1	5	0.412	13455.5	8600	0.639
2004	10.1	5	0.494	13095.1	8025	0.613
2005	9.0	12.4	1.377	13684.2	9410	0.688
2006	12.6	16.2	1.286	7307.7	4920	0.673
2007	16.2	20	1.235	3979.8	2630	0.661
2008	17.4	25	1.436	2958.3	2162	0.731
2009	17.8	24	1.347	2586.6	2130	0.823
2010	18.2	26	1.427	1512.6	2317	1.532
2011	18.6	27	1.450	2909.3	2298	0.790
2012	19.0	29	1.502	3080.4	2385	0.774

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-7: Area, production and yield of soybean in Bangladesh, 2006-2012

Year	Area (ha)	Production (ton)	Yield (t/ha)
2006	40,617	61,485	1.514
2007	39,231	57,715	1.471
2008	39,389	59,158	1.502
2009	40,195	59,395	1.478
2010	40,699	69,522	1.708
2011	41,459	65,883	1.589
2012	42,101	69,296	1.646

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-8: Division wise area, production and yield of soybean in Bangladesh, 2006-2012

Year	Chittagong			Dhaka		
	Area (ha)	Production (ton)	Yield (t/ha)	Area (ha)	Production (ton)	Yield (t/ha)
2006	40,601	61,465	1.514	16.2	20	1.235
2007	39,144	57,595	1.471	76.9	105	1.365
2008	39,299	59,042	1.502	88.7	114	1.286
2009	40,096	58,771	1.466	89.5	113	1.263
2010	40,606	69,410	1.709	84.6	98	1.158
2011	41,373	65,779	1.590	81.0	96	1.186
2012	42,022	69,482	1.653	76.9	88	1.146

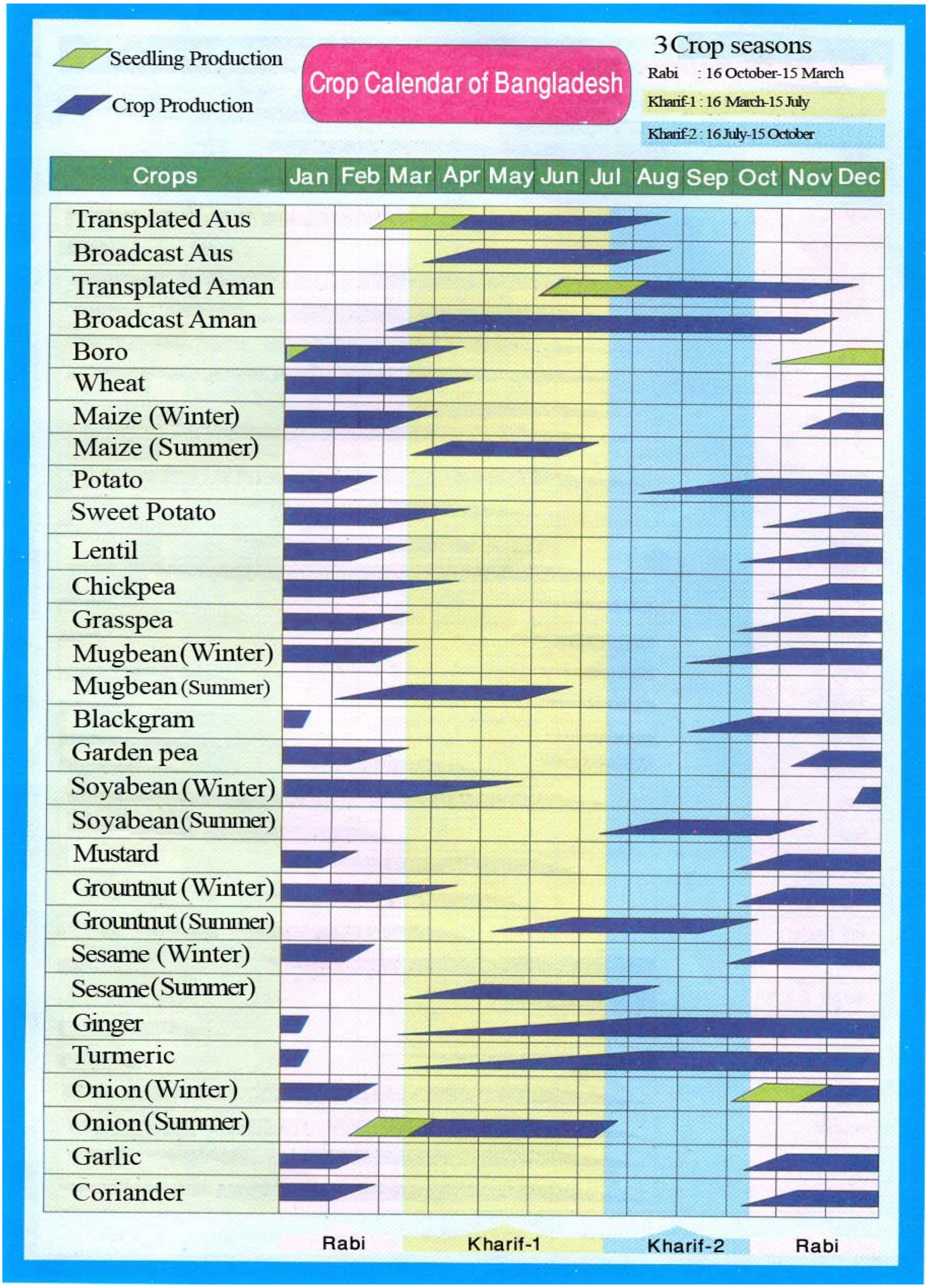
Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-8: ***Continued …………………………..***

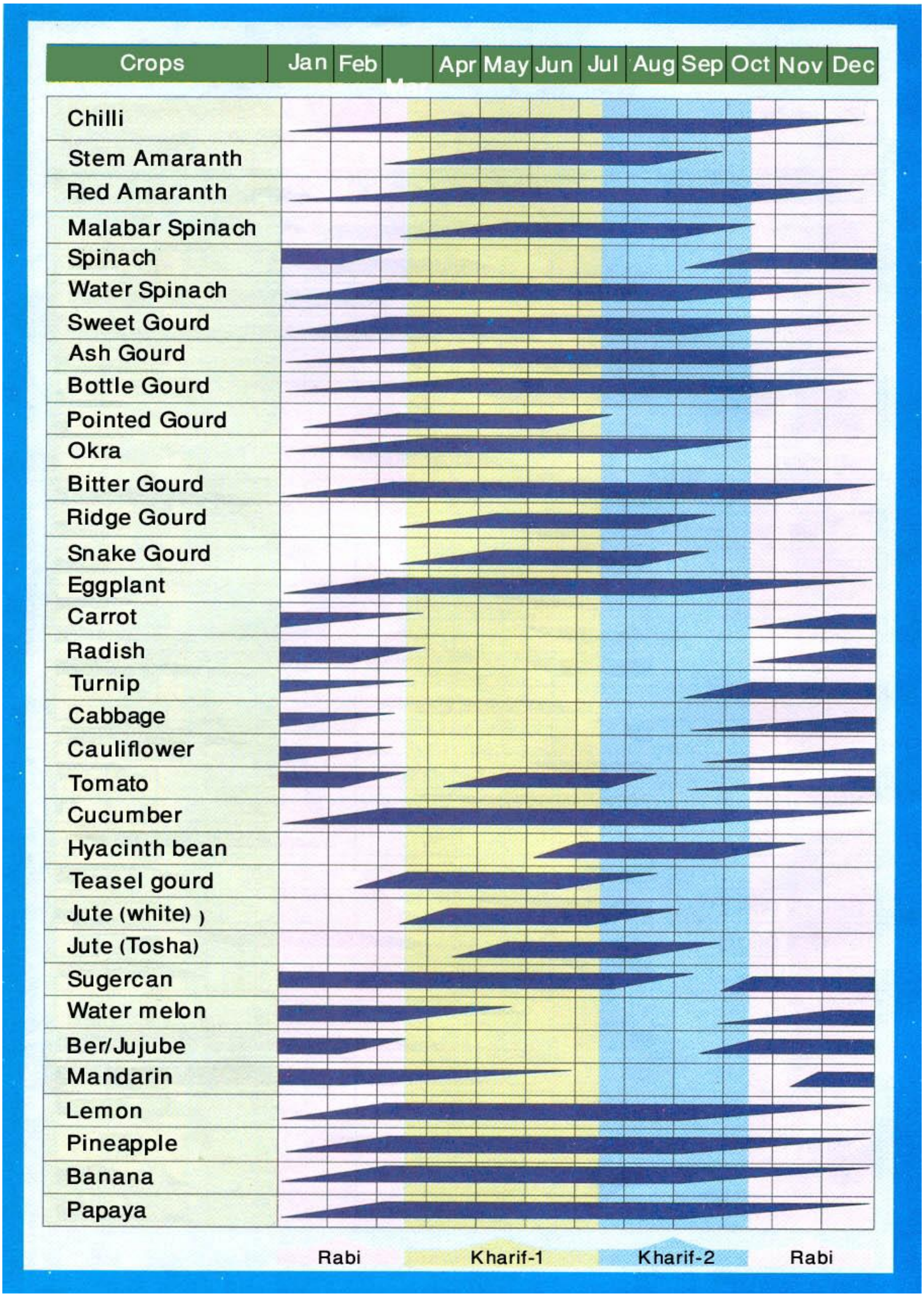
Year	Khulna			Rangpur		
	Area (ha)	Production (ton)	Yield (t/ha)	Area (ha)	Production (ton)	Yield (t/ha)
2006	2.0	5	2.470	2.0	2	1.112
2007	2.0	5	2.470	8.1	10	1.235
2008	1.2	2	1.647	5.7	7.5	1.323
2009	6.5	11	1.698	3.2	5	1.544
2010	5.7	10	1.764	2.8	4	1.411
2011	3.6	7	1.921	1.2	1.0	0.823
2012	2.6	5.4	2.088	0.6	0.2	0.316

Note: Data for 2012 are extrapolated based on the last three years data.
Source: Various issues of BBS

A-9. Crop calendar of Bangladesh



A-9. Crop calendar of Bangladesh *(continued……)*



A-10: Instability of area, production and yield of mustard, 1989-2012

Division	Mean	SD	CV (%)	R^2	Instability (%)
	AREA (HA)				
Barisal	6473	3117	48.16	0.663	27.95
Chittagong	38459	20000	52.00	0.678	29.50
Dhaka	116034	15770	13.59	0.458	10.00
Khulna	51873	13011	25.08	0.235	21.94
Rajshahi	50803	12212	24.04	0.039	23.57
Sylhet	5930	2942	49.61	0.667	28.65
Rangpur	21182	6729	31.77	0.585	20.47
Bangladesh	291956	50276	17.22	0.602	10.87
	PRODUCTION (TON)				
Barisal	2861	1336	46.68	0.577	30.36
Chittagong	27446	13003	47.38	0.666	27.38
Dhaka	81384	14522	17.84	0.032	17.56
Khulna	42423	10213	24.08	0.025	23.77
Rajshahi	44757	14095	31.49	0.478	22.76
Sylhet	4660	2112	45.33	0.555	30.24
Rangpur	16547	4267	25.79	0.314	21.36
Bangladesh	221207	29007	13.11	0.010	13.05
	YIELD (TON/Ha)				
Barisal	0.4580	0.0550	12.01	0.6065	7.53
Chittagong	0.7658	0.1218	15.91	0.4701	11.58
Dhaka	0.7070	0.1174	16.60	0.4854	11.91
Khulna	0.8266	0.1311	15.86	0.6044	9.98
Rajshahi	0.8953	0.2662	29.74	0.3530	23.92
Sylhet	0.8584	0.1780	20.73	0.8443	8.18
Rangpur	0.8041	0.1049	13.04	0.8991	4.14
Bangladesh	0.7710	0.1115	14.46	0.7878	6.66

A-11: Instability of area, production and yield of groundnut, 1989-2012

Division	Mean	STD	CV (%)	R^2	Instability (%)
	AREA (HA)				
Barisal	2880	630	21.88	0.5684	14.37
Chittagong	11359	2282	20.09	0.5315	13.75
Dhaka	10991	1264	11.50	0.3581	9.21
Khulna	787	494	62.79	0.2786	53.33
Rajshahi	2194	465	21.21	0.3546	17.04
Sylhet	1287	187	14.53	0.4673	10.61
Rangpur	3535	1328	37.56	0.0103	37.37
Bangladesh	33119	3815	11.52	0.4909	8.22
	PRODUCTION (TON)				
Barisal	3305	1416	42.84	0.0209	42.39
Chittagong	13908	1491	10.72	0.0127	10.65
Dhaka	14119	3090	21.88	0.0529	21.30
Khulna	1145	943	82.33	0.4478	61.18
Rajshahi	3309	789	23.83	0.0051	23.77
Sylhet	1731	301	17.41	0.0818	16.69
Rangpur	4283	2214	51.68	0.0102	51.42
Bangladesh	41398	6205	14.99	0.1112	14.13
	YIELD (TON/HA)				
Barisal	1.253	0.887	70.74	0.2867	59.74
Chittagong	1.273	0.296	23.28	0.5785	15.11
Dhaka	1.293	0.293	22.63	0.3456	18.31
Khulna	1.328	0.447	33.64	0.5173	23.37
Rajshahi	1.522	0.262	17.19	0.4044	13.27
Sylhet	1.362	0.240	17.62	0.7799	8.26
Rangpur	1.148	0.331	28.83	0.0949	27.43
Bangladesh	1.260	0.207	16.43	0.7394	8.39

A-12: Instability of area, production and yield of sesame, 1989-2012

Division	Mean	SD	CV (%)	R^2	Instability
	AREA (HA)				
Barisal	5641	5303	94.01	0.693	52.08
Chittagong	11449	7504	65.55	0.862	24.36
Dhaka	15963	13012	81.51	0.532	55.77
Khulna	8870	1532	17.27	0.272	14.74
Rajshahi	5909	1771	29.98	0.017	29.73
Sylhet	144	167	116.08	0.698	63.76
Rangpur	6885	3661	53.17	0.109	50.18
Bangladesh	54327	24774	45.60	0.679	25.84
	PRODUCTION (TON)				
Barisal	3512	3371	95.98	0.660	55.97
Chittagong	7505	4522	60.25	0.793	27.43
Dhaka	9924	7137	71.92	0.262	61.77
Khulna	7344	4510	61.41	0.596	39.03
Rajshahi	4108	1808	44.01	0.181	39.83
Sylhet	66	66	99.62	0.375	78.77
Rangpur	4141	2246	54.25	0.000	54.24
Bangladesh	36804	11314	30.74	0.363	24.53
	YIELD (TON/HA)				
Barisal	0.651	0.161	24.79	0.020	24.55
Chittagong	0.699	0.115	16.44	0.562	10.88
Dhaka	0.679	0.133	19.59	0.784	9.10
Khulna	0.837	0.558	66.64	0.380	52.47
Rajshahi	0.676	0.120	17.75	0.703	9.67
Sylhet	0.741	0.469	63.25	0.640	37.93
Rangpur	0.641	0.215	33.52	0.633	20.31
Bangladesh	0.773	0.375	48.45	0.460	35.62

A-13: Instability of area, production and yield of soybean, 2006-2012

Division	Mean	SD	CV (%)	R^2	Instability
	Instability in area (%)				
Chittagong	99260.5	2107.224	2.12	0.318611	1.75
Dhaka	191.8333	80.8243	42.13	0.484153	30.26
Khulna	8	4.732864	59.16	0.352152	47.62
Bangladesh	99454.5	2090.07	2.10	0.351192	1.69
	Instability in production (%)				
Chittagong	62010.33	4648.758	7.50	0.423573	5.69
Dhaka	91	35.56403	39.08	0.359036	31.29
Khulna	6.508333	3.502915	53.82	0.285228	45.50
Bangladesh	62193	4580.92	7.37	0.452115	5.45
	Instability in yield (%)				
Chittagong	0.624335	0.037746	6.05	0.370242	4.80
Dhaka	0.485541	0.071191	14.66	0.273712	12.50
Khulna	0.822824	0.134035	16.29	0.01432	16.17
Bangladesh	0.624954	0.036833	5.89	0.395558	4.58

Note: Soybean productions/data are not available at Rajshahi, Rangpur, Barisal and Sylhet division

A-14: Value of imported oilseeds and edible oils in Bangladesh during 1994-2012

(Million taka)

Year	Oilseeds	Edible oil
1994	1600	4680
1995	3220	8840
1996	3640	7310
1997	2650	9220
1998	4230	9820
1999	4810	13970
2000	4530	12880
2001	3470	11750
2002	4120	14390
2003	3690	21100
2004	4340	27730
2005	5260	26980
2006	6070	31740
2007	7360	40220
2008	9320	69050
2009	10950	59520
2010	9000	72600
2011	7360	76000
2012	14200	130510

Source: Bangladesh Bank, 2012

A-15: Focus Group Discussion (FGD) with extension personnel, farmers, and scientists

UAO, Sadar, Tangail

UAO, Sadar, Pabna

UAO, Nawabgonj, Dinajpur

Oilseed farmers & extension personnel, Noakhali

Scientists, Oilseeds Research Centre BARI, Joydebpur, Gazipur

Project Completion Workshop, BARC, Farmgate, Dhaka

A-16: Collection of field level primary data from oilseed farmers

Nawabgonj, Dinajpur

Nawabgonj, Dinajpur

Hakimpur, Dinajpur

Kabirhaat, Noakhali

Godagari, Rajshahi

Tangail Sadar, Tangail

A-17: Percent distribution of oilseeds farmers by training received on agriculture

No. of training	Mustard *(n=540)*	Groundnut *(n=540)*	Sesame *(n=540)*	Soybean *(n=360)*	All *(n=1980)*
A. Adopter	*n=197*	*n=95*	*n=116*	*n= 56*	*n= 464*
No training	55.83	62.11	57.75	--	50.86
1-2 Nos.	25.38	25.26	31.04	91.07	34.70
3-4 Nos.	10.66	4.21	3.45	5.36	6.90
5-6 Nos.	8.13	8.42	7.76	3.57	7.54
Total	100	100	100	100	100
B. Non-adopter	*n=343*	*n=445*	*n=424*	*n= 304*	*n= 1516*
No training	58.01	57.53	61.55	76.31	62.53
1-2 Nos.	30.03	30.57	28.30	18.75	27.44
3-4 Nos.	8.46	6.06	6.14	3.95	6.20
5-6 Nos.	3.50	5.84	4.01	0.99	3.83
Total	100	100	100	100	100

A-18: Percent of mustard farmers involved with different social organizations

Type of social organization	Percent responses as:			
	Organization head	Executive member	General member	Overall
A. Adopter ***(n=197)***				
Farmer`s coop society	1.5	2.0	10.7	14.2
Youth coop society	0.5	2.0	6.6	9.1
School committee	2.0	2.0	14.7	18.8
IPM/ICM club	2.5	4.6	35.0	42.1
Mosque committee	1.5	2.0	33.5	37.1
Market committee	--	0.5	7.1	7.6
Union council	0.5	0.5	1.5	2.5
B. Non-adopter ***(n=343)***				
Farmer`s coop society	--	0.3	4.1	4.4
Youth coop society	--	0.3	2.6	2.9
School committee	1.2	0.3	7.0	8.5
IPM/ICM club	0.6	1.5	12.5	14.6
Mosque committee	2.0	1.2	15.7	19.0
Market committee	--	--	3.5	3.5
Union council	0.3	0.3	1.7	2.3

A-19: Percent of groundnut farmers involved with different social organizations

Type of social organization	Percent responses as:			
	Organization head	Executive member	General member	Overall
A. Adopter (n=95)				
1. Farmer`s coop society	1.1	--	10.5	11.7
2. Youth coop society	--	--	2.1	2.1
3. School committee	3.2	--	9.5	12.7
4. IPM/ICM club	1.1	2.1	25.3	28.5
5. Mosque committee	--	6.3	20.0	**9.3**
6. Market committee	--	--	3.2	3.2
7. Union council	--	1.1	2.1	3.2
B. Non Adopter (n=445)				
1. Farmer`s coop society	--	0.4	2.5	2.9
2. Youth coop society	0.2	--	0.9	1.1
3. School committee	0.4	0.4	4.0	4.9
4. IPM/ICM club	--	0.7	3.4	4.0
5. Mosque committee	0.9	2.2	10.6	13.7
6. Market committee	--	0.2	1.8	2.0
7. Union council	0.4	0.2	0.4	1.1

A-20: Percent of sesame farmers involved with different social organizations

Type of social organization	Percent responses as:			
	Organization head	Executive member	General member	Overall
A. Adopter (n=116)				
1. Farmer`s coop society	--	--	0.9	0.9
2. Youth coop society	--	--	1.7	1.7
3. School committee	--	0.9	7.8	8.6
4. IPM/ICM club	--	0.9	9.5	10.3
5. Mosque committee	--	0.9	33.6	34.5
6. Market committee	--	--	0.9	0.9
7. Union council	--	--	0.9	0.9
B. Non Adopter (n=424)				
1. Farmer`s coop society	--	0.2	1.2	1.4
2. Youth coop society	--	0.2	0.7	0.9
3. School committee	0.5	0.5	5.7	6.6
4. IPM/ICM club	--	0.2	4.0	4.2
5. Mosque committee	0.5	1.2	18.4	20.0
6. Market committee	--	0.5	2.1	2.6

A-21: Percent of Soybean farmers involved with different social organizations

Type of social organization	Percent responses as:			
	Organization head	Executive member	General member	Overall
A. Adopter (n=56)				
1. Farmer`s coop society	--	--	37.5	37.5
2. Youth coop society	--	--	--	--
3. School committee	3.6	16.1	19.6	39.3
4. IPM/ICM club	1.8	--	41.1	42.9
5. Mosque committee	--	--	17.9	17.9
6. Market committee	--	--	26.8	26.8
7. Union council	--	--	1.8	1.8
B. Non Adopter (n=304)				
1. Farmer`s coop society		0.3	1.3	1.6
2. Youth coop society	--	--	--	--
3. School committee	1.3	0.3	8.6	10.2
4. IPM/ICM club	1.3	0.7	6.3	8.2
5. Mosque committee	1.0	2.6	16.8	20.4
6. Market committee	--	0.3	2.3	2.6
7. Union council	0.3	--	1.0	1.3

A-22: Percent responses on the level of cosmopolitans of the mustard farmers

Place of visit	Frequently	Often	Rarely	Never
A. Adopter (n=197)				
5. *Upazila Sadar*	80.7	17.3	2.0	--
6. District	26.9	64.5	8.1	0.5
7. Capital city	2.0	24.9	61.4	11.7
8. Foreign country	--	1.0	5.6	93.4
B. Non-adopter (n=343)				
5. *Upazila Sadar*	39.4	48.7	11.4	0.5
6. District	5.2	67.7	24.8	2.3
7. Capital city	0.3	11.1	64.1	24.5
8. Foreign country	--	--	1.5	98.5

A-23: Percent responses on the level of cosmopolitans of the groundnut farmers

Place of visit	Frequently	Often	Rarely	Never
A. Adopter (n=95)				
1. *Upazila Sadar*	75.8	24.2	--	--
2. District	18.9	70.6	10.5	--
3. Capital city	1.1	61.1	36.7	1.1
4. Foreign country	--	1.1	10.5	88.4
B. Non-adopter (n=445)				
1. *Upazila Sadar*	48.3	48.5	3.1	--
2. District	2.1	75.7	21.3	0.9
3. Capital city	--	12.8	62.7	24.5
4. Foreign country	--	--	--	100

A-24: Percent responses on the level of cosmopolitans of the sesame farmers

Place of visit	Frequently	Often	Rarely	Never
A. Adopter (n=116)				
1. *Upazila Sadar*	75.9	24.1	--	--
2. District	11.2	87.9	0.9	--
3. Capital city	--	41.4	58.6	--
4. Foreign country	--	--	19.8	80.2
B. Non-adopter (n=424)				
1. *Upazila Sadar*	70.8	26.2	3.1	--
2. District	5.0	77.1	16.7	1.2
3. Capital city	0.2	9.0	75.9	14.9
4. Foreign country	--	0.5	3.8	95.7

A-25: Percent responses on the level of cosmopolitans of the soybean farmers

Place of visit	Frequently	Often	Rarely	Never
A. Adopter (n=56)				
1. *Upazila Sadar*	71.4	28.6	--	--
2. District	14.3	85.7	--	--
3. Capital city	--	35.7	64.3	--
4. Foreign country	--	--	37.5	62.5
B. Non-adopter (n=304)				
1. *Upazila Sadar*	75.4	23.0	1.6	--
2. District	19.4	69.4	10.2	1.0
3. Capital city	1.0	6.6	77.6	14.8
4. Foreign country	--	0.3	3.0	96.7

A-26: Level of association of mustard farmers with different extension medias

Extension medias	Farmers' responses (%)				
	Regular	Often	Sometimes	Rare	None
A. Adopter (n=197)					
1. Extension personnel	51.3	31.5	15.7	1.5	--
2. Neighbor (farmer)	40.1	46.7	12.2	1.0	--
3. Agriculture fair	1.0	2.0	33.0	43.7	20.3
4. Radio	0.5	3.6	13.2	36.0	46.7
5. Television	8.6	12.7	49.2	10.7	18.8
6. Demonstration plot	2.5	3.6	25.4	38.6	29.9
7. Agricultural book	--	3.6	12.2	34.0	50.3
8. Newspaper	11.7	14.2	17.8	6.1	50.3
9. Research institute visit	--	--	4.1	12.2	83.8
10. Field day	1.0	1.5	2.0	14.7	80.7
B. Non-adopter (n=343)					
1. Extension personnel	23.3	40.5	34.1	1.2	0.9
2. Neighbor (farmer)	32.7	47.8	17.2	1.2	1.2
3. Agriculture fair	0.9	2.3	18.1	26.8	51.9
4. Radio	1.5	2.3	8.5	5.2	82.5
5. Television	6.4	9.9	42.0	9.0	32.7
6. Demonstration plot	0.6	2.3	19.2	16.9	60.9
7. Agricultural book	--	1.2	12.0	6.7	80.2
8. Newspaper	10.8	3.5	16.0	5.2	64.4
9. Research institute visit	--	--	1.5	5.5	93.0
10. Field day	--	0.9	1.2	3.8	94.2

A-27: Level of association of groundnut farmers with different extension medias

Extension medias	Farmers' responses (%)				
	Regular	Often	Sometimes	Rare	None
A. Adopter (n=95)					
1. Extension personnel	14.7	83.2	1.1	--	1.1
2. Neighbor farmer	9.5	62.1	27.4	--	1.1
3. Agriculture fair	--	14.7	15.8	26.3	43.2
4. Radio	1.1	4.2	33.7	--	61.1
5. Television	1.1	29.5	17.9	2.1	49.5
6. Demonstration plot	--	2.1	11.6	29.5	56.8
7. Agricultural book	1.1	2.1	29.5	3.2	64.2
8. Newspaper	1.1	8.4	24.2	2.1	64.2
9. Research institute visit	--	1.1	2.1	12.6	84.2
10. Field day	--	--	1.1	11.6	87.4
B. Non-adopter (n=445)					
1. Extension personnel	--	78.2	16.0	4.9	0.9
2. Neighbor farmer	11.9	48.1	37.1	0.9	2.0
3. Agriculture fair	--	0.9	17.8	11.7	69.7
4. Radio	0.7	1.6	15.7	6.1	76.0
5. Television	0.9	3.8	20.7	5.2	69.4
6. Demonstration plot	0.2	1.8	16.4	7.2	74.4
7. Agricultural book	0.2	1.3	10.3	3.8	84.3
8. Newspaper	2.0	2.5	12.4	4.9	78.2
9. Research institute visit	--	--	1.6	5.4	93.0
10. Field day	--	--	--	1.6	98.4

A-28: Level of association of sesame farmers with different extension medias

Extension medias	Farmers' responses (%)				
	Regular	Often	Sometimes	Rare	None
A. Adopter (n=116)					
1. Extension personnel	14.7	50.9	31.0	3.4	--
2. Neighbor farmer	25.9	20.7	46.6	6.0	0.9
3. Agriculture fair	--	--	18.1	10.3	71.6
4. Radio	--	1.7	7.8	2.6	87.9
5. Television	1.7	1.7	18.1	8.6	69.8
6. Demonstration plot	0.9	0.9	15.5	6.0	76.7
7. Agricultural book	1.7	--	5.2	0.9	92.2
8. Newspaper	3.4	--	4.3	3.4	88.8
9. Research institute visit	0.9	--	1.7	3.4	94.0
10. Field day	--	--	--	0.9	99.1
B. Non-adopter (n=424)					
1. Extension personnel	14.4	49.1	29.0	3.3	4.2
2. Neighbor farmer	20.8	35.1	33.5	5.9	4.7
3. Agriculture fair	--	--	8.3	10.6	81.1
4. Radio	--	--	4.2	0.5	95.3
5. Television	0.5	1.2	15.3	3.8	79.2
6. Demonstration plot	--	---	9.7	6.1	84.2
7. Agricultural book	0.2	--	5.0	1.7	93.2
8. Newspaper	2.1	0.7	4.2	3.3	89.6
9. Research institute visit	--	--	0.9	1.7	97.4
10. Field day	--	--	--	0.2	99.8

A-29: Level of association of soybean farmers with different extension medias

Extension medias	Farmers' responses (%)				
	Regular	Often	Sometimes	Rare	None
A. Adopter (n=56)					
1. Extension personnel	42.9	55.4	1.8	--	--
2. Neighbor farmer	28.6	42.9	28.6		
3. Agriculture fair	1.8	14.3	26.8	30.4	26.8
4. Radio	--	--	50.0	5.4	44.6
5. Television	--	7.1	57.1	3.6	32.1
6. Demonstration plot	--	5.4	28.6	10.7	55.4
7. Agricultural book	--	--	37.5	1.8	60.7
8. Newspaper	7.1	7.1	41.1	7.1	37.5
9. Research institute visit	--	--	10.7	12.5	76.8
10. Field day	--	--	--	10.7	89.3
B. Non-adopter (n=304)					
1. Extension personnel	16.4	46.7	35.9	1.0	--
2. Neighbor farmer	3.9	50.7	42.8	2.6	--
3. Agriculture fair	--	0.7	12.2	16.4	70.4
4. Radio	--	0.7	7.6	5.6	86.2
5. Television	0.3	1.0	15.1	6.6	77.0
6. Demonstration plot	--	1.6	8.9	7.6	81.9
7. Agricultural book	0.3	1.3	4.3	3.3	90.8
8. Newspaper	1.3	1.3	5.6	3.0	88.8
9. Research institute visit	--	--	0.3	3.3	96.4
10. Field day	--	--	0.3	1.0	98.7

A-30: Variety wise area and production of mustard in 61 districts of Bangladesh, 2008/09-201011

Variety	No. of District	2010-2011		2009-2010		2008-2009	
		Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
BARI Mustard 2 (Rai)	33	13632	16581.1	16387	18551.4	12142	11644.55
BARI Mustard 3 (Kollaneya)	16	1142	1417.1	1065	1146.3	1204	1129.35
BARI Mustard 4 (Sonali)	30	9380	10945.75	9430	11228.7	12709	12815.41
BARI Mustard 5 (Dawlat)	19	1368	1513	1562	1484	1136	1168.5
BARI Mustard 6 (Dholy)	21	12061	17262	11032	15133.3	11483	12993
BARI Mustard 7	16	803	948	796	848	2915	3138.43
BARI Mustard 8	4	1052	1229	715	723	245	275
BARI Mustard 9	56	48358	61836.2	43458	51043.1	37666	41169.56
BARI Mustard 10	5	58	85.35	206	231	667	804
BARI Mustard 11	36	12809	16721.4	10097	12378.3	8672	9657.11
BARI Mustard 12	8	472	537	1014	1206.56	491	552.4
BARI Mustard 13	9	1437	1751	1199	1498.7	711	772.5
BARI Mustard 14	39	13390	18084.75	7418	9485.62	5457	6723.95
BARI Mustard 15	40	9666	13497.04	5104.25	6481.96	3135	3474.2
BARI Mustard 16	3	10	9.5	705	1073.5	5	4.5
BINA Mustard 3	15	1011	1172	707	791.1	384	401
BINA Mustard 4	18	2382	2967.62	3283	4759.4	741	838.4
BINA Mustard 5	13	1149	1499.4	784	910.2	611	699
BINA Mustard 6	10	265	319.7	79	93.5	208	211
Local	11	18017	17394.78	15957	17127.08	18803	16967.55
Tori-7	61	285437	272832.5	260379	272788.95	300620	265514.5
Total		**433899**	**458604.2**	**391377.3**	**428983.67**	**420005**	**390953.9**

Source: District level DAE Offices 2012

A-31: Variety wise area and production of groundnut 46 districts of Bangladesh

Variety	No. of District	2010-2011		2009-2010		2008-2009	
		Area (ha)	Production (t)	Area (ha)	Production (t)	Area (ha)	Production (t)
BARI Groundnut 5	10	194	320	147	233	93	126
BARI Groundnut 6	6	87	134	52	79	43	64
BARI Groundnut 7	2	35	55	60	90	30	47
BARI Groundnut 8	3	35	64	2	3.5	5	8.5
BARI Groundnut 9	2	12	24	2	3	1	2
Basonty Badam	20	2218.5	3942.6	2402	4355.9	2855.5	4884.6
DM-1 (Tridana)	18	1007	1897	829	1418	735	1143.4
Jhingha Badam	25	2221	3409.1	3860.5	6007.18	1542.6	2292.38
Dhaka-1	46	48866	78520.5	42220.5	66804.39	47082.5	70199.16
BINA -1	3	30	40	42	55	30	35
BINA -2	3	153	293	35	88	33	60
BINA -3	3	79	133	1	1.4	1	1.5
Local	9	2630	3577.4	3309.5	5056	2905	4499.84
Maizchar	25	6623.5	9985.34	7435	12794.15	3875.5	6212.72
Total		**64191**	**102394.94**	**60397.5**	**96988.52**	**59232.1**	**89576.1**

Source: District level DAE Offices, 2012

A-32: Per hectare input use pattern for mustard cultivation

Particular	Improved (n=217)			Tori-7 (n=323)			t-value
	Min	Max	Mean	Min	Max	Mean	
Labour (Manday)							
Family labour	00	99.1	**46.2 (197)	0.0	94.5	37.6 (343)	0.000
Hired labour	7.0	96.0	***32.2 (176)	5.0	81.0	24.2 (295)	0.000
Total labour	51.9	110.5	***75.1 (197)	51.1	99.8	62.4 (343)	0.000
Seed (kg)	3.7	18.5	**8.7 (197)	2.1	15.9	9.5 (343)	0.014
Fertilizer (kg)							
Urea	35.3	395.2	***168.8 (197)	16.5	411.7	150.7 (341)	0.005
TSP	49.4	411.7	***149.4 (139)	28.1	370.5	127.1 (234)	0.002
MoP	14.1	231.6	***92.6 (176)	8.2	205.8	74.3 (282)	0.000
DAP	37.4	308.8	**147.8 (71)	28.1	329.3	124.5 (111)	0.011
Zypsum	7.4	494.0	115.4 (86)	8.2	322.2	103.2 (120)	0.280
Zinc	2.5	26.0	10.9 (36)	1.2	29.9	10.5 (63)	0.754
Boron	0.5	32.9	10.2 (46)	1.1	29.9	9.2 (61)	0.485
Manure (kg)	105	19760	6477 (197)	92.6	19760	6417 (343)	0.919
Pesticide (Tk)	247	3892	**1619 (197)	371.0	4803	1340 (343)	0.015
Irrigation (Tk)	449	3984	2250 (197)	524.0	3952	2042 (343)	0.121

Note: Figures in the parentheses are no. of respondent
"**" and "***" indicate significant at 5% and 1% level

A-33: Per hectare input use pattern for groundnut cultivation

Particular	Improved (n=95)			Dhaka No.-1 (n=445)			t-value
	Min	Max	Mean	Min	Max	Mean	
Labour (Manday)							
Family labour	13.0	105.0	**58.0 (95)	7.7	108.1	53.0 (445)	0.014
Hired labour	12.4	100.0	***55.6 (95)	0.0	109.8	49.8 (437)	0.002
Total labour	100.0	132.1	***113.5 (95)	69.9	135.2	101.9 (445)	0.000
Seed (kg)	55.6	224.5	***110.8 (95)	28.1	247.0	100.1(445)	0.006
Fertilizer (kg)							
Urea	24.7	149.7	**70.0 (59)	9.4	149.7	62.0 (235)	0.017
TSP	12.4	149.7	79.2 (38)	15.4	123.5	67.1 (196)	0.665
MoP	9.4	149.7	**69.2 (37)	10.3	98.8	47.8 (151)	0.021
DAP	49.4	110.3	63.1 (7)	32.1	92.6	68.9 (13)	0.162
Zypsum	37.4	61.8	53.8 (5)	4.9	74.8	37.5 (26)	0.637
Manure (kg)	1059	3742	2469 (11)	247.0	3742	1656 (58)	0.441
Pesticide (Tk)	557	2196	931 (11)	226.4	2882	1212 (66)	0.086
Irrigation (Tk)	1372	3742	2625 (5)	1098	3742	2164 (27)	0.962

Note: Figures in the parentheses are no. of respondent
"**" and "***" indicate significant at 5% and 1% level

A-34: Per hectare input use pattern for sesame cultivation

Particular	Improved (n=116)			Til-6 (n=424)			t-value
	Min	Max	Mean	Min	Max	Mean	
Labor (Manday)							
Family labor	9.8	94.0	***47.5 (116)	4.1	94.5	41.6 (424)	0.000
Hired labor	7.5	91.4	***53.8 (116)	4.1	88.3	44.6 (421)	0.000
Total labor	67.4	116.8	***101.3(116)	38.9	123.0	85.9 (424)	0.000
Seed (kg)	3.1	10.1	**7.0 (116)	2.9	9.9	7.0 (424)	0.999
Fertilizer (kg)							
Urea	18.5	187.1	*93.1(100)	7.5	190.0	85.0 (309)	0.061
TSP	18.7	195.0	91.1 (86)	7.5	190.0	85.2 (228)	0.246
MoP	5.5	187.1	68.9 (71)	1.9	164.7	60.3 (173)	0.794
DAP	105.9	154.4	130.1 (2)	3.7	112.3	58.8 (26)	0.213
Zypsum	24.7	98.8	60.2 (12)	32.9	98.8	63.3 (31)	0.683
Manure (kg)	294.4	13722	***5395 (33)	74.8	9880	3445 (56)	0.010
Pesticide (Tk)	169	1976	1133 (53)	162.5	1976	1045 (152)	0.235
Irrigation (Tk)	390	3742	2330 (60)	617.5	3742	2270 (146)	0.126

Note: Figures in the parentheses are no. of respondent
"*", "**" and "***" indicate significant at 10%, 5% and 1% level

A-35: Per hectare input use pattern for soybean cultivation

Particular	Improved variety (n=56)			Sohag (n=484)			t-value
	Min	Max	Mean	Min	Max	Mean	
Labor (Manday)							
Family labour	6.3	86.6	***40.6 (56)	1.0	95.0	31.8 (304)	0.000
Hired labour	6.0	85.0	47.2 (56)	3.7	99.1	50.5 (300)	0.171
Total labour	50.6	115.0	**87.8 (56)	34.1	115.4	81.7 (304)	0.019
Seed (kg)	30.9	98.8	69.5 (56)	24.7	113.2	67.7 (304)	0.469
Fertilizer (kg)							
Urea	10.3	123.5	68.6 (43)	4.4	123.5	65.3 (260)	0.539
TSP	30.9	154.4	**83.9 (49)	4.9	147.0	72.8 (247)	0.039
MoP	9.3	123.5	*52.7 (30)	2.5	123.5	41.3 (135)	0.089
DAP	--	--	--	24.7	98.8	65.8 (15)	0.000
Zypsum	6.2	82.3	29.7 (14)	4.9	82.3	27.7 (23)	0.761
Manure (kg)	412	3705	1565 (9)	143	4940	1818.9 (47)	0.548
Pesticide (Tk)	198	1930	*1027 (25)	216	2823	1224 (204)	0.063
Irrigation (Tk)	1544	2205	1764 (3)	749	2744	1908 (9)	0.899

Note: Figures in the parentheses are no. of respondent
"*", "**" and "***" indicate significant at 10%, 5% and 1% level

A-36: Calculation of import parity border prices of oilseed crops

Particulars	Mustard	Groundnut	Sesame	Soybean
A. CIF price at Chittagong (US$/mt)	483	1500	1049	498
B. CIF price at Chittagong (Tk/mt)	34293	106500	74479	35358
C. Marketing margin from the port of entry to the wholesale market	2197	4363	3402	2229
Import handling cost	1029	3195	2234	1061
Transportation cost	1016	1016	1016	1016
Domestic trading cost	152	152	152	152
D. Border price at wholesale level (B+C)	36490	110863	77881	37587
E. Components of the marketing spread between the wholesale market to the produce level	2188	2273	2010	1899
Cost from farm gate to wholesale	1144	1144	1144	1144
Interest cost	1119	1129	866	755
F. Border price of farm produce at farm gate (D-E)	34302	108590	75872	35688

A-37: Calculation of import parity border prices of different fertilizers

Particulars	Urea (Middle East)	TSP (Morocco)	MoP (Jordan)	DAP (US Gulf)
A. CIF price at Chittagong (US$/mt)	418	535	381	630
B. CIF price at Chittagong (Tk/mt)	29678	37985	27051	44730
C. Marketing margin from the port of entry to the wholesale market				
Import handling cost	890	1140	812	1342
Transportation cost	1016	1016	1016	1016
Domestic trading cost	152	152	152	152
D. Border price at wholesale level (B+C)	31736	40293	29031	47240
E. Components of the marketing spread between the wholesale market to the produce level	384	384	384	384
Cost from farm gate to wholesale	384	384	384	384
Interest cost	-	-	-	-
F. Border price of farm produce at farm gate (D-E)	32120	40677	29415	47624

A-38. Maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production functions for mustard estimated according to study areas

(Per hectare)

Independent variable	Parameter	Manikgonj *(n=180)*	Rajshahi *(n=180)*	Dinajpur *(n=180)*
Constant	β_0	5.8237 (0.681)***	4.9454 (0.642)***	7.164 (1.191)***
Human labour (man-day)	β_1	0.0004 (0.049)*	0.2083 (0.068)***	0.1118 (0.148)
Land preparation cost (Tk)	β_2	0.1158 (0.067)	-0.0017 (0.053)	-0.0224 (0.093)
Seed (kg)	β_3	-0.0170 (0.034)	-0.0529 (0.053)	0.0044 (0.066)
Organic fertilizers (kg)	β_4	-0.0036 (0.003)	0.0016 (0.003)	-0.0044 (0.012)
Urea (kg)	β_5	0.0233 (0.021)	0.0275 (0.023)	0.0373 (0.042)
TSP (kg)	β_6	0.0091 (0.009)	0.0030 (0.007)	-0.0164 (0.021)
MoP (kg)	β_7	0.0072 (0.008)	0.0048 (0.007)	0.0111 (0.016)
DAP (kg)	β_8	0.0102 (0.009)	0.0053 (0.007)	-0.0305 (0.020)
Gypsum (kg)	β_9	-0.0038 (0.004)	0.0037 (0.005)	0.0081 (0.011)
Zinc sulphate (kg)	β_{10}	0.0079 (0.010)	-0.0058 (0.014)	0.0171 (0.026)
Boron (kg)	β_{11}	-0.0157 (0.011)	0.0217 (0.013)*	-0.0209 (0.029)
Irrigation cost (Tk)	β_{12}	0.0022 (0.006)	-0.0019 (0.003)	-0.0078 (0.008)
Pesticides cost (Tk)	β_{13}	0.0015 (0.003)	0.0037 (0.004)	0.0001 (0.006)
Land rent (Tk)	β_{14}	0.0255 (0.028)	0.1364 (0.046)***	-0.0398 (0.057)
Dummy for soil type (1=Loamy, 0= otherwise)	β_{15}	0.0207 (0.021)	-0.0373 (0.024)	0.0448 (0.045)
Dummy for variety (1= Improved, 0=otherwise)	β_{16}	0.3453 (0.021)***	0.2214 (0.029)***	0.3077(0.055)***

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

A-39. Maximum likelihood estimates of technical inefficiency models estimated for mustard farmers of different study areas

Independent variable	Para-meter	Manikgonj *(n=180)*	Rajshahi *(n=180)*	Dinajpur *(n=180)*
Constant	δ_0	0.680 (0.394)*	-1.336 (0.941)	-1.227 (2.008)
Farm size (ha)	δ_1	-0.011 (0.048)***	-0.014 (0.057)	-0.009 (0.059)
Proportion of family labor to total labor	δ_2	0.740 (0.184)	-0.3118 (0.269)	0.759 (0.806)
Age (year)	δ_3	0.002 (0.003)	0.010 (0.005)**	0.007 (0.009)
Education (year of schooling)	δ_4	0.011 (0.009)	0.039 (0.014)***	0.021 (0.059)
Farming experience (year)	δ_5	-0.006 (0.004)	-0.009 (0.008)	-0.010 (0.016)
Training on oilseeds (no./life time)	δ_6	-0.084 (0.045)*	-0.290 (0.186)*	-0.217 (0.269)*
Societal membership (wt. score) (Scale,0-3; 0= no membership , 3= executive)	δ_7	-0.127 (0.039)***	-0.207 (0.118)*	-0.258 (0.245)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit, 3= frequently)	δ_8	-0.109 (0.025)***	-0.233 (0.075)***	0.319 (0.290)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_9	-0.073 (0.300)**	0.148 (0.072)**	-0.153 (0.153)
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular)	δ_{10}	-0.032 (0.012)***	-0.022 (0.015)	-0.034 (0.039)*
Variance parameters:				
Sigma-squared	σ^2	0.044 (0.007)***	0.070 (0.023)***	0.432 (0.366)
Gamma	γ	0.891 (0.031)***	0.870 (0.054)***	0.950 (0.046)***
Log likelihood function		153.2912	105.2140	-16.0103

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability respectively.
Figures in the parentheses represent standard errors. Dependent variable = Yield (kg/ha)

A-40. Maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production functions for groundnut estimated according to study area

(Per hectare)

Independent variable	Parameter	Noakhali *(n=180)*	Pabna *(n=180)*	Tangail *(n=180)*
Constant	β_0	7.615 (1.008)***	7.6877 (0.456)***	6.3095 (0.653)***
Human labour (man-day)	β_1	0.0829 (0.233)	-0.0802 (0.079)	0.2107 (0.104)**
Land preparation cost (Tk)	β_2	-0.0203 (0.043)	-0.0074 (0.013)	0.0096 (0.004)***
Seed (kg)	β_3	-0.0200 (0.071)	0.0553 (0.021)***	0.0293 (0.034)
Organic fertilizers (kg)	β_4	-0.0056 (0.007)	-0.0054 (0.003)*	-0.0056 (0.016)
Urea (kg)	β_5	0.0123 (0.012)	-0.0045 (0.004)	-0.0088 (0.006)
TSP (kg)	β_6	0.0177 (0.013)	0.0023 (0.009)	-0.0252 (0.016)*
MoP (kg)	β_7	-0.0072 (0.013)	0.0004 (0.009)	0.0246 (0.018)
DAP (kg)	β_8	-0.0711 (0.047)	0.0084 (0.009)	0.0105 (0.014)
Gypsum (kg)	β_9	0.0020 (0.020)	0.0021 (0.008)	0.0033 (0.033)
Irrigation cost (Tk)	β_{10}	0.0132 (0.014)	0.0001 (0.004)	0.0049 (0.006)
Pesticides cost (Tk)	β_{11}	-0.0009 (0.009)	0.0035 (0.003)	0.0059 (0.007)
Land rent (Tk/ha)	β_{12}	-0.0122 (0.065)	0.0049 (0.032)	0.0012 (0.040)
Dummy for soil type (1=Loam, 0= Otherwise)	β_{13}	-0.0908 (0.055)*	0.0094 (0.016)	0.0415 (0.029)
Dummy for groundnut variety (1= Improved, 0=Otherwise)	β_{14}	0.2290 (0.078)***	0.2718 (0.019)***	0.2916 (0.021)***

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

A-41. Maximum likelihood estimates of technical inefficiency models estimated for groundnut farmers of different study areas

Independent variable	Para-meter	Noakhali *(n=180)*	Pabna *(n=180)*	Tangail *(n=180)*
Constant	δ_0	1.2722 (0.275)***	0.7975 (0.210)***	0.0916 (0.125)
Farm size (ha)	δ_1	-0.0756 (0.018)***	0.0008 (0.016)	0.0133 (0.015)
Proportion of family labour to total labour	δ_2	-0.1858 (0.223)	0.1849 (0.195)	0.0172 (0.074)
Age (year)	δ_3	-0.0049 (0.002)***	-0.0012 (0.002)	0.0011 (0.001)
Education (year of schooling)	δ_4	-0.0141 (0.008)**	-0.0007 (0.007)	-0.0011 (0.003)
Farming experience (year)	δ_5	-0.0038 (0.005)	-0.0004 (0.003)	-0.0013 (0.002)
Training on oilseeds (no./life time)	δ_6	-0.2237 (0.068)***	-0.0387 (0.039)	-0.0102 (0.014)
Availability of HYVseed (Score) (Scale,0-4; 0= not available, 4= plenty)	δ_7	-0.4687 (0.070)***	-0.3578 (0.086)***	-0.1080 (0.023)***
Dummy for society member (1=Member, 0= Otherwise)	δ_8	0.0998 (0.042)**	0.0235 (0.019)	-0.0047 (0.011)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit , 3= frequently)	δ_9	-0.0571 (0.033)*	-0.0916 (0.033)***	0.0175 (0.012)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_{10}	0.0211 (0.039)	-0.0820 (0.042)**	-0.0201 (0.012)*
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular)	δ_{11}	-0.0086 (0.009)*	0.0040 (0.006)	0.0024 (0.003)
Variance parameters:				
Sigma-squared	σ^2	0.04870 (0.008)***	0.0248 (0.008)***	0.0179 (0.002)***
Gamma	γ	0.2647 (0.173)*	0.8720 (0.062)***	0.0050 (0.171)
Log likelihood function		31.5060	177.4616	105.3694

Note: ***, ** and * indicate significant at 1, 5 and 10% level of probability respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

A-42. Maximum likelihood estimates of the parameters of Cobb-Douglas stochastic frontier production functions for sesame estimated according to study area

(in hectare)

Independent variable	Parameter	Jessore *(n=180)*	Faridpur *(n=180)*	Comilla *(n=180)*
Constant	β_0	4.5595 (0.856)***	6.7786 (0.963)***	6.6258 (1.027)***
Human labour (man-day)	β_1	0.2796 (0.054)***	0.1027 (0.065)*	0.3185 (0.081)***
Land preparation cost (Tk)	β_2	-0.0053 (0.029)	-0.1055 (0.039)***	-0.1640 (0.044)***
Seed (kg)	β_3	-0.0066 (0.037)	-0.0446 (0.046)	0.0399 (0.082)
Organic fertilizers (kg)	β_4	-0.0009 (0.002)	0.0083 (0.012)	0.0085 (0.006)*
Urea (kg)	β_5	0.0100 (0.009)	-0.0089 (0.007)	-0.0110 (0.009)
TSP (kg)	β_6	-0.0113 (0.008)	0.0111 (0.010)	-0.0003 (0.007)
MoP (kg)	β_7	0.0051 (0.006)	-0.0021 (0.011)	0.0018 (0.007)
DAP (kg)	β_8	0.0082 (0.012)	-0.0085 (0.009)	-0.0006 (0.002)
Gypsum (kg)	β_9	-0.0120 (0.006)**	-0.0461 (0.047)	0.0096 (0.009)
Irrigation cost (Tk)	β_{10}	0.0005 (0.003)	0.0032 (0.003)	0.0044 (0.005)
Pesticides cost (Tk)	β_{11}	0.0023 (0.003)	-0.0074 (0.007)	0.0043 (0.004)
Land rent (Tk/ha)	β_{12}	0.1575 (0.091)*	0.0981 (0.091)	0.0450 (0.112)
Dummy for soil type (1=Loamy, 0= Otherwise)	β_{13}	0.0008 (0.016)	-0.0001 (0.033)	0.0710 (0.034)**
Dummy for sesame variety (1=Improved, 0=Otherwise)	β_{14}	0.1199 (0.019)***	0.2154 (0.049)***	0.0610 (0.029)**

Note: ***, ** and * indicate significant at 1%, 5% and 10% level of probability, respectively.
Figures in the parentheses represent standard errors.
Dependent variable = Yield (kg/ha)

A-43. Maximum likelihood estimates of technical inefficiency models estimated for sesame farmers of different study areas

Independent variable	Para-meter	Jessore *(n=180)*	Faridpur *(n=180)*	Comilla *(n=180)*
Constant	δ_0	-0.0206 (0.738)***	-1.1612 (0.641)*	1.8418 (0.924)**
Farm size (ha)	δ_1	-0.0344 (0.031)	-0.0233 (0.029)	-0.2055 (0.159)
Proportion of family labour to total labor	δ_2	0.7730 (0.218)***	1.6263 (0.417)***	0.9024 (0.393)**
Age (year)	δ_3	-0.0110 (0.004)***	0.0037 (0.004)	0.0136 (0.006)**
Education (year of schooling)	δ_4	-0.0256 (0.001)***	-0.0266 (0.013)**	-0.0565 (0.022)***
Experience (year)	δ_5	0.0028 (0.006)	0.0044 (0.005)	-0.0189 (0.008)**
Training on oilseeds (no./life time)	δ_6	-0.5494 (0.215)***	-1.2007 (0.747)*	-0.0843 (0.169)
Availability of HYV seed (Score) (Scale,0-4; 0= not available, 4= plenty	δ_7	-0.4565 (0.126)***	-0.2031 (0.088)**	-0.8306 (0.297)***
Dummy for society member (1=Member, 0= Otherwise)	δ_8	-0.3447 (0.100)***	-0.1302 (0.087)*	-0.1443 (0.129)
Cosmopolitness (wt. score) (Scale,0-3; 0= no visit, 3= frequently)	δ_9	0.0582 (0.029)**	0.0040 (0.032)	0.1141 (0.084)
Innovativeness (wt. score) (Scale,0-1; 0= no, 1= yes)	δ_{10}	0.1411 (0.058)**	0.0025 (0.040)	-0.2821 (0.094)***
Extension contact (wt. score) (Scale,0-4; 0= no contact, 4= regular)	δ_{11}	-0.0125 (0.008)*	-0.0465 (0.021)**	-0.0585 (0.029)**
Variance parameters:				
Sigma-squared	σ^2	0.0698 (0.009)***	0.0833 (0.019)***	0.1421 (0.035)***
Gamma	γ	0.9439 (0.015)***	0.8910 (0.036)***	0.9403 (0.020)***
Log likelihood function		164.79	92.10	83.65

Note: ***, ** and * indicate significant at 1%, 5%, and 10% level of probability, respectively.
Figures in the parentheses represent standard errors. Dependent variable = Yield (kg/ha)

A-38: Area under different oilseeds and the rate of adoption of improved varieties

Year	Mustard		Groundnut		Sesame		Soybean	
	Total area ('000'ha)	% of adoption	Total area ('000'ha)	% of adoption	Total area ('000'ha)	% of adoption	Total area ('000'ha)	% of adoption
1998	343.77	6.00	--	--	--	--	--	--
1999	344.13	6.00	--	--	--	--	--	--
2000	328.91	8.00	--	--	--	--	--	--
2001	317.70	8.00	--	--	--	--	--	--
2002	303.06	10.00	28.47	5.00	--	--	--	--
2003	297.55	12.00	26.67	7.00	--	--	--	--
2004	279.23	15.00	26.04	7.00	--	--	--	--
2005	241.54	18.00	28.85	8.00	38.92	5.00	--	--
2006	216.81	20.00	29.42	8.00	30.68	7.00	40.62	8.00
2007	210.54	21.00	33.67	9.00	36.04	8.00	39.23	10.00
2008	233.70	22.00	31.09	9.00	11.68	9.00	39.39	12.00
2009	234.02	23.90	31.31	8.95	32.95	6.40	40.20	14.50
2010	174.68	29.40	33.60	12.18	35.57	12.50	40.70	50.90
2011	252.35	30.00	38.09	9.05	34.74	11.20	41.40	21.60
2012	276.11	35.00	31.17	12.00	33.20	13.00	42.12	30.00

Note: (i) Adoption rates for 2009-11 were calculated using DAE data. The remaining adoption rates were estimated based on expert opinion.

A-39. Model for the economic impact analysis of oilseed research & development in Bangladesh

Year	Mustard &mustard			Groundnut			Sesame			Soybean		
	Supply Shifter (k)	Inflated price (Base: 2011-12 =100 Tk/ha)	Quantity production (Metric ton)	Supply Shifter (k)	Inflated price (Base: 2011-12 =100 Tk/ha)	Quantity production (Metric ton)	Supply Shifter (k)	Inflated price (Base: 2011-12 =100 Tk/ha)	Quantity production (Metric ton)	Supply Shifter (k)	Inflated price (Base: 2011-12 =100 Tk/ha)	Quantity production (Metric ton)
1992-93	0.000	50,260	218000	-	-	-	-	-	-	-	-	-
1993-94	0.000	51,403	239080	-	-	-	-	-	-	-	-	-
1994-95	0.000	48,181	218725	-	-	-	-	-	-	-	-	-
1995-96	0.000	46,730	245885	-	-	-	-	-	-	-	-	-
1996-97	0.000	47,353	249355	0.000	46,463	39525	-	-	-	-	-	-
1997-98	0.019	50,991	253640	0.000	44,454	39540	-	-	-	-	-	-
1998-99	0.019	45,051	252515	0.000	40,161	38755	-	-	-	-	-	-
1999-00	0.025	42,568	249080	0.000	37,690	42210	0.000	39,231	22005	-	-	-
2000-01	0.025	36,930	237660	0.000	43,749	31835	0.000	32,857	22120	-	-	-
2001-02	0.032	35,655	232740	0.016	44,988	29835	0.000	32,284	22180	-	-	-
2002-03	0.038	35,159	217980	0.023	44,362	34240	0.000	31,835	24440	-	-	-
2003-04	0.048	42,874	210570	0.023	38,595	34075	0.000	33,912	25485	-	-	-
2004-05	0.057	34,699	191375	0.026	37,262	38880	0.011	31,781	37260	0.003	35,141	510
2005-06	0.063	34,456	183465	0.026	39,958	37980	0.015	29,925	39225	0.004	32,020	61485
2006-07	0.067	41,804	188880	0.029	40,649	45910	0.017	35,222	29180	0.005	30,809	57715
2007-08	0.070	57,686	227930	0.029	40,440	44268	0.020	45,874	27043	0.006	30,215	59158
2008-09	0.076	46,091	202717	0.029	43,797	46533	0.014	29,282	28461	0.007	31,757	59395
2009-10	0.093	44,954	151251	0.040	39,939	53467	0.027	34,886	32306	0.025	27,810	69522
2010-11	0.095	38,974	62970	0.030	50,803	58068	0.024	31,940	31363	0.011	28,232	65883
2011-12	0.111	45,630	57445	0.039	55,130	63293	0.028	38,780	31835	0.015	25,896	69296

Note: The estimates of price elasticities of supply and demand for sesame were 0.30 and 0.50 respectively under closed-economy market situation. The price elasticity of supply and demand for other oilseed crops were 0.30 and 10000000000 respectively, to make consumer surplus zero as small open-economy market situation.
Source: Using production and price data from various issues of BBS

A-40. Foreign exchange savings due to adoption of improved varieties of oilseeds in Bangladesh

Year	Rapeseed & Mustard			Groundnut			Soybean			National CPI	Total savings
	Current price ($/ton)	Inflated price ($/ton)	Savings ($)	Current price ($/ton)	Inflated price ($/ton)	Savings ($)	Current price ($/ton)	Inflated price ($/ton)	Savings ($)		
1997-98	264.60	683.19	3,292,299	--	--	--	--	--	--	38.73	3,292,299
1998-99	231.29	546.40	2,621,615	--	--	--	--	--	--	42.33	2,621,615
1999-00	232.17	534.22	3,326,559	--	--	--	--	--	--	43.46	3,326,559
2000-01	212.32	481.78	2,862,731	--	--	--	--	--	--	44.07	2,862,731
2001-02	248.57	554.97	4,133,399	552.15	1232.75	588023	--	--	--	44.79	4,721,422
2002-03	257.13	555.00	4,597,038	464.29	1002.14	789684	--	--	--	46.33	5,386,722
2003-04	250.30	505.25	5,106,545	686.62	1385.99	1086617	--	--	--	49.54	6,193,162
2004-05	311.02	581.78	6,346,065	758.87	1419.51	1435125	--	--	--	53.46	7,781,190
2005-06	355.31	616.75	7,128,403	685.57	1190.02	1174549	274.81	477.02	117346	57.61	8,420,298
2006-07	315.40	506.34	6,407,749	500.00	802.70	1068390	277.93	446.19	128948	62.29	7,605,087
2007-08	399.85	571.79	9,122,847	750.00	1072.50	1377091	308.03	440.48	156372	69.93	10,656,310
2008-09	481.32	642.10	9,892,231	1000.0	1334.05	1799627	345.74	461.23	191873	74.96	11,883,731
2009-10	435.00	534.73	7,521,463	875.00	1075.60	2300706	327.00	401.97	698618	81.35	10,520,787
2010-11	606.00	652.81	3,905,087	938.00	1010.45	1760202	336.00	361.95	262415	92.83	5,927,704
2011-12	521.00	521.00	3,321,896	907.00	907.00	2238476	332.00	332.00	344948	100.00	5,905,320
Total			**79585927**			**15618490**			**1900520**		**97104937**

Note: For inflated price, Base: 2011-12 =100 $/ton
Source: Using import price data from FAOstat

A-41. Requirements of labour for cultivating oilseeds at farm levels

(Man-day/ha)

Oilseed	Improved variety	BARI old variety	No. of additional labour
Mustard	75.1	62.4	12.7
Groundnut	113.5	101.9	11.6
Sesame	101.3	85.9	15.4
Soybean	87.8	81.7	6.1

11. **Research Highlights**

- Acute shortage of edible oils has been prevailing in Bangladesh during last several decades and spending on edible oils and oilseeds imports has been increasing to meet the country's demand. But the area under oilseeds cultivation is decreasing year after year.
- Adoptions of improved oilseed varieties and crop management technologies at farm level are very depressing. Most farmers used BARI old or local varieties of oilseeds. About 20% mustard, 18% groundnut, 21.5% sesame, and 15.6% soybean farmers used improved varieties.
- The availability of family labour, availability of improved seed, cosmopolitness, and extension contact significantly influenced oilseed farmers to grow improved varieties. Farmers are very much enthusiastic towards BARIMustard-14 & -15 varieties due to their short duration and high yielding characteristics.
- The yields of improved oilseed varieties are found to be much better (5-33% higher) than that of BARI old or local varieties at farm level.
- Irrespective of varieties, oilseed cultivation is profitable at farm level both from financial and economic point of view, but their profits are lower than most of their competing crops. Domestic production of oilseeds has lucrative comparative advantage in Bangladesh.
- Different inputs, such as human labour, organic fertilizer, urea, TSP, loamy soil, pesticide, and land rent have positive and significant impacts on the yield of oilseeds. Farmers with higher education, more farming experience, extension contact, improved seed, and innovativeness are technically more efficient in production than other farmers.
- The adoptions of improved oilseed technologies at farm level have made significant positive impacts on productivity growth, farmers' income, employment generation, and foreign exchange savings through producing more of these crops.
- The past investment (Tk.1268.91 million) on oilseeds R&D during 1998-2012 is found to be a good effort. Because the IRR, NPV, BCR, and the amount of foreign exchange savings due to R&D of oilseeds are 24%, Tk. 4,769.04 million, 3.15, and US$ 97.105 million respectively.
- There are enough strengths and opportunities to invest more on R&D of oilseeds in Bangladesh.

12. **Major Attainments** ***(in relation to the set objectives)*** **:**

a. Technical : Output, Outcome and Impact

Sl. No	**Major technical activities performed in respect of the set objectives**	**Output (i.e product obtained, visible, measurable)**	**Outcome (short term effect of the research)**	**Impact (long term effect of the research)**	**Remarks (reason, if anything otherwise)**
01.	Literature review	Some literature/data on oilseed production, ex-ante evaluation, prices, export, and import were collected.	Collected data and information were used in preparing the project report.	--	--
02.	Scientific staff training	12 scientific personnel (SA) were provided training on oilseed cultivation and data collection.	Trained enumerators collected project data from oilseed farmers efficiently.	Trained enumerators can collect accurate data in future.	--
03.	Questionnaire preparation and its pre-testing at farm level	Prepared and pre-tested 02 questionnaires for collecting field level data from oilseed farmers and district level data from DAE personnel/offices.	Used these questionnaires for collecting project data from oilseed farmers and DAE personnel/offices.	Pre-tested questionnaire may be used in future for similar type of study.	--
04.	Data collection at field level	Using the pre-tested questionnaire, a total of 1980 oilseed farmers were interviewed.	Primary data on oilseed cultivation were collected for the project.	--	--
05.	Data entry into computer spared sheet	Collected data were entered into computer spared sheet for analysis.	Data analyses for the project could be possible for computerized data.	--	--
06.	Data analysis	The following data and information were generated: **1.** About 60% mustard, 82% groundnut, 79% sesame, and 84% soybean farmers used BARI old or local varieties. **2.** In 2010-11, the areas planted to improved mustard, groundnut, and sesame varieties were 27%, 7%, and 11%. **3.** The yields of improved mustard, groundnut, sesame, and soybean varieties were 46.4, 48.7, 27.8, and 5.2% higher than their corresponding old oilseeds varieties.	A good number of tables along with their illustrations could be made possible for fulfilling the project objectives.	The outputs of the project will be used by policy planners, research managers, scientists, extension personnel, donor agencies, and oilseed farmers in future.	

a. Technical .... continued.

Sl. No	**Major technical activities performed in respect of the set objectives**	**Output (i.e product obtained, visible, measurable)**	**Outcome (short term effect of the research)**	**Impact (long term effect of the research)**	**Remarks (reason, if anything otherwise)**
06.	Data analysis	**4**. The net incomes from improved mustard, groundnut, and sesame cultivation were 290, 330, and 245% higher than their corresponding old oilseed varieties. **5**. The domestic production of oilseeds was found to be more beneficial than imports from foreign countries. **6**. The respondent farmers could produce oilseeds to 68-89% of the potential (stochastic) frontier production levels, given the levels of inputs and technologies currently being used. The farmers with higher education, more farming experience, extension contact, improved seed, and innovativeness were technically more efficient than other farmers. 7. The adoptions of improved oilseed technologies at farm level had made some significant positive impacts on productivity growth, farmers' income, employment generation (6-15 m-day /ha), and foreign exchange savings (US$ 97.11 million) through producing more of these crops. **8.** The estimated IRR, BCR, and NPV of the investment in oilseed R&D during 1998-2012 were 24%, 3.15, and Tk.4,769.04 million respectively. **9.** SWOT analysis revealed that the strength and opportunities of oilseed cultivation in Bangladesh outweigh the weaknesses and threats in oilseed cultivation.			

b. Procurement Status

Items	Qty	Price (Tk.)	Location of the equipments	Users
Secretariat table	1	27,000/-	PI's room	Principal Investigator (PI)
Half-secretariat table	4	40,000/-	Co-PIs and other two scientist's room	Co-PIs & two other scientists
Cushion chair (big)	1	15,240/-	PI's room	PI
Cushion chair (small)	4	19,760/-	PI & Co-PI's room	PI & Co-PIs
File cabinet (steel)	2	30,000/-	PI & Co-PI's room	PI & Co-PI
Computer table	1	8,000/-	Co-PI's room	Co-PI
Computer (desktop)	1	55,000/-	Co-PI's room	Co-PI
Computer (laptop)	1	80,000/-	PI's room	PI
Laser printer	1	25,000/-	PI's room	PI & Co-PIs
IPS	1	30,000/-	PI's room	PI
Digital camera	1	20,000/-	PI's room	PI, Co-PIs & other div. scientists
Bicycle	2	15,000/-	Used by Accountant and PA to CSO	Accountant & PA
Spiral machine	1	23,000/-	CSO's room	Div. Scientists
Scanner	1	8,100/-	CSO's room	Div. Scientists

c. HRD/ Training

Title (Ph.D/MS/ Trainings, workshops conducted etc.)	Target	Attain ments (%)	No. of participa nts	Benefit of the higher studies/trainings (application of the learning, productivity enhancement	Remarks (reason, if anything otherwise)
One-day enumerators' training	12 Nos.	100%	12 Nos.	Enumerators collected field level data efficiently.	Conducted at BARI
Workshop on inception report	--	--	50 Nos.	Suggestions were incorporated in the final study.	Conducted at BARC
Workshop on research progress	--	--	50 Nos.	Suggestions were incorporated in the final study.	Conducted at BARC
Workshop on PCR	--	--	60 Nos.	Suggestions were incorporated in the final report.	Conducted at BARC

d. Financial status

Major head	Fund received (Tk.)	Expenditure (Tk.)	Balance/ Unspent (Tk)	Remarks
A. Honorarium and Contractual Staff Salary	15,25,477	15,25,477	0	
B. Field Research/Lab Expenses Supplies	1,69,800	1,69,800	0	
C. Operating Expenses	4,66,947	4,66,947	0	
D. Vehicle Hire and Fuel, Oil & Maintenance	5,73,110	5,73,110	0	
E. Training/Workshop/Seminar etc.	10,000	10,000	0	
F. Publications and Printing	1,30,000	1,30,000	0	
G. Contingencies	82,686	82,686	0	
H. Capital Expenses	3,96,141	3,96,141	0	
Grand Total	**33,54,161**	**33,54,161**	**0**	

e. Materials developed/Publications made:

Type of material/publication	Title	Number	Remarks
Journal publication	01. Factors affecting adoption of improved groundnut varieties in Bangladesh. *The Bangladesh Journal of Agriculture* 02. Factors of adoption and farmers' attitudes toward mustard cultivation in Bangladesh. *Bangladesh Journal of Agricultural Research*	02	Submitted for publication
Books/Monographs/ Manual published	NA		
Booklet/leaflet/flyer etc. published	NA		
Any other (patenting of technology etc.)	NA		

13. Sub-project Auditing (cover all types of audit performed)

Types of Audit (BARC/ /FAPAD/World Bank)	Major observations/ /objections raised	Status at the sub-project end	Remarks/ Date of auditing
Chartered Accounting Firm	Very good		16.10.11
FAPAD	Very good		18.11.12
Chartered Accounting Firm	Very good		29.09.13
FAPAD	Very good		19.11.13
World Bank	Bank reconciliation procedure should be maintained.		25.02.14

14. Reporting

Report type	Actual date of submissions	Total Number	Remarks
a. Inception report	June, 2011	01	
b. Monthly reports	*July, 2011-Feb, 2014	32	
c. Statement of expenditure (SoE)	*July, 2011-Feb, 2014	32	
d. Quarterly report(s)	04.01.12; 25.04.12; 10.11.11	03	
e. Six monthly report	19.01.12; 13.02.13	02	
f. Yearly report	05.11.12; 04.09.13	02	
g. Procurement plan	04.07.11	01	
g. Annual research program format	NA	--	
h. Environmental monitoring	NA	--	
i. Social safeguard status	NA	--	
j. Field monitoring report(s)**	08.01.13; 06.02.13; 11.02.13	03	

* *Dates of monthly reports & SoE*: 03.08.11; 04.09.11; 02.10.11; 10.11.11; 05.12.11; 04.01.12; 06.02.12; 05.03.12; 02.04.12; 02.05.12; 03.06.12; 12.07.12; 05.08.12; 04.09.12; 08.10.12; 06.11.12; 09.12.12; 08.01.13; 06.02.13; 05.03.13; 09.04.13; 09.05.13; 13.06.13; 11.07.13; 12.08.13; 05.09.13; 06.10.13; 12.11.13; 08.12.13; 10.02.14; 23.02.14; 30.03.14

*** Conducted at the local level by implementing agencies.*

15. Problems/Constraints (Bullet points- max. 5 nos.) :

- Delay in scientific staff recruitment due to lengthy official procedures and formalities.
- Resignation of some scientific staff at the crucial stage of the project.
- Difficulties in collecting variety adoption data from DAE Offices at district levels.
- Delay in fund release.
- Political unrest.

16. Suggestions for future, if any:

- Scientific staff should be recruited timely for the project.
- Approved fund should be released timely for the project.
- Political stability is one of the pre-requisites for successful completion of the project.
- District level DAE Offices should be more responsive in supplying agricultural research related data and information to the scientists.

Signature of the Principal Investigator
Date ………………………….
Seal

Counter signature of the Head of the agency/authorized representative
Date …………………………..
Seal