Self Sufficiency in Pulses Production in India: An Analysis Based on the Successful Performance of Pulse Production and its Export from Myanmar

Project Coordinator
Poornima Varma

Project Research Associate
Drishti Vishwanath

विद्याविनियोगाद्विकास:

CENTER FOR MANAGEMENT IN AGRICULTURE (CMA)
INDIAN INSTITUTE OF MANAGEMENT AHMEDABAD (IIMA)
VASTRAPUR, AHMEDABAD – 380015

Supported by
MINISTRY OF AGRICULTURE AND FARMERS WELFARE
GOVERNMENT OF INDIA

MARCH 2023

Final Report

Self Sufficiency in Pulses Production in India: An Analysis Based on the Successful Performance of Pulse Production and its Export from Myanmar

Project Coordinator

Poornima Varma

Project Research Associate

Drishti Vishwanath

विद्याविनियोगाद्विकासः

CENTER FOR MANAGEMENT IN AGRICULTURE (CMA)

INDIAN INSTITUTE OF MANAGEMENT AHMEDABAD (IIMA)

VASTRAPUR, AHMEDABAD – 380015

Supported by

MINISTRY OF AGRICULTURE AND FARMERS WELFARE

GOVERNMENT OF INDIA

MARCH 2023

ACKNOWLEDGEMENTS

This study would not have been possible without the generous help and support of several individuals and institutions. I would like to express my sincere gratitude to the Ministry of Agriculture, Government of India, for financial support in undertaking this study. My sincere gratitude to all the AERCs involved in this study. This stud would not have materialized without their active involvement and meticulous data collection. I would like to thank AERCs of Vallabh Vidya Nagar, Visakhapatnam, Jabalpur and Rajasthan and their team members.

My special thanks to my CMA colleagues – Profs. Vidya Vemireddy, Ranjan Kumar Ghosh, Hari Nagarajan and Sukhpal Singh for their support and help in several ways. I would like to also thank Prof. Vijay Paul Sharma, Chairman, CACP for some of his valuable suggestions and comments during the initial stages of this study. I also thank Dr. Brajesh Jha, IEG, for his valuable comments and suggestions that helped in further enriching this study.

My sincere gratitude to Drishti Viswanath for her immense contribution and support during this study. Without her hard work and commitment, this study would have been impossible. I would like to also thank Mr. Rajendra Petkar from Jamanlal Bajaj Foundation for helping me with the data collection.

I would like to extend my gratitude to Mr. Viral Navik of IIMA library for being very proactive in helping me with the materials required for writing this report. Thanks, are also due to CMA staff – Uma Baskaran, Dipali Chauhan and Viji Bejoy for their enthusiastic help in each and every stage of this study.

Needless to mention while I owe a lot to the numerous individuals who contributed significantly to conduct this study, the data analysis and the views expressed in this report and any omissions or errors that remain in the report are entirely mine.

Poornima Varma

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES: APPENDICES

EXECUTIVE SUMMARY

Pulses, which are the edible seeds of plants in the legume family, are extensively cultivated for both food and feed across the world. They serve as an important plant-based source of protein, minerals, dietary fibre, vitamins, minerals, phytochemicals and complex carbohydrates. There are various other benefits associated with the production and consumption of pulses; (a) they offer an economical alternative to more expensive sources of protein such as meat (in terms of gram for gram nutritional value), (b) they help prevent chronic health issues such as diabetes and heart disease, increase the diversity of diets, and have a long shelf life, reducing food loss and waste (c) their nitrogen fixing properties contribute to improved soil biodiversity and fertility, (d) including pulses in crop rotations can improve chemical fertilizer use and efficiency, and (e) they have a smaller carbon footprint, amongst others. Thus, globally, there has been an emphasis on the potential of pulses to create economic, social and environmental opportunities for sustainable agri-food systems (Food and Agriculture Organization of the United Nations, 2022).

Pulses play a critical role in meeting the protein requirement of the Indian population; they are considered to be as the "poor man's meat" given that the consumption of dairy and animal products is relatively low among the poorest section of the country. India is the largest producer and consumer of pulses in the world, constituting 28 percent of the world's total production and 30 percent of the world's total consumption of pulses in 2020 respectively (Organisation for Economic Cooperation and Development (OECD) and Food Agricultural Organization (FAO), 2021). These efforts have contributed to an increase in the production of pulses from 18.24 million tonnes in 2010-11 to 25.46 million tonnes in 2020-21, marking an increase of almost 40 percent. The average growth of pulses during the five-year period 2016-17 to 2020-21 was estimated to be 10.89 percent. However, the production of pulses has not kept up with the increasing demand; there is a widening gap between the demand and supply of pulses, and this has eventually led to a sharp decline in the per capita net availability of pulses over the last several years. The production of pulses in 2020-21-25.46 million tonnes fell short of the projected consumption demand of 26.64 million tonnes in the same year (NITI Aayog, 2018). The stagnation in production has been attributed to several factors; these include was a substitution of pulses production with high yielding varieties of cereals in the green revolution period, climate related constraints , losses due to biotic and abiotic stresses, non-availability or low distribution of location specific or recommended high yielding varieties quality certified seed, inadequate institutional support, ineffective government procurement operations and lack of access to institutional credit, lack of adoption of recommended agronomic practices amongst others. The excess domestic demand for pulses, as well as the soaring domestic prices resulted in an increased import dependency by the country to meet the domestic consumption requirements, which has contributed to making India the largest importer of pulses in the world (Negi and Roy, 2015).

The major states contributing to pulse production in 2020-21 include Rajasthan (4.82 million tonnes), Madhya Pradesh (4.36 million tonnes), Maharashtra (4.22 million tonnes), Uttar Pradesh (2.62 million tonnes) and Karnataka (2.17 million tonnes)Chickpea, pigeon pea, black gram and green gram are the major pulses produced and consumed in India. Green gram (moong) and black gram (urad) are among the major pulses imported by India and around 80 percent of India's imports are sourced from Myanmar.

In this context, a detailed analysis of factors affecting the production and productivity of black gram and green gram in India is undertaken by assessing major agronomic practices recommended by the government for improving the productivity of these pulses. The study examines how the adoption of these practices takes place and measures impact of the adoption of these agronomic practices on crop yield. This analysis enables us to undertake a detailed examination of the impact of government interventions in the form of minimum support price policy and crop insurance, NFSM etc. in encouraging the adoption of yield enhancing agronomic practices. The study also makes an attempt to draw lessons from the successful experience of Myanmar as Myanmar is the largest importer of green gram and black gram to India.

Therefore, the specific objectives of the study are:

- To analyse the factors affecting the adoption of various yield enhancing agronomic practices among the black gram and green gram farmers.
- To understand the impact of adoption of various agronomic practices on crop yield.
- To study the impact of government interventions such as Minimum Support Price (MSP) in encouraging the adoption of various agronomic practices.
- To analyse the role of crop insurance in encouraging the farmers' adoption of various agronomic practices.
- To study the factors affecting the access to seed by taking into consideration various seed sources.
- To study the impact of seed sources on the market price received by farmers.
- To analyse the factors influencing the consumption demand and import dependency on pulses imported from Myanmar

The study is based on a comprehensive primary survey undertaken in four states that rank amongst the top six in terms of the pulse production. The survey was undertaken in the year 2022. The States are Madhya Pradesh (constituting 20.6% of India's total pulse production), Rajasthan (16.75%), Maharashtra (16.71%) and Andhra Pradesh (4.22%)[1]. Within the states, one district each has been selected for black gram (urad) and green gram (moong) bean for the primary survey; these districts lie in the top 10 districts in terms of area covered under urd and moong bean, but have the lowest yield in the respective pulse category. The selected districts were Pali district for green gram and Jhalawar district for black gram in Rajasthan, Satna district for both black gram and green gram in Maharashtra; Satna district for both black gram and green gram in Madhya Pradesh, Guntur district for green gram and Srikakulam district for black gram in Andhra Pradesh. The farmers were selected through random sampling technique.

This report has been divided into 10 chapters including introduction and conclusion. Chapter 1 gives the introduction, objectives, methodology and chapter scheme of the report. Chapter 2 provides an overview of the Indian pulses economy with a special emphasis on black gram and green gram. Chapter 3 provides a brief over-view of the socio-economic profile of the black gram and green gram sample households.

Chapter 4 discusses major yield enhancing agronomic practices recommended by the government for black gram and green gram to improve the production and productivity of these crops. The chapter also makes a detailed analysis of the factors influencing the adoption of these agronomic practices by black gram and green gram farmers by employing multivariate and ordered probit models. In addition to this, the chapter also makes an attempt to analyse the adoption of these agronomic practices using a multivariate probit and ordered probit models. These models help

[1] Based on the fourth advance estimates for the year 2020-21, Directorate of Economics and Statistics, Department of Agriculture and Farmers' Welfare, Government of India

us to jointly analyse the adoption of multiple practices and the number of agronomic practices adopted while recognising the interrelationship among them. Our approach extends the existing empirical studies by allowing for correlations across different agronomic practices. The results from the analysis showed that the contact with government extension agents, access to off-farm activities, availing of MSP, price at which the crop is sold and own stock of seed increased the likelihood of adopting several practices for both black gram and green gram. While these results were not counter-intuitive, the results for membership in input supply co-operatives and distance to main market was counter-intuitive. As per the literature one would expect a positive relationship between the membership in input supply co-operatives and the adoption of agronomic practices. Similarly, one would expect a negative relationship between the distance and the adoption. However, the findings are just the opposite.

Chapter 5 analyses the impact of minimum support price in influencing farmers' adoption of various agronomic practices among both green gram and black gram farmers. The results indicated that the availing of MSP is an important factor in positively affecting the adoption of almost all agronomic practices among the black gram and green gram farmers. Availing of MSP model showed that information about MSP received from radio was more important than newspaper and this was especially true in the case of black gram farmers. Similarly, crop failure and crop insurance resulted in the lowering of availing of MSP. This could be due to the insurance coverage that the farmers receive during crop loss, or the lack of enough crops to be sold when there is a crop loss. As expected, membership in input supply co-operatives, education, knowledge of KCC and access to off-farm activities generally increased the likelihood of availing MSP. Household income lowered the probability in the case of black gram farmers and shows the importance of MSP as a risk mitigating strategy for resource poor farm households, especially when they experience crop failure.

Chapter 6 makes an attempt to analyse the impact of the adoption of agronomic practices on crop yield employing a multinomial endogenous treatment effects regression framework. The results regarding the positive impact of farm size, training from government or NGOs, selling price on agronomic practice adoption were in line with studies undertaken in the Indian context. Other important variables such as family/ household size (a proxy for labour supply), education of farmers, membership in farmer organisations were negative and insignificant. The results from both the exogenous and endogenous adoption decisions showed that the adoption of various agronomic practices increased the yield. The impact was much more when we consider the yield impact as endogenous. Also, the results showed that the impact was greater under seed management, and the adoption of all the practices.

Chapter 7 analyses the various seed sources and factors affecting the access to these seed sources and its impact on market price received by farmers. The results showed that the percentage of farmers who use government seed was more among the green gram farmers than black gram farmers. Similarly, a greater number of black gram farmers obtained the seed from private companies. Still, it was observed that a large chunk of both green gram and black gram farmers were still using own seed from previous year. Those who had better knowledge about the production techniques were not using their own seed. As far as the impact of seed sources on the prices received, the results were quite mixed. The black gram farmers who sourced their seed from government received higher prices for the crop while selling, whereas opposite was the case for green gram farmers.

Chapter 8 makes an attempt to analyse the role of crop insurance availed by farmers in influencing farmers risk aversion behaviour, thereby measuring its impact on the adoption of agronomic practices. The results indicate that the availing of crop insurance has a positive impact on the adoption of almost all agronomic practices among black gram farmers. Similarly, variables such as farm size, membership in input supply co-operatives, crop failure, access to off-farm activities etc. increased the likelihood of accessing the crop insurance. Apart from crop insurance the other factors that affected the likelihood of adopting various agronomic practices were farm size, access to government's extension services and availing of MSP.

Chapter 9 provides a detailed discussion about Myanmar's domestic production of pulses and their exports in order to draw lessons from their success story. The analysis showed that India is the largest export destination of Myanmar for black gram and green gram, constituting almost 39 per cent of total exports. The success of Myanmar in the export market is due to the relatively higher yield that they have achieved since 1960s. Whereas in India, the pulses production, including black gram and green gram were stagnant since the 1960s and the yield was also poor. The differences in the food security policies in the two countries are also a reason for the differences in the emphasis on the crops.

The study provided unique policy insights for the promotion of cultivation of pulses in general, green gram and black gram in particular. The study showed the importance of various agronomic practices which are environment friendly. The agronomic practices are yield enhancing without harming the environment. However, in order to remove the barriers that farmers face from adoption of these practices, the government needs to take effective measures to reduce the risk and uncertainty. Price risk and yield risk are the two main sources of uncertainty. The study showed that the MSP can reduce the risk and uncertainty faced by farmers and thereby encourage the adoption of yield enhancing agronomic practices. The price-stabilisation policies would encourage farmers to adopt yield enhancing technologies. Thus, appropriate actions need to be taken to increase the awareness of MSP among farmers, scale up the procurement operations, ensure that farmers can avail MSP (especially in states such as Andhra Pradesh) and make the procurement more effective in order to encourage the uptake of recommended yield-enhancing agronomic practices for black gram and green gram. Similarly, crop insurance plays a crucial role in encouraging farmers in adopting agronomic practices. Furthermore, in order to enhance the adoption of yield enhancing agronomic practices, the government can bolster training efforts in terms of input requirements, crop management and post-harvest management across the study states, especially in Andhra Pradesh and Maharashtra.

The better pulses production and export performance of Myanmar was mainly due to the high levels of yield that they have achieved since 1960s. During the same period India's production of pulses declined and yield remained low. Currently also, the yield remains the lowest due to the lack of adequate public investment and the higher risk and uncertainty perceived by the farmers. Along with this, the cereal oriented food security policies followed by India until recently also resulted in the crowing out of the pulses from the farm. Correcting such biases and a more balanced approach in terms of incentives such as MSP will help the pulses sector to become self-sufficient.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Pulses play a significant role in a country like India, and serve as an important part of the diet. They are considered to be as the "poor man's meat" given that the consumption of dairy and animal products is relatively low among the poorest section of the country. They are also an important source of protein, minerals and fibre. The protein content in pulses is double the protein content of wheat, and three times more than that of rice. Additionally, pulses are used as green manure and contribute in improving soil health, offering the possibility for a mixed/ intercropping system (Rawal and Navarro, 2019). Thus, pulses play a vital role in improving human health as well as soil health through their nitrogen fixing properties. The critical role played by pulses in meeting the protein requirement of the Indian population, and its contribution to the agricultural system makes it an ideal crop for achieving food and nutritional security by reducing poverty and hunger.

India is the largest producer and consumer of pulses in the world, constituting 28 percent of the world's total production and 30 percent of the world's total consumption of pulses in 2020 respectively (Organisation for Economic Cooperation and Development (OECD) and Food Agricultural Organization (FAO), 2021). These efforts have contributed to an increase in the production of pulses from 18.24 million tonnes in 2010-11 to 25.46 million tonnes in 2020-21, marking an increase of almost 40 percent. The average growth of pulses during the five year period 2016-17 to 2020-21 was estimated to be 10.89 percent. However, the production of pulses has not kept up with the increasing demand; there is a widening gap between the demand and supply of pulses, and this has eventually led to a sharp decline in the per capita net availability of pulses over the last several years. For example, the per capita net availability of pulses declined from 60.7 grams/day in 1951 to 41.9 grams/day in 2013. The projected pulse requirement is 50 million tons by 2050 which requires an annual growth rate of 4.2 percent(Indian Institute of Pulses Research, 2013). The production of pulses in 2020-21-25.46 million tonnes fell short of the projected consumption demand of 26.64 million tonnes in the same year (NITI Aayog, 2018). The excess domestic demand for pulses, as well as the soaring domestic prices resulted in an increased import dependency by the country to meet the domestic consumption requirements, which has contributed to making India the largest importer of pulses in the world (Negi and Roy, 2015). Lack of substitutability in consumption due to strong region-specific preferences for each type of pulses are also adding to the problem (Joshi et.al. 2017). The genetic potential for high yields is also limited and as a result the gap between actual and potential yield remains to be very high, which is also negatively affected by pests and diseases.

As a result, government intervention in pulses production in order to enhance domestic production and productivity in pulses has assumed significance. The National Development Council in May 2007 adopted the resolution to launch the National Food Security Mission, with the objectives to increase rice production by 10 million tons, wheat by 8 million tons and pulses by 2 million tons by the end of Eleventh Five Year plan (2011-12). The pulse component of NFSM was initially launched in 171 districts across 14 states of the country. The pulse component of Integrated Scheme for Oilseeds, Pulses, Oil Palm and Maize (ISOPOM) was serving the pulse growers in the non-NFSM districts. Later the pulses component of ISOPOM was merged with NFSM to avoid administrative difficulties and duplication of efforts.

One of the key interventions under NFSM was the delivery of quality seeds of improved variety which resulted in an increase in pulse production in 2010-11. Further, the NFSM program was responsible in providing technological inputs for plant protection and production technologies to the farmers cultivating pulses in the NFSM districts. Two important components in case of pulses were the integrated soil nutrient management (INM) and integrated pest management (IPM) (Thomas et.al, 2013). Furthermore, there is continued research to develop better seed varieties for a technological breakthrough. Since 2015, the procurement of pulses is also made under the minimum support price as per the Pradhan Mantri Annadata Aay Sanrakshan Abhiyan (P-AASHA).

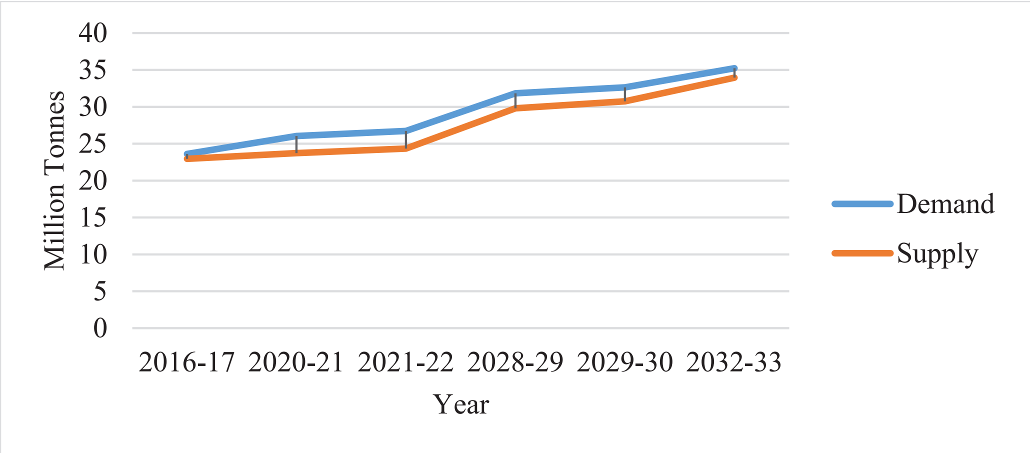
Chickpea, pigeon pea, black gram and green gram are the major pulses produced and consumed in India. Gram (Chickpeas) is the most dominant pulse with an average share of around 46 percent in the total pulse production during the past five years. The major states contributing to pulse production in 2020-21 include Rajasthan (4.82 million tonnes), Madhya Pradesh (4.36 million tonnes), Maharashtra (4.22 million tonnes), Uttar Pradesh (2.62 million tonnes) and Karnataka (2.17 million tonnes)[2] . Green gram (moong) and black gram (urad) are among the major pulses imported by India and around 80 percent of India's imports are sourced from Myanmar.

In this context, this study examines various factors influencing the production, productivity and the adoption of major agronomic practices by farmers who cultivate two major pulse categories- black gram and green gram using comprehensive district level household data collected across major pulses producing states in the year 2022.

1.2 Key Issues: Production Uncertainty and High Import Dependency

As per the Working Group Report on Crop Husbandry, Agricultural Inputs, Demand and Supply Projections constituted by the National Institution for Transforming India (NITI) Aayog, the projected demand of pulses in 2032-33 is 35.23 million tonnes, while the projected supply is 33.95 million tonnes. The report concludes that while India is poised for surplus in wheat and rice, it will continue facing an acute deficit in pulses in the next decade. Figure 1.1 draws out the demand supply gap as per these projections for the period 2016-17 to 2032-33.

Figure 1.1: Demand and Supply Estimates of Pulses as per the Working Group on Crop Husbandry, Agricultural Inputs, Demand and Supply Projections, 2018



Source: NITI Aayog, 2018 https://www.niti.gov.in/sites/default/files/2021-08/Working-Group-Report-Demand-Supply-30-07-21.pdf

[2] As per the third advance estimates, Ministry of Agriculture and Farmers Welfare

The stagnation in production has been attributed to several factors. Historically, there was a significant fall in pulses cultivation in the 1960s-early 1970s following the introduction of Green Revolution technologies, wherein there was a substitution of pulses production with high yielding varieties of cereals. As a result, pulse production witnessed a shift to rainfed areas, wherein less quantities of water were required for cultivation. The promotion of Green Revolution technologies was also accompanied by subsidies on farm inputs such as fertilizer, irrigation water and electricity to farmers at below open market prices, which have tended to favor the cultivation of crops which require higher dosage of inputs, such as rice and wheat; thus, there has been a distortion in the crop pattern. In a study by Srivastava et l. (2010), revenue terms of trade between pulses and cereals was evaluated and it was inferred that farmer's preference was inclined towards the production of cereals rather than pulses, despite the increasing minimum support price for pulses.

In the following decades, the yields of major pulses such as chana, tur, urd and moong have remained unstable and volatile (for example, see Figure 2.11). Lingareddy (2015) notes that while the production of other food crops such as rice and wheat rose by over 225 per cent and 808 per cent respectively in the triennium ending (TE) 2013-14 from the TE 1960-61, pulse production only increased by 47 per cent and yield increased by only 45 per cent (from 518 kg/ ha to 750 kg/ha) in the same period. Given that pulses are mainly grown under rainfed conditions, studies such as Ahlawat, Sharma and Singh, (2016) and Reddy (2010) have noted climate related constraints include erratic or below normal monsoons which lead to moisture stress at phases of critical growth, cloudy weather and high relative humidity in rabi pulses. These factors subsequently contribute to instability in yields. Furthermore, pulses are impacted by a number of biotic stresses such as root rot, sucking insect pests, etc. and abiotic stresses such as low temperature, salt stress, waterlogging across seasons (Reddy, 2010). Studies such as Indian Institute of Pulses Research (2011) indicate that the losses due to biotic and abiotic stresses comprise 15-20 per cent of normal production. The technological breakthrough in terms of crop protection to decrease the incidence of these stresses is yet to be realised.

In terms of inputs, non-availability or low distribution of location specific or recommended high yielding varieties quality certified seeds at the village or block level have been identified as a key impediment Further, studies have noted that there is a wide gap between yields realized in demonstrations plots and on farmers' fields given that sub-optimal doses of fertilizer, insecticides are applied for pulses along with limited irrigation.

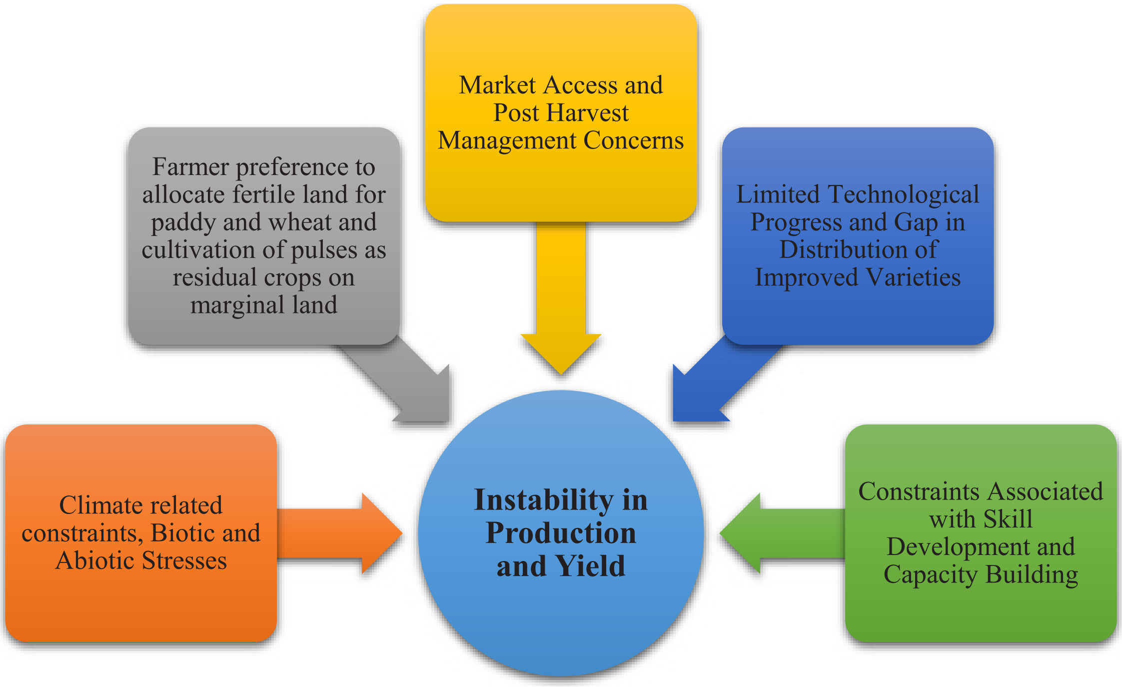
Apart from this, farmers also experience inadequate institutional support, ineffective government procurement operations and lack of access to institutional credit due to their low asset base, low risk bearing ability, and unstable returns (Reddy, 2010). Studies have further observed a number of marketing and post-harvest related constraints; lack of an assured market, lack of price security, issues associated with access and connectivity to mandis, storage related losses and lack of scientific storage facilities etc. Farmers have been observed to not benefit from the high price of pulses due to the presence of middlemen such as large traders/ wholesalers, to whom the market surplus is sold immediately after harvest. Pulse production is also less lucrative for farmers compared to other crops due to trade liberalisation, as the relative profitability of pulse crops has reduced in spite of an exorbitant increase in pulse prices (Thomas et.al. 2013).

Market access of pulses relative to other crops is further hindered by information asymmetry in terms of quality and price, low landholding, high agro-climatic risk and issues associated with connectivity (Abraham and Pingali, 2021). Reddy (2010) notes that post-harvest losses account for 9.5 per cent total pulses production, while losses during processing, threshing and transport amount to 1 per cent, 0.5 per cent, and 0.5 per cent of total pulses production. Further, there is lack of awareness and capacity building in terms of mechanization adoption, input use efficiency, disease prevention and management, amongst others (Byerlee and White, 1997; Chand, 2000, Tripathi, 2019). Mechanical harvesting of the pulse crop and crop production and protection technologies have also been limited (Indian Institute of Pulses Research, 2013).

High volatility in process for long periods due to both lower stock levels and less domestic production in domestic and global markets, and speculative activities in commodity future markets. With low yields, studies such as Gowda et al. (2013); Joshi and Saxena (2002); Lingareddy (2015); Srivastava (2010) have observed that low growth and uncertainty in yield have led to a farmer preference to allocate their best parcel of irrigated/ fertile land for high productivity-high input crops such as paddy and wheat, and pulses are grown as residual/ alternate crops on marginal lands with no use of production inputs. Thus, the vicious cycle of low yields continues in this manner.

Figure 1.2 summarises the key issues witnessed in terms of production.

Figure 1.2: Key Barriers Associated with Production of Pulses



Source: Compiled by the author from the review of relevant literature

The prices of pulses have also been continually increasing. The decline in pulse production during the mid 2000s resulted in excess demand, and an unprecedented rise in pulse price. An upward trend was observed in the price of pulses especially after 2005. In 2006, there was a sudden increase in imports of pulses which led to a high global price. The year 2009 was a poor agricultural year which led to an increase in price due to shortage in supply. Further in 2012, high Minimum Support Prices, high world prices and a depreciation of the Indian rupee led to an exorbitant increase in pulse price (Reddy, 2015). A double-digit trend in Wholesale Pirce Index (WPI) inflation of pulses was observed in 2015, reaching 39 percent in September 2015-16 which is very high relative to that of cereals (Ministry of Commerce & Industry, 2016).

Additionally, based on the MSP recommended by Commission on Cost and Agricultural Prices (CACP) for 2015, the movement of MSP for major pulses in the last five years has shown a continuous increase. The compound annual growth rate in the MSP for Tur, Gram, Moong and Urad has been higher than that of cereals.

Due to a growing population, stagnant and uncertain pulse production, as well as rising pulse prices, the net per capita availability of pulses in India has witnessed a sharp decline. The per capita net availability of pulses has declined from 22.1 kg/year in 1951 to 17.5 kg/ year in 2020-21 (Government of India, 2020).

In order to meet the supply-demand gap, the dependency on imports has been consistent since the 1990s. During the 1970s and 1980s, imports were restricted in order to protect the interest of domestic farmers. The government achieved this by imposing trade barriers such as quotas, tariffs and quantitative restrictions. It was in 1990-91 when India faced a balance of payment crisis that the possible growth benefits of trade liberalisation were realised and import duties declined steadily. From 2007-12, imports of pulses were made duty free and in 2013 the custom's duty on imports was reduced to zero (Negi and Roy, 2015). The perpetual shortage in India's pulses production in the wake of rising demand and adoption of a more liberal approach to international trade has led to a rise in the volume of imports in the past decade.

1.3 Context and Objectives for the Study

In this context, a detailed analysis of factors affecting the production and productivity of black gram and green gram in India is undertaken by assessing major agronomic practices recommended by the government for improving the productivity of these pulses. The factors that affect the adoption of various yield enhancing agronomic practices have been analysed in greater detail. Furthermore, the impact of government interventions in the form of minimum support price policy and crop insurance are analysed, To work towards achieving self-sufficiency in pulse production in India, the domestic and export performance of India's key import partner in pulses, especially green and black gram-Myanmar is additionally analysed to serve as an example to emulate.

The specific objectives of the study have been outlined below:

- To analyse the factors affecting the adoption of various yield enhancing agronomic practices among the black gram and green gram farmers.
- To understand the impact of adoption of various agronomic practices on crop yield.
- To study the impact of government interventions such as Minimum Support Price (MSP) in encouraging the adoption of various agronomic practices.
- To analyse the role of crop insurance in encouraging the farmers' adoption of various agronomic practices.
- To study the factors affecting the access to seed by taking into consideration various seed sources.
- To study the impact of seed sources on the market price received by farmers.
- To analyse the factors influencing the consumption demand and import dependency on pulses imported from Myanmar

1.4 Data Collection and Study Region

The study is based on a comprehensive primary survey undertaken in four states that rank amongst the top six in terms of the pulse production. The survey was undertaken in the year 2022. The States are Madhya Pradesh (constituting 20.6% of India's total pulse production), Rajasthan (16.75%), Maharashtra (16.71%) and Andhra Pradesh (4.22%)[3]. Within the states, one

[3] Based on the fourth advance estimates for the year 2020-21, Directorate of Economics and Statistics, Department of Agriculture and Farmers' Welfare, Government of India

district each has been selected for black gram (urad) and green gram (moong) bean for the primary survey; these districts lie in the top 10 districts in terms of area covered under urd and moong bean, but have the lowest yield in the respective pulse category. The selected districts were Pali district for green gram and Jhalawar district for black gram in Rajasthan, Satna district for both black gram and green gram in Maharashtra; Satna district for both black gram and green gram in Madhya Pradesh, Guntur district for green gram and Srikakulam district for black gram in Andhra Pradesh. The farmers were selected through random sampling technique.

The total number of cultivator households interviewed was 789; 200 farmers each were surveyed in Rajasthan, Madhya Pradesh and Andhra Pradesh and 189 farmers were surveyed in Maharashtra. The total number of green gram cultivators was 390 whereas the total number of black gram cultivators were 399. An analysis of Myanmar's export and production performance are undertaken using the secondary data on trade and production.

1.5 Methodology

A detailed methodology has been discussed in each chapter before each analysis.

The study makes use of three kinds of econometric analysis. The analysis of various factors determining the adoption of agronomic practices recommended for black and green gram is undertaken using multi variate probit and an ordered probit models. Multi variate probit analysis is useful in analysing the factors affecting various kinds of agronomic practices (for example, climate management, soil management, plant management, water management and so on) by considering their error terms as correlated. So, under multi variate analysis, each agronomic practices are taken as binary dependant variables (for example plant, yes=1, no=0). An ordered probit analysis will help us in taking the dependant variable in an ordered manner (for example plant management plus seed management plus soil management=3 if all three practices have been adopted by the farmer).

Second set of analysis is undertaken using conditional mixed process (CMP) estimator. CMP helps us in running multi equation using a joint framework. So, we have analysed the factors affecting the access to MSP (or insurance) and its impact on adopting various agronomic practices.

Third set of analysis is undertaken using multi nomial endogenous treatment effects regression technique. Such a framework is useful in analysing the factors affecting the adoption of various agronomic practices and its impact on crop yield. The joint framework is useful when the unobserved factors affecting the outcome (yield) variable is correlated with the adoption decisions.

The AERCs that are covered for this study are: AERC VV Nagar (Gujarat), AERC Jabalpur (Madhya Pradesh), AERC Visakhapatnam (Andhra Pradesh) and AERC Pune (Maharashtra).

1.6 Chapter Scheme

This study has been divided into 10 chapters including introduction and conclusion. Chapter 1 gives the introduction, objectives, methodology and chapter scheme of the report. Chapter 2 provides an over view of the Indian pulses economy with a special emphasis on black gram and green gram. Chapter 3 provides a brief over-view of the socio-economic profile of the black gram and green gram sample households. Chapter 4 discusses major yield enhancing agronomic practices recommended by the government for black gram and green gram to improve the production and productivity of these crops. The chapter also makes a detailed analysis of the factors influencing the adoption of these agronomic practices by black gram and green gram farmers by employing multivariate and ordered probit models. Chapter 5 analyses the impact of minimum support price in influencing farmers' adoption of various agronomic practices among both green gram and black gram farmers. Chapter 6 makes an attempt to analyse the impact of the adoption of agronomic practices on crop yield employing a multinomial endogenous treatment effects regression framework. Chapter 7 analyses the various seed sources and factors affecting the access to these seed sources and its impact on market price received by farmers. Chapter 8 makes an attempt to analyse the role of crop insurance availed by farmers in influencing farmers risk aversion behaviour, thereby measuring its impact on the adoption of agronomic practices. Chapter 9 provides a detailed discussion about Myanmar's domestic production of pulses and their exports in order to draw lessons from their success story. Chapter 10 provides the conclusion and policy implications of the study.

CHAPTER 2

PULSES PRODUCTION IN INDIA – AN OVERVIEW

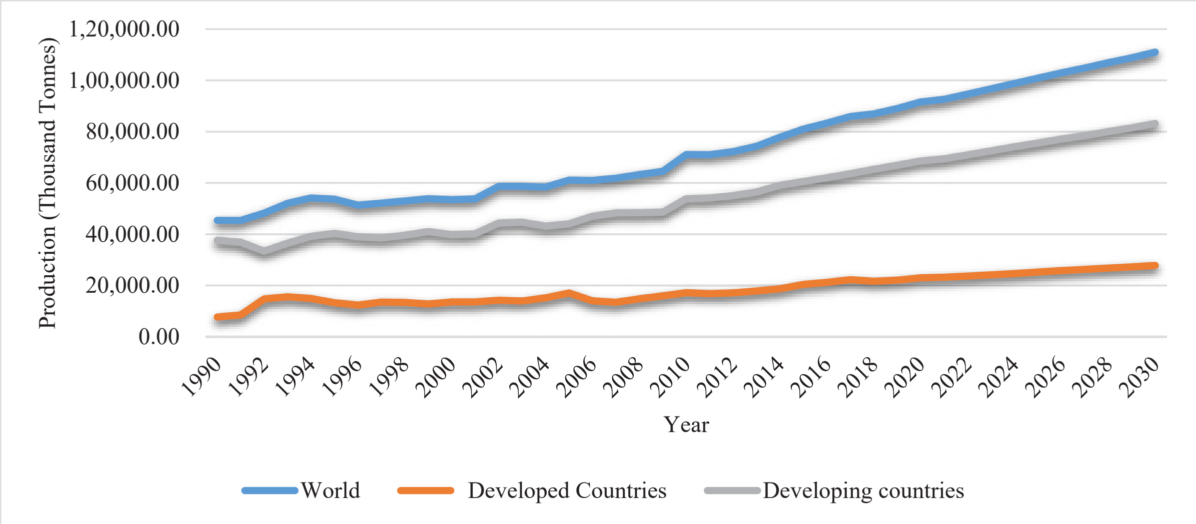
2.1 Introduction

Pulses, which are the edible seeds of plants in the legume family, are extensively cultivated for both food and feed across the world. They serve as an important plant-based source of protein, minerals, dietary fibre, vitamins, minerals, phytochemicals and complex carbohydrates. There are various other benefits associated with the production and consumption of pulses; (a) they offer an economical alternative to more expensive sources of protein such as meat (in terms of gram for gram nutritional value), (b) they help prevent chronic health issues such as diabetes and heart disease, increase the diversity of diets, and have a long shelf life, reducing food loss and waste (c) their nitrogen fixing properties contribute to improved soil biodiversity and fertility, (d) including pulses in crop rotations can improve chemical fertilizer use and efficiency, and (e) they have a smaller carbon footprint, amongst others. Thus, globally, there has been an emphasis on the potential of pulses to create economic, social and environmental opportunities for sustainable agrifood systems (Food and Agriculture Organization of the United Nations, 2022).

There have been substantial changes in the global economy of pulses over the last two decades. While the production of pulses had stagnated prior to the 2000s due to limited access and availability of high yield varieties, lack of policy traction and support for pulse growers, etc, the production of pulses has been witnessing an annual increase of around 3 per cent globally since the early 2000s. As per the Organisation for Economic Cooperation and Development (OECD)-Food Agricultural Organization (FAO) Agricultural Outlook[4], 2021, the production of pulses amounted to 91.6 million tonnes in 2020, with projected production of 111 million tonnes in 2030. The top three pulse producing countries in 2020 included India (24.6% of the total production), Canada (8.3%) and China (5.2%). The developing countries contributed to almost 75 per cent of the total world's production of pulses, while Asia alone contributed to 44.4 per cent of the total production in the world in 2020. Figure 2.1 presents the trends in production of pulses in the world, developed countries and developing countries in the period 1990-2030, drawing from existing data until 2020 with projections for the period 2021-2030.

[4] The Agricultural Outlook has been prepared as a joint report by the Organisation for Economic Co-operation and Development (OECD) and the Food and Agriculture Organization (FAO) of the United Nations- The report provides a ten year forward looking, assessment of trends and prospects in the major temperate-zone agricultural commodity markets of cereals, cotton, oilseeds, sugar, meat, fish and dairy products- It is published annually, in the middle of the second quarter, as part of a continuing effort to promote informed discussion of emerging market and policy issues.

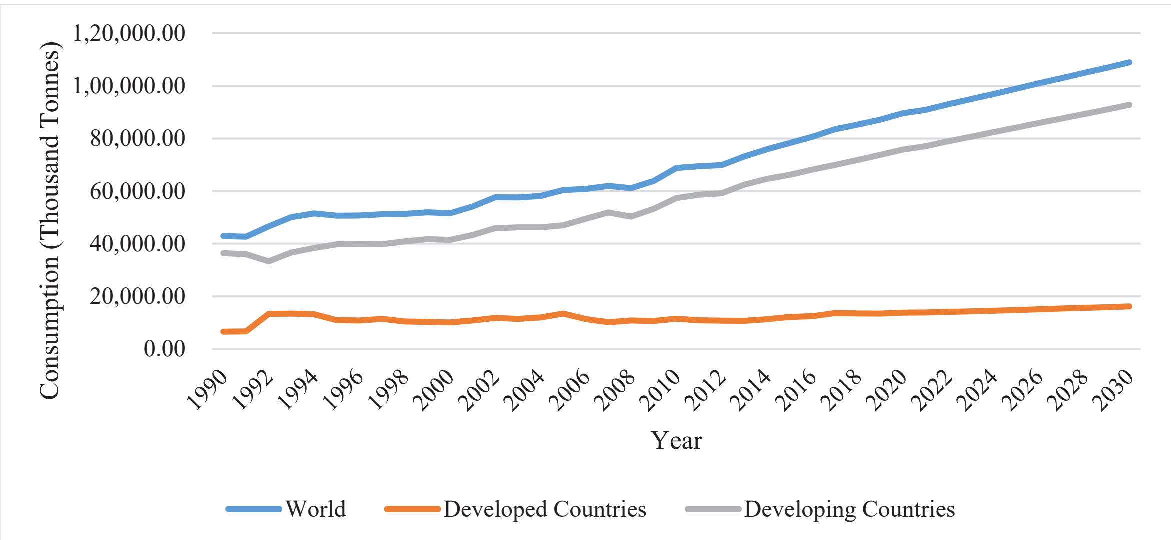
Figure 2.1: Production of Pulses in the World – Developing and Developed Countries, 1990-2030



Source: Compiled from OECD-FAO Agriculture Outlook 2021-30

In terms of per capita consumption of pulses, there are variations of pulse consumption across different countries and regions depending on the dietary patterns and the availability of pulses. However, a decline in the world's consumption of pulses has been witnessed between the 1960s to 1990s, which has been attributed to various factors; such as the rise in prices due to a slow growth in yields, a shift in preferences in terms of human diets spurred by rise in incomes and urbanization. In 2020, the volume of the world's consumption amounted to 89.6 million tonnes in 2020, with projected increase of 19 million tonnes by 2030; contributed largely by developing countries (84.6% in 2020), where pulses remain an integral source of protein. The trends (present and projected) in consumption between the period 1990-2030 have been captured in Figure 2.2. The top three countries and regions in terms of pulse consumption in the world are India (30% of total consumption), China (6.4%) and the European Union (5.8%).

Figure 2.2: Consumption of Pulses in the World – Developing and Developed Countries, 1990-2030



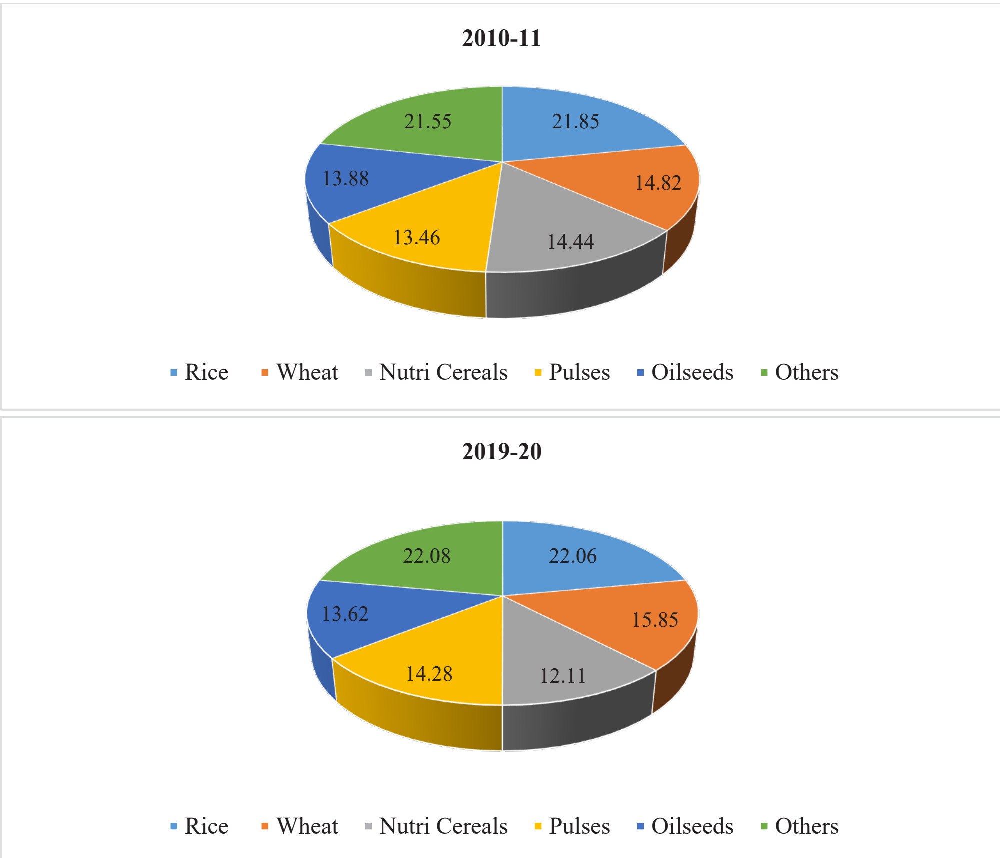
Source: Compiled from OECD-FAO Agriculture Outlook 2021-30

The major types of pulses in terms of global production and consumption include the common bean, chickpea, dry pea, lentil, cow pea, mung bean, urad bean and pigeonpea, and for animal feed, dry pea, faba bean and lupins are widely used.

2.2 Pulses in India: Area, Production and Yield

India is the largest producer and consumer of pulses in the world. As per the latest data estimates from 2020, it accounts for 39 per cent of the world's harvested area and 24.6 per cent of the world's production of pulses (OECD and FAO, 2021). As per latest data (as of February 2022) of the Directorate of Economics and Statistics, the production of pulses was 26.96 million (second advance estimates) in the financial year (FY) 2021-22, marking an increase of 16.5 per cent since FY 2016-17. The area under pulses was 29.15 million hectares in 2018-19, constituting 14 percent of the total area as per the latest estimates (Directorate of Economics and Statistics, 2021)[5]. In comparison, area under crops such as rice and wheat comprised 22.06 percent and 15.85 percent of the gross cropped area in 2019-20. Figure 2.3 presents the changes in percentage share of area under major crops in the period between 2010-11 and 2019-20. In this period, the area under pulses has increased from 13.46 percent of total area to 14 percent of total area.

Figure 2.3: Changes in Percentage Share of Area Under Major Crops

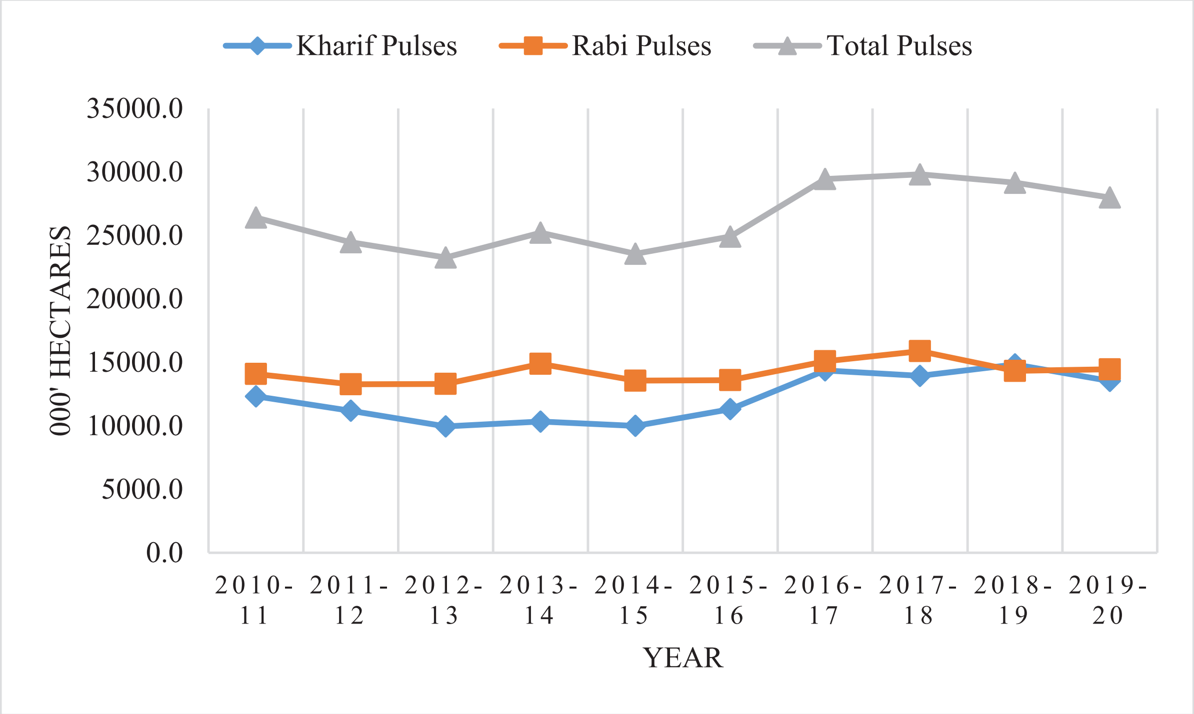


Source: Compiled from data available in the Pocket Book of Agricultural Statistics, 2020

Figure 2.4 (a), (b), and (c) present the area, production and yield of pulses (kharif, rabi and total) in the period 2010-11 to 2019-20.

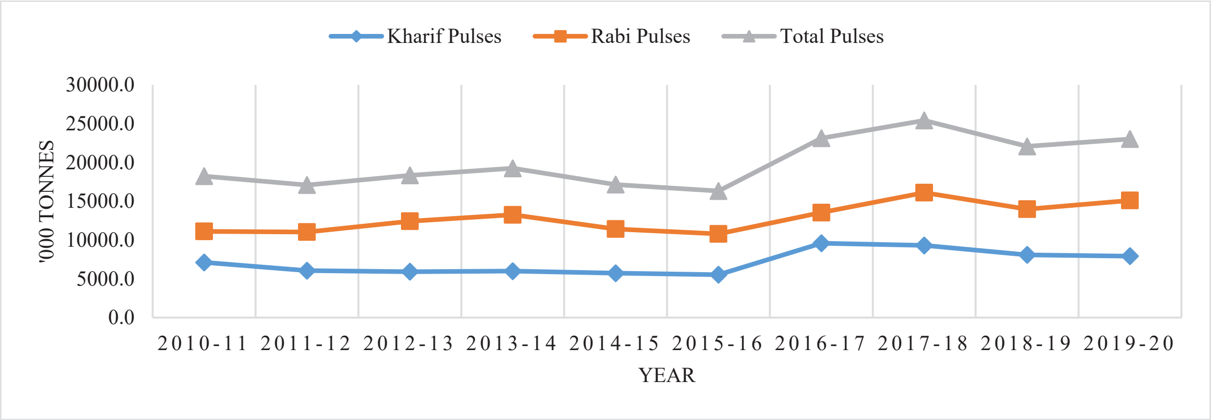
[5] Provisional

Figure 2.4 (a): Area Under Pulses in India, 2010-11 to 2019-20



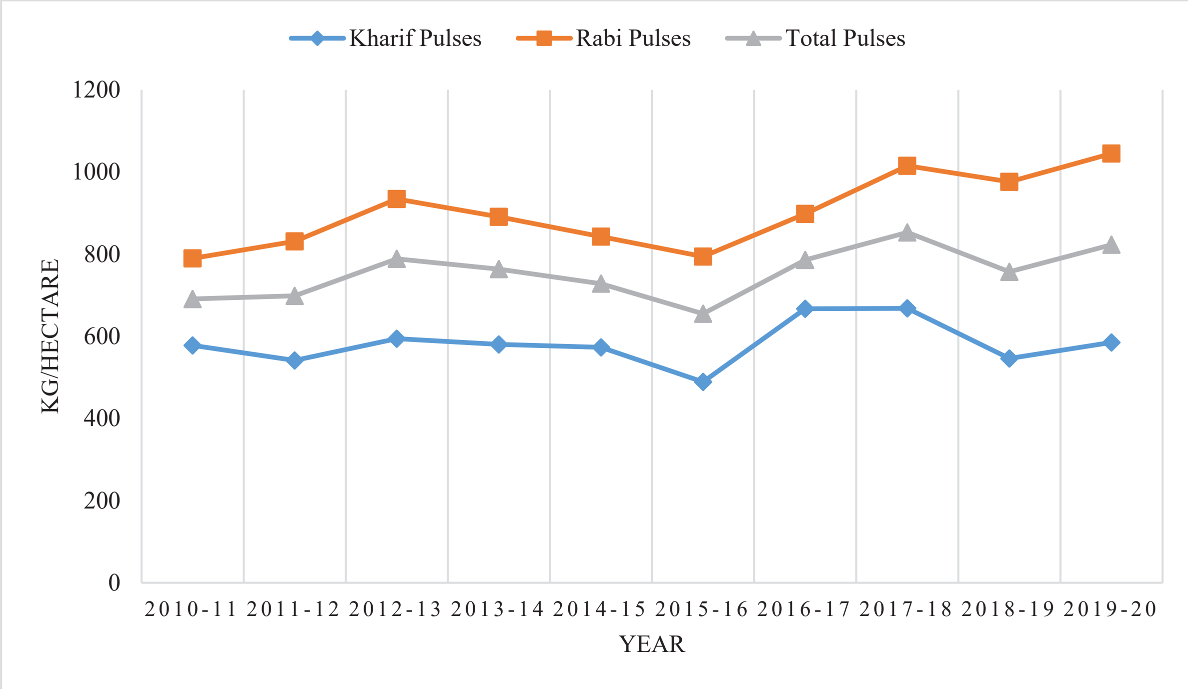
Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

Figure 2.4 (b): Production of Pulses in India, 2010-11 to 2019-20



Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

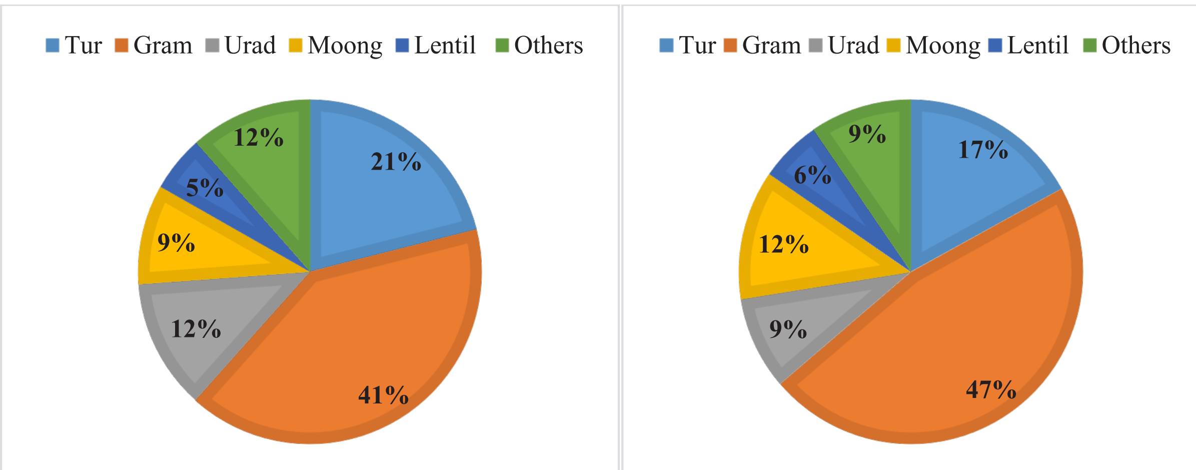
Figure 2.4 (c): Yield of Pulses in India, 2010-11 to 2019-20



Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

The major pulse crops grown in India include Gram (Chick Peas), Pigeonpea (tur or arhar), Urd bean, Moong bean, Masur (lentil), and peas. The share of major pulses in FY 2016-17 and 2021-22 have been demonstrated in Figure 2.5. Chickpea and pigeonpea constitute more than 60 per cent of total production of all pulses in the country in FY 2016-17 and 2020-21, while black gram and green gram constitute 21 per cent of total pulse production in the same years.

Figure 2.5: Share of Major Pulses (by Type) in Total Production of Pulses, FY 2016-17 and 2021-22[6]

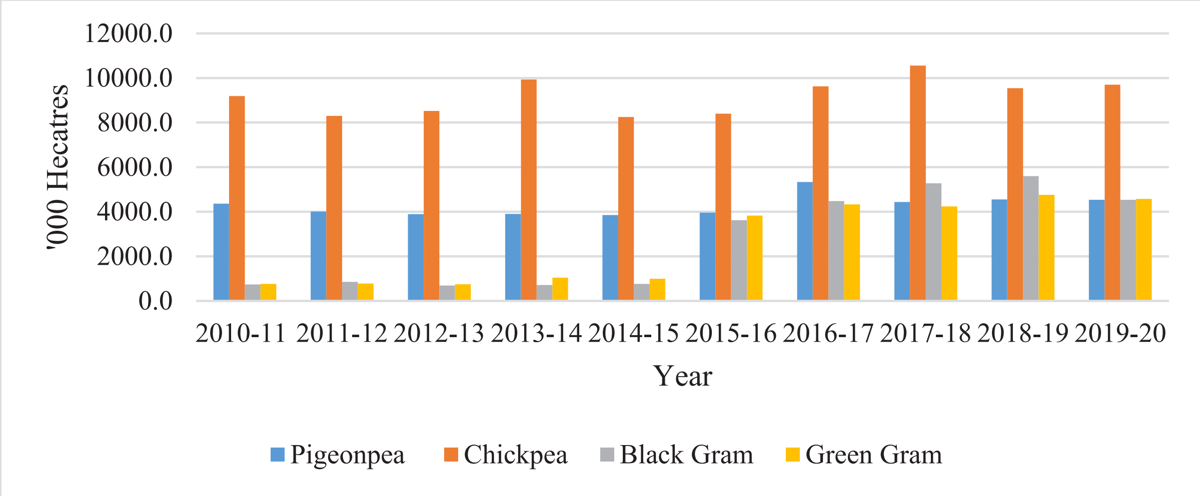


Source: Second Advance Estimates of Production of Food grains for 2021-22, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare

We further examine the area, production and yield data pertaining to four major pulse types; chickpea, pigeon pea, black gram, green gram in Figure 2.6 (a), 2.6 (b) and 2.6 (c).

[6] Tur refers to pigeonpea, gram refers to chickpea, urd bean to black gram and moong bean to green gram

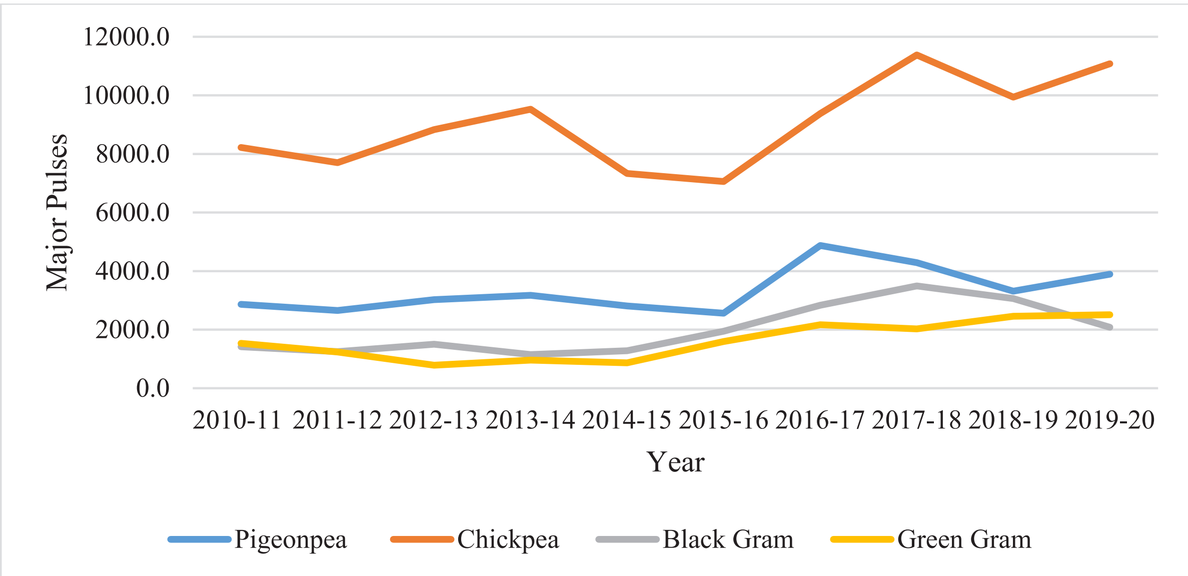
Figure 2.6 (a): Area under Major Pulses, 2010-11 to 2019-20



Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

Amongst the major pulse varieties, chickpea constitutes the highest area; 9.6 million hectares while the area under pigeonpea, black gram and green gram is 4.53, 4.53 and 4.58 million hectares respectively. It can be observed that the area under green gram and black gram increased to a great extent from the years upto 2014-15 to 2015-16 and the subsequent years; the area under black gram bean increased from 0.99 million hectares in 2014-15 to 3.82 million hectares (an increase of 284.9%) in 2015-16, and the area under black gram increased from 0.76 in 2014-15 to 3.62 million hectares (an increase of 375.9%) in 2015-16. This was accompanied by a corresponding increase in production; from 0.86 million tonnes in 2014-15 to 1.59 million tonnes in 2015-16 in the case of green gram and from 1.28 million tonnes in 2014-15 to 1.94 million tonnes in the case of urd bean.

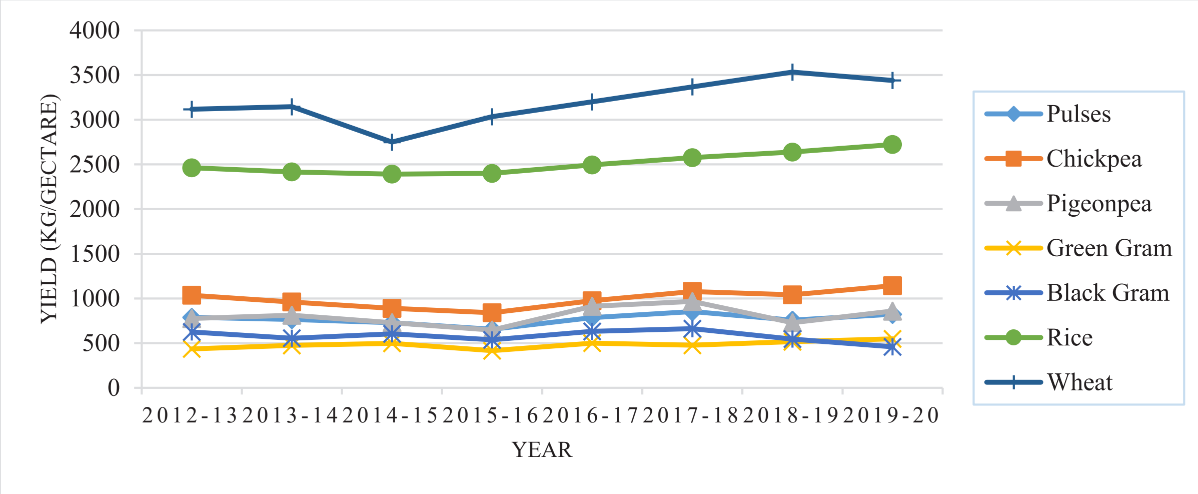
Figure 2.6 (b): Production of Major Pulse Varieties, 2010-11 to 2019-20



Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

The yield of pulses has remained more or less stagnant in the last decade, with an average of 576 kg/ hectare between 2015-16 to 2019-20. This is in contrast to an average yield of 2473 kg/hectare and 3436 kg/hectare of rice and wheat respectively. Figure 2.6 (c) presents the yields of major pulses vis a vis other food crops such as wheat and rice between the period 2012-13 to 2019-20[7]. Amongst the major pulses, chickpea has the highest yield; 1142 kg/hectare in 2019-20. It can be observed that among pulses, green gram and black gram have witnessed the lowest yields, and while the yield of green gram has been consistently lower than black gram, in 2019-20 the yield of urd fell from 546 kg/hectare to 459 kg/hectare, and the yield of green gram (548 kg/hectare) exceeded that of black gram.

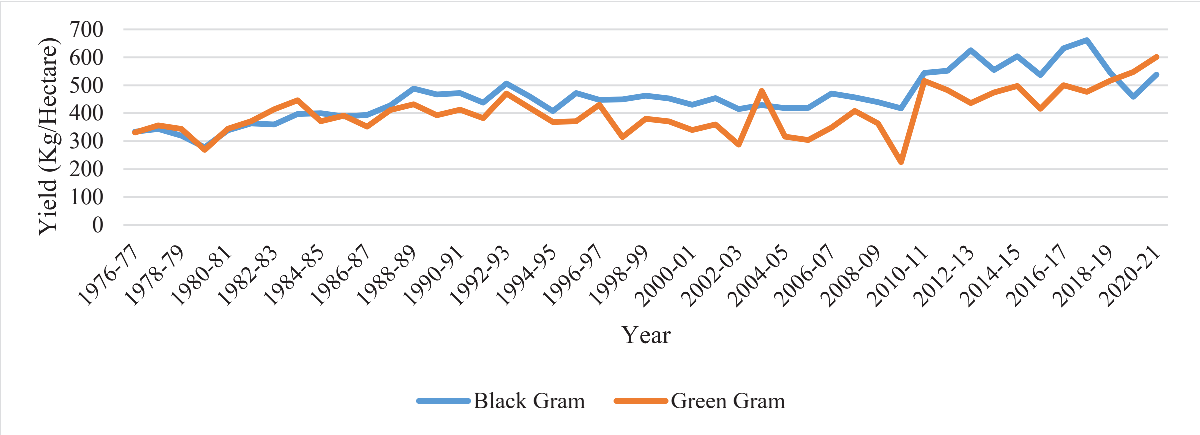
Figure 2.6 (c): Yield (Kg/Hectare) of Food grains in the period 2012-13 to 2019-20: Pulses, Rice and Wheat



Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

A greater emphasis on the yield of black gram and green gram since 1976 reveals that the yield of both pulse categories have more or less remained constant with minor fluctuations (see Figure 2.7).

Figure 2.7: Yield of Black Gram and Green Gram, 1976-77 to 2020-21



Source: CMIE

2.3 Major Pulse Producing States in India

The top six pulse producing states in the financial year 2019-20 included Rajasthan (4.49 million tonnes), Madhya Pradesh (4.1 million tonnes), Maharashtra (3.73 million tonnes), Uttar Pradesh

[7] Note: The data for yields of moong and urd (total) is not available at a disaggregated level prior to 2012-13. They have been placed under 'other rabi and other kharif pulses'.

(2.44 million tonnes), Karnataka (2.15 million tonnes) and Andhra Pradesh (1.16 million tonnes) Table 2.1 provides the state wise ranking in terms of production for the year 2019-20 and compares it with production related data of 2015-20.

Table 2.1: State Wise Ranking in Pulse Production, 2019-20 and 2015-16

Rank in 2019-20	State/Union Territory	Production in 2019-20 ('000 Tonnes)	Production in 2015-16 ('000 Tonnes)	Change in Rank
1	Rajasthan	4497.1	1990.2	+1
2	Madhya Pradesh	4108.4	5302.5	-1
3	Maharashtra	3736.0	1544.7	0
4	Uttar Pradesh	2447.3	1164.6	+1
5	Karnataka	2155.9	1138.8	+1
6	Andhra Pradesh	1166.7	1229.0	-2
7	Gujarat	1057.3	543.6	+1
8	Jharkhand	814.9	527.0	+1
9	Tamil Nadu	605.4	554.8	-2
10	Telangana	549.2	239.6	+4
11	Odisha	432.5	375.1	+1
12	West Bengal	384.9	334.0	+1
13	Bihar	334.4	420.7	-2
14	Chhattisgarh	241.3	511.9	-4
15	Assam	106.1	107.6	0
16	Haryana	64.4	65.7	0
17	Uttarakhand	57.8	51.6	0
18	Himachal Pradesh	55.2	40.5	+2
19	Nagaland	46.8	43.1	0
20	Jammu and Kashmir	44.2	9.3	+5
21	Punjab	29.2	43.5	-3
22	Manipur	25.2	29.8	-1
23	Tripura	18.7	10.9	+1
24	Arunachal Pradesh	14.2	13.0	-2
25	Meghalaya	12.0	11.7	-2
26	Mizoram	5.5	5.0	+1
27	Sikkim	5.0	5.4	-1
28	Goa	3.9	0.3	+3
29	Kerala	2.2	4.3	-1
30	Puducherry	0.5	0.8	0
31	NCT of Delhi	0.0	1.2	-2

Note: The study states have been highlighted.

Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

Rajasthan, Madhya Pradesh and Maharashtra remain the top pulse producing states, while Andhra Pradesh has slid down from being the fourth largest producer to being the sixth largest producer.

Table 2.2 further provides the state wise average area, production, and yield for the period between 2015-16 and 2019-20.

Table 2.2: State wise Average Area, Production, and Yield for the Period between 2015-16 and 2019-20

State	Area ('000 Hectares)	Production ('000 Tonnes)	Yield (Kg/Hectare)
Andhra Pradesh	1369.60	1056.75	772
Arunachal Pradesh	13.13	13.15	1001
Assam	147.48	110.09	746
Bihar	480.76	424.89	882
Chhattisgarh	803.56	519.87	641
Goa	4.47	4.23	905
Gujarat	799.66	804.55	1003
Haryana	79.01	71.49	921
Himachal Pradesh	28.60	54.09	1885
Jammu & Kashmir	17.95	16.94	962
Jharkhand	745.40	744.06	992
Karnataka	3056.11	1751.53	571
Kerala	2.45	2.50	1007
Madhya Pradesh	6275.28	5971.83	942
Maharashtra	4061.18	3015.80	731
Manipur	30.34	28.96	954
Meghalaya	8.50	12.17	1433
Mizoram	3.67	5.27	1437
Nagaland	38.78	45.37	1170
Odisha	770.91	425.67	552
Punjab	35.10	31.96	907
Rajasthan	5342.96	3366.66	621
Sikkim	5.38	5.16	958
Tamil Nadu	832.71	538.97	647
Telangana	553.40	455.76	820
Tripura	23.63	18.19	765
Uttar Pradesh	2262.80	2080.86	909
Uttarakhand	61.18	54.38	890
West Bengal	402.98	358.11	900
A & N Islands	0.92	0.40	425
D & N Haveli	2.76	3.50	1262
Delhi	0.08	0.25	2278
Daman & Diu	0.11	0.11	-
Puducherry	1.71	0.76	509

Note: The study states have been highlighted.

Source: Compiled from the Crop Production Statistics Information System, Directorate of Economics and Statistics, Government of India, 2021

2.4 Government's Policy Interventions

The Government of India has taken several measures to provide impetus to the pulses sector since the last six decades. In 1971, the Directorate of Pulses Development was established as one of the eight Commodity Directorates under the Ministry of Agriculture and Farmers Welfare, with the responsibility of coordination and monitoring of all schemes pertaining to the development of pulses. Since 1969, a number of centrally sponsored schemes have been launched in order to enhance pulse production in line with domestic demand, intensify extension efforts and promote the adoption of technological interventions to ensure that the cultivation of pulses emerges as a profitable endeavour. These schemes were complemented by special initiatives for pulses as provisions under other centrally sponsored schemes; such as the incentives for "Pulses and Oilseeds in Dry Land Area" under the Rashtriya Krishi Vikas Yojana (RKVY) in 2010-11, the Integrated Development of 60,000 Pulses Villages in Rainfed Areas under RKVY in 2011-12 through in situ moisture conservation activities such as seed minikits, and the " Special Plan to Achieve 19+ Million Tonnes of Pulses Production During Kharif 2012-13, through utilisation of new areas, improving planting techniques and irrigation use efficiency, etc. Furthermore, the 'Forecasting Agricultural output Using Space, Agro-Meteorology and Land Based Observations' (FASAL) project launched by the Ministry of Agriculture and Farmers Welfare in 2012 generates pre-harvest crop forecasts at the district, state and national level for 9 major crops using satellite and agro-meteorological data, including rabi pulses. At present, the most significant intervention is the National Food Security Mission-Pulses, wherein the target has been to achieve 3 million tonnes of additional pulses production by 2019-20 across 29 states and 638 districts. The major objective of the programme was to address the issue of food security by devising programmes targeted to escalate production of pulses, rice, and wheat in the country. Accordingly, the programme aimed to enhance the pulses production by 2 million tonnes respectively by 2012. Though NFSM pulses programme was initially implemented only in 468 districts in 16 states, from 2016-17 onwards, 644 districts that cover almost all the states have been included in the programme. Several initiatives were brought under the NFSM and the distribution of quality seeds was one of the important initiatives.

A timeline of all the schemes that have been launched by the Government of India since the 1970s has been laid out in Figure 2.8.

Figure 2.8: Centrally Sponsored Schemes Pertaining to Pulses since the Fourth Five Year Plan

1969-70 to 1973-74 (Fourth Five Year Plan): A centrally sponsored scheme called' **The Pulses Development Scheme**" was launched, which focused on the introduction of production technologies and improved varieties amongst farmers.

1985-90 (Seventh Five Year Plan): All centrally sponsored schemes pertaining to pulse production were brought under the ambit of the **National Pulses Development Project (NPDP)**.

1988-89: NPDP was supplemented by a **Special Food Grain Production Programme (SFPP) on Pulses**.

1990-91: Pulse development programmes weree brought under the "Technology Mission on Oilseeds (constituted 1985-86), which was renamed **Technology Mission on Oilseeds, Pulses and Maize**. This subsumed interventions under NPDP. The focus was on crop protection technology, post harvest technology, input and service support to farmers, and price support, storage, proecssing and marketing.

2007-08: **A Centrally Sponsored Scheme on National Food Security Mission (NFSM)** was launched, where the primary goal was to enhance the production of rice, wheat and pulses by 10, 8, and 2 millon tonnes respectively by the end of the 11th Five Year Plan, through area expansion, productivity enhancement, restoring soil fertility, creating employment opportunities and enhancing farm level economy.

NFSM Pulses is one of the components under NFSM. All the pulse components of the Integrated SCheme on Oilseeds, Pulses, Oil palm and Maize have been merged under this scheme.

2010-11 to 2013-14: In order to enable the vigorous development of NFSM Pulses, the **'Accelerated Pulses Production Programme (A3P)** was launched to demonstrate plant nutritent and plant protection centric improved technologies and management practices in blocks which had high area coverage for five major pulse crops; gram, (black gram)urd, moong (green gram), pigeon pea and lentils.

Source: Compiled from various government documents

2.4.1 Minimum Support Prices and Agronomic Practices

For the purpose of this study, we focus on two key interventions; recommended agronomic practices as well as price support through the MSP for the two crops

2.4.1.1 Agronomic Practices

The importance of adopting smart agronomic practices in order to mitigate production related risks and their contribution to productivity gains has been acknowledged both in the literature and by policymakers alike (Oyetunde-Usman et al., 2021). Crop specific agronomic practices play a crucial role in maximizing the yield potential especially in water stress regions. For example, frontline demonstrations for pulses across the country indicate that the adoption of agronomic practices has the potential to generate a yield advantage of between 25-40 percent (Ali & Gupta, 2012). Similarly, a field experiment on the seed yield of horse gram in Odisha showed positive results; nitrogen @ 20 kg/ha and phosphorus @ 17.5 kg/ ha increased the seed yield by 51.5 percent and 31.6 percent respectively as opposed to non-adoption of nitrogen and phosphorus, and one hand-weeding 25 days after sowing led to an increase of seed yield by 12.2 percent as opposed to a situation of no weeding (Patra and &Nayak, 2000). Yang et al (2021) showed that optimisation of agronomic practices such as planting pattern, seeding rate, etc for a period of two years lead to a grain yield increase to 5879-7093 kg/ha in the case of wheat (Yang et al., 2021). Tufa et al. (2019) empirically demonstrated that in the case of soybean, agronomic practice adopters saw a significantly higher yield and net income; the endogenous switching regression model further indicated that there was a 61 percent yield gain and a 53 percent income gain for adopters.

There have been increasing efforts taken by the government to increase awareness of, and engage in capacity development of farmers and extension personnel through frontline demonstrations, on-farm testing, development of resource centres, provision of farm advisories and conduction of training to update knowledge and skills, in the specific context of enhancing crop productivity. For instance, there is an increasing emphasis on the use of critical inputs such as irrigation, fertilizers, as well as the significance of non-monetary/low cost inputs such as seed treatment with fungicides, weed management, provision of sowing parameters, with specific focus on the relevant crop (Krishi Vigyan Kendra, 2016).This study makes use of key agronomic practices, drawing on the recommended list of practices published by the Directorate of Pulses Development, Government of India. The list of these practices have been included in the study questionnaire to understand the factors affecting the adoption of these practices among the black gram and green gram farmers.

The specific practices include (a) management with respect to climatic requirement and sowing time[8] (b) soil management, which includes soil type and field preparation, fertiliser and manure application (c) seed management (seed rate and spacing, and seed treatment) (d) plant protection related measures (e) water management (f) harvesting, threshing and storage. Appendix table A. 1 outlines the specific practices under each of these agronomic categories for green gram and black gram respectively.

2.4.1.2 Minimum Support Price

The Minimum Support Prices (MSPs) are decided based on the recommendations provided by the Commission for Agricultural Costs and Prices (CACP) to the government; these recommendations are provided separately for two crop seasons. – Kharif and Rabi[9]. Both the crops selected for analysis in our study are kharif crops.

The calculation of MSP is largely based on the cost of production, demand and supply, price trend in both domestic and international market, inter-crop price parity and the likely implications of the support price on consumers[10]. The data shows that the MSP for black gram and green gram in the last ten years has shown a consistent significant increase (see Appendix A.1 in Supplementary Materials). The MSP for green gram increased from Rs 4400 per quintal in 2012-13 to Rs.7755 per quintal in 2022-23, marking a 76 percentage increase in this period. Similarly, the MSP for black gram increased from Rs. 4300 to Rs. 6600 during the same period, marking a 53.48 percent increase (see Table 2.3).

Table 2.3: Trends in MSP for Green Gram and Black Gram (Rupees/ Quintal)

Crops	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
Green Gram	4400	4500	4600	4850	5225	5575	6975	7050	7196	7275	7755
Black Gram	4300	4300	4350	4625	5000	5400	5600	5700	6000	6300	6600

Source: CACP

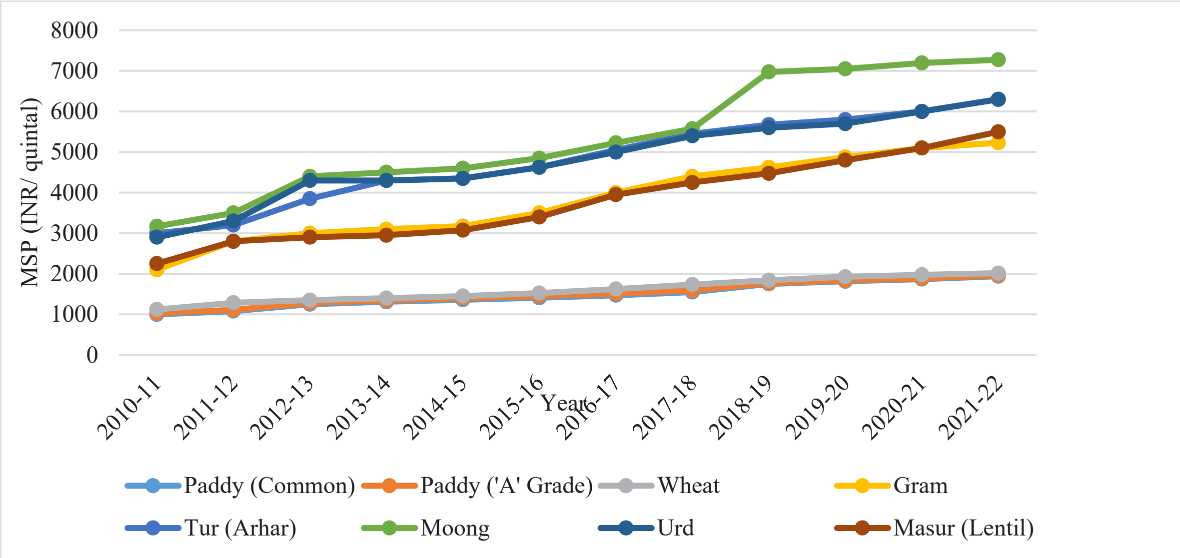
[8] In India, pulse crops have been recognised as an integral component of climate resilient agriculture and the government of India takes initiatives through various agricultural departments to impart information and training pertaining to climate related effects on pulse production. Adoption of various agronomic practices that we have described in this paper need to anticipate the likely impact of climate change on production. Therefore, it is important for farmers to have an understanding of the best sowing time, sowing method, sowing depth and so on (Gudadhe et al.,2018). In our study we take climate management as whether the farmers received information and training pertaining to climate and the sowing time.

[9] The crops-black gram and green gram are mainly a kharif season crop in the states selected for analysis. Khariff crops are sown during the months June and July and harvested by September-October. The rabi crops are sown around mid-November, preferably after the monsoon rains are over, and harvested around April-May.

[10] https://cacp.dacnet.nic.in/content.aspx?pid=62

Figure 2.9 further provides a comparative picture of paddy, wheat and major pulse categories to highlight the rising MSPs for pulses.

Figure 2.9: Minimum Support Price of Food Crops: Paddy, Wheat and Pulses



Source: Farmers' Portal, Ministry of Agriculture and Farmers Welfare, Government of India

CHAPTER 3

SOCIO ECONOMIC PROFILE OF THE SAMPLE HOUSEHOLDS

This chapter provides a descriptive analysis of the survey data collected. A detailed descriptive analysis is also given in each chapters pertaining to each empirical analysis.

3.1 Study Area

The primary data is collected through a comprehensive household survey. The farmers were selected through random sampling technique. All green gram and black gram farming households in the selected blocks of the selected districts were listed and stratified into adopters of various agronomic practices and non-adopters. The adopters and non-adopters were divided into marginal, small, medium and semi-medium farmers.

Four major pulse producing states were identified for the purpose of analysis; these included. Madhya Pradesh (constituting 20.6% of India's total pulse production), Rajasthan (16.75%), Maharashtra (16.71%) and Andhra Pradesh (4.22%)[11]. Within the states, districts that ranked among the top ten in terms of area covered under green gram and black gram, but were characterised by the lowest yields in the respective pulse category were selected. Thus, the selected districts were Pali district for green gram and Jhalawar district for black gram in Rajasthan, Amravati district for both black gram and green gram in Maharashtra; Satna district for both black gram and green gram in Madhya Pradesh, Guntur district for green gram and Srikakulam district for black gram in Andhra Pradesh.

Table 3.1: District Wise Statistics Pertaining to Land Use Pattern

State	District	Geographical Area ('000 hectares)	Gross Cropped Area('000 hectares)	Net Sown Area('000 hectares)	Annual Rainfall	Gross Irrigated Area ('000 hectares)
Madhya Pradesh	Satna	742.4	456.2	341.3	1092.1	127.2
Rajasthan	Pali	1238.7	283.92	202.15	653.4	184.20
	Jhalawar	632.2	510.5	322.9	844.3	211.8
Maharashtra	Amravati	1304	712	602	886.4	63.8
Andhra Pradesh	Guntur	1139.1	803.6	597.0	881	427.2
	Srikakulam	583.7	450.9	322.0	1162	211.9

Source: Compiled from Agriculture Contingency Plan for the respective districts as well as other state government documents

Table 3.2 presents the district wise taluk and villages covered in the survey.

[11] Based on the fourth advance estimates for the year 2020-21, Directorate of Economics and Statistics, Department of Agriculture and Farmers' Welfare, Government of India

Table 3.2: Survey Location

State	District	Taluks
Madhya Pradesh	Satna	Raghurajnagar, Maihar, Nagod, Rampur Baghela, Amarpathan, Majhgawan
Rajasthan	Pali	Pali, Rohat
	Jhalawar	Khanpur
Maharashtra	Amravati	Bhatkuli, Dharni, Nandgaon. Daryapur, Achalpur, Chandurbazar,
Andhra Pradesh	Guntur	Amruthaluru, Pedakakani
	Srikakulam	Narsannapeta, Gara

Source: Survey inputs

3.2 Socio Economic Profile

The total number of cultivator households interviewed was 789; 200 farmers each were surveyed in Rajasthan, Madhya Pradesh and Andhra Pradesh and 189 farmers were surveyed in Maharashtra (see Table 3.3).

Table 3.3: Sampled Households According to Pulse Variety

State	Number of Black Gram Cultivators	Number of Green Gram Cultivators	Total Number of Households
Rajasthan	100	100	200
Madhya Pradesh	100	100	200
Maharashtra	90	99	189
Andhra Pradesh	100	100	200

Source: Survey data

Agriculture was the main occupation and livelihood strategy for most (98.3%) of the farm households in the study districts (see Table 3.4).

Table 3.4: Distribution of Cultivator Households with Agriculture as the Key Occupation(%)

State	Black Gram Cultivators with Agriculture as Main Occupation	Green Gram Cultivators with Agriculture as Main Occupation	Total Cultivators with Agriculture as Main Occupation
Rajasthan	94	98	96
Madhya Pradesh	100	100	100
Maharashtra	97.7	96.9	97.3
Andhra Pradesh	100	100	100

Source: Survey data

A majority of the households (more than 82 percent) interviewed were either marginal farmers, small farmers or semi-medium farmers. The marginal farmers were around 28 percent, small farmers were around 30 percent, semi-medium farmers were around 25 percent, medium farmers were around 14 percent and large farmers around 2.6 percent (see Table 3.5).

Table 3.5: Distribution of Households as per Operational Landholdings

State	Marginal	Small	Semi-medium	Medium	Large
Rajasthan	54	25	15.5	5.5	0
Madhya Pradesh	28.5	40	17.5	10	4
Maharashtra	9.5	31.2	39.7	15.9	3.7
Andhra Pradesh	22	22	28	25	3
Total	28.1	29.5	24.9	14	2.6

Source: Survey data

3.3 Availing MSP and Source of Information Regarding MSP

In the case of green gram, 54 percent of respondents were able to avail the minimum support price for green gram. A majority of respondents received information regarding MSP from the newspaper (73 %) or radio (56%), while the information from sources such as other farmers, smartphone updates and other sources was 15 percent, 25 percent and 20 percent respectively. In the case of black gram), 47 percent of respondents are able to avail the minimum support price; more than half of the farmers received smartphone updates, around 42 percent of respondents received this information about MSP from the newspaper, 32 percent received it from other farmer (See tables 3.6 and 3.7).

Table 3.6: Availing MSP for Green Gram and Sources of Information about MSP

Variable	Mean
Availing MSP	.54 (.49)
MSP Source -Newspaper	.73 (.44)
MSP Source-Radio	.56 (.49)
MSP Source -Other Farmers	.15 (.36)
MSP Source- Smartphone Updates	.25 (.43)
MSP Source- Others	.20 (.40)
Number of Observations	399

Note: Standard deviation in given in parentheses.

Table 3.7: Availing MSP for Black Gram – Sources of Information

Variable	Mean
Availing MSP	.47 (.49)
MSP Source -Newspaper	.42 (.49)
MSP Source-Radio	.29 (.45)
MSP Source -Other Farmers	.32 (.46)
MSP Source- Smartphone Updates	.56 (.49)
Number of Observations	390

Note: Standard deviation is given in parentheses

Table 3.8: Availing MSP for Green Gram – State Wise Distribution

State	Availing MSP for Green Gram	Availing MSP for Black Gram
Andhra Pradesh	0 (0)	0 (0)
Maharashtra	.58 (.49)	.61 (.49)
Madhya Pradesh	.97 (.17)	1 (0)
Rajasthan	.61 (.49)	.29 (.45)
Number of Observations	399	390

Note: Standard deviation is given in parentheses

With respect to the state wise distribution of farmers availing MSP for the respective pulse category, none of the respondents in Andhra Pradesh were observed to be availing the MSP for green gram and black gram. In contrast, in Madhya Pradesh, 97 percent of respondents were availing the MSP for green gram while all respondents were availing MSP for black gram. The state wise source of information for MSP is further presented in Table 3.9 and 3.10.

Table 3.9: State-Wise Source of Information for MSP – Green Gram

Variables	MSP Source -Newspaper	MSP Source-Radio	MSP Source -Other Farmers	MSP Source-Smartphone Updates	MSP Source-Others
Andhra Pradesh	.69 (.46)	.67 (.47)	0 (0)	0 (0)	0 (0)
Maharashtra	.39 (.49)	0 (0)	0 (0)	.16 (.36)	.54 (.50)
Madhya Pradesh	1 (0)	1 (0)	0 (0)	.73 (.44)	.27 (.44)
Rajasthan	.84 (.36)	.59 (.49)	.62 (.48)	.11 (.31)	0 (0)
Number of Observations	399	399	399	399	399

Note: Standard deviation is given in parentheses

Table 3.10: State-Wise Source of Information for MSP – Black Gram

Variables	MSP Source -Newspaper	MSP Source -Radio	MSP Source -Other Farmers	MSP Source – Smartphone Updates
Andhra Pradesh	.13 (.33)	0 (0)	.82 (.38)	.18 (.38)
Maharashtra	.3 (.46)	.01 (.10)	.06 (.25)	.4 (.49)
Madhya Pradesh	1 (0)	1 (0)	0 (0)	.97 (.17)
Rajasthan	.27 (.44)	.13 (.33)	.38 (.48)	.68 (.46)
Number of Observations	390	390	390	390

Note: Standard deviation is given in parentheses

3.4 Frequency of Government Training

Table 3.11: Government Training for Green Gram and Black Gram

Variable	Green Gram	Black Gram
Government Training Frequency Per Year	1.79 (.69)	1.12 (.77)
Training in Input Requirement	.43 (.49)	.07 (.26)
Training in Crop Management	.20 (.40)	.51 (.50)
Training in Post-Harvest Management	.44 (.49)	.08 (.27)
Training in Risk Management	.08 (.27)	.03 (.17)

Note: Standard deviation is given in parentheses

While 43 percent of green gram cultivators availed any training from government departments, only 7 percent of black gram cultivators received training from government departments. While 43 percent of respondents cultivating green gram received government training on input requirement and 44 percent received training on post-harvest management, the corresponding figures for black gram are 7 percent and 8 percent respectively.

As far as the frequency of training is concerned, Rajasthan's green gram farmers and Madhya Pradesh's black gram farmers reported the lowest frequency of training. Otherwise, there were not much of disparity across the states and farmers from most states received 2 rounds of training (see Table 3.12).

Table 3.12: State-Wise Frequency of Government Training – Green Gram and Black Gram

State	Government Training Frequency – Green Gram	Government Training Frequency – Black Gram
Andhra Pradesh	2 (0)	1.19 (.39)
Maharashtra	2.17 (1.05)	1.88 (1.05)
Madhya Pradesh	2 (0)	.5 (.50)
Rajasthan	1 (0)	1 (0)
Number of Observations	399	390

Note: Standard deviation is given in parentheses

The analysis on the type of government training showed that 88 percent of farmers from Rajasthan and 74 percent of farmers from Madhya Pradesh received training on input requirements. Andhra Pradesh and Maharashtra farmers received less or no training on inputs (see Table 3.13). Farmers from Rajasthan received more training on various aspects. 73 percent of them received training in crop management and post-harvest management, 31 percent received training in risk management. Andhra Pradesh and Maharashtra farmers received lowest or no training on almost all the aspects.

Table 3.13: State-Wise Government Training – Green Gram

State	Government Training in Input Requirement	Government Training in Crop Management	Government Training in Post- Harvest Management	Government Training in Risk Management	Government Training in Exports and Imports	Government Training (Others)
Andhra Pradesh	.1 (.30)	.07 (.25)	.03 (.17)	.01 (0)	0 (0)	2 (0)
Maharashtra	0 (0)	0 (0)	0 (0)	0 (0)		
Madhya Pradesh	.74 (.44)	0 (0)	1(0)	0 (0)	0 (0)	2 (0)
Rajasthan	.88 (.32)	.73 (.44)	.73 (.44)	.31 (.46)	.06 (.23)	2 (0)
Number of Observations	399	399	399	399	399	399

Note: Standard deviation is given in parentheses

3.5 Information Pertaining to Improved Varieties

As far as the improved varieties are concerned the highest source of information among both green gram and black gram farmers were the government department. 25 percent of green gram farmers and 26 percent of black gram farmers obtained the information pertaining to improved seed varieties from the government department (see Table 3.14).

Table 3.14: Improved Variety Information Provision – Green Gram and Black Gram

Variable	Green Gram	Black Gram
Information by State Agriculture Department	.25 (.43)	.26 (.44)
Information by Distribution of Seed Minikits	.17 (.38)	.11 (.32)
Information by KVKs	.09 (.28)	.10 (.30)
Information by Agri-Research Universities	.07 (.25)	.07 (.27)
Information by Peers	.18 (.38)	.03 (.18)
Information by Private Companies	.20 (.40)	.23 (.42)
Information by Farmer Friends	.14 (.34)	.13 (.33)

Note: Standard deviation is given in parentheses

Table 3.15: State-Wise Improved Variety Information Provision – Green Gram

State	Information by State Agriculture Department	Information by Distribution of Seed Minikits	Information by KVKs	Information by Agri-research Universities	Information by Peers	Information by Private Companies	Information by Farmer Friends
Andhra Pradesh	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Maharashtra	.33 (.47)	.19 (.39)	.01 (.10)	.08 (.27)	.13 (.33)	.28 (.45)	.13 (.33)
Madhya Pradesh	.63 (.48)	0 (0)	0 (0)	0 (0)	.21 (.40)	.07 (.25)	0(0)
Rajasthan	.36 (.48)	.44 (.50)	.20 (.40)	.36 (.48)	.43 (.49)	.46 (.50)	.43 (.49)
Number of Observations	399	399	399	399	399	399	399

Note: Standard deviation is given in parentheses

Table 3.16: State-Wise Improved Variety Usage and Information Provision – Black Gram

State	Used Improved Variety	Information by State Agriculture Department	Information by Distribution of Seed Minikits	Information by KVKs	Information by Agri-research Universities	Information by Peers	Information by Private Companies	Information by Farmer Friends
Andhra Pradesh	.88 (.32)	.22 (.41)	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Maharashtra	.11 (.31)	.18 (.39)	.42 (.49)	.31 (.46)	.08 (.28)	.22 (.41)	.06 (.25)	.12 (.32)
Madhya Pradesh	.01 (.1)	.03 (.17)	0 (0)	.01 (.1)	.04 (.19)	.7 (.46)	.01 (.1)	0(0)
Rajasthan	.03 (.17)	.04 (.19)	.03 (.17)	.02 (.14)	.02 (.14)	.01 (.1)	.44 (.49)	.5 (.50)
Number of Observations	390	390	390	390	390	390	390	390

Note: Standard deviation is given in parentheses

3.6 Procurement Agency

When it comes to procurement agency, 41 percent of green gram farmers and 64 percent of black gram farmers sold their crop at APMC and the remaining were sold to miller or trader (See table 3.17). This reveals the huge dependance of farmers on APMC as a major platform.

Table 3.17: Type of Procurement Agency – Green Gram and Black Gram

Variable	Green Gram	Black Gram
Procurement Agency as APMC	.41 (.49)	.64 (47)
Procurement Agency as Miller/Trader	.24 (.43)	.35 (.47)
Number of Observations	399	390

Note: Standard deviation is given in parentheses

Farmers who relied on APMC as a major platform to sell the crops were the highest in Rajasthan, 78 percent of green gram farmers and all black gram farmers. This was followed by Madhya Pradesh. 58 percent of green gram farmers and 95 percent of black gram farmers sold their crop at APMC. In Maharashtra 29 percent of green gram farmers and 54 percent of black gram farmers sold their crop at APMC (See table 3.18). The reliance on APMC was the lowest in Andhra Pradesh, perhaps due to the availability of alternate marketing channels.

Table 3.18: State-Wise Procurement Agency as APMC – Green Gram and Black Gram

State	Procurement Agency as APMC – Green Gram	Procurement Agency as APMC – Black Gram
Andhra Pradesh	0 (0)	.09 (.28)
Maharashtra	.29 (.45)	.54 (.50)
Madhya Pradesh	.58 (.49)	.95 (.21)
Rajasthan	.78 (.41)	1 (0)
Number of Observations	399	390

Note: Standard deviation is given in parentheses

Table 3.19: State-Wise Procurement Agency as Miller or Trader – Green Gram and Black Gram

State	Procurement Agency as Miller or Trader -Moong	Procurement Agency as Miller or Trader -Urd
Andhra Pradesh	0 (0)	.91 (.28)
Maharashtra	.64 (.48)	.45 (.50)
Madhya Pradesh	.14 (.34)	.05 (.21)
Rajasthan	.21 (.40)	0 (0)
Number of Observations	399	390

Note: Standard deviation is given in parentheses

CHAPTER 4

AGRONOMIC PRACTICES FOR BLACK GRAM AND GREEN GRAM AND ITS ADOPTION AMONG FARMERS

4.1 Introduction

The present chapter will discuss various initiatives taken by the Government of India in recent years to promote the cultivation of pulses. The focus will be mainly major agronomic practices specifically recommended for black gram and green gram and its determinants. The recommended agronomic practices were supposed to enhance crop production and productivity by mitigating various production related risks. Despite an increase in number of studies that describe the benefits of adopting various agronomic practices with respect to contributing to sustained production, (Ali and Gupta, 2012; Reddy et al., 2017; Bantilan and Parthasarthy, 1998; Tripathi, 2019), our understanding of what drives a farmer to adopt different agronomic practices remains limited. A better understanding of factors that influence farmer's adoption of multiple agronomic practices, is therefore important for designing policies that could stimulate their adoption, and thereby enhance pulse productivity and farm income. Since there are multiple practices that are inter-connected with each other, adoption decisions can be interdependent, and practices may influence each other (Teklewold et al., 2013). Analysis based on univariate modelling would exclude important economic information about interdependent and simultaneous adoption decisions (Dorfman, 1996). Therefore, an analysis without controlling for technology inter-dependence and simultaneous adoption might lead to inconsistent parameter estimates (Teklewold et al., 2013).

There have been attempts to model the interrelationship in the adoption of multiple agricultural technologies with one of the pioneering attempts made by Feder (1982), and this is followed by several recent studies (e.g.Teklewold et al, 2013; Manda et al., 2015). There have been hardly any attempts to analyse the adoption of various agronomic practices using a multivariate framework. This is especially true for India. This chapter contributes to the growing technology adoption literature by analysing the factors influencing the adoption of various agronomic practices in detail, with a specific focus on two pulse varieties; black gram and green gram.

The remainder of the chapter is organised as follows. Section 4.2 briefly discusses the various agronomic practices that are relevant for black and green gram cultivation and are also widely encouraged through government's extension services. Section 4.3 provides the conceptual and econometric framework for the analysis along with variable description. Section 4.4 presents the main analytical results. Concluding observations and policy implications are presented in Section 4.5.

4.2 Agronomic Practices

The importance of adopting smart agronomic practices in order to mitigate production related risks in pulses and contribute to productivity gains has been acknowledged both in the literature and by policymakers, and has been expounded on in Chapter 2 (see 2.1.1.1). This study makes use of key agronomic practices for green gram and black gram specifically, drawing on the recommended list of practices published by the Directorate of Pulses Development, Government of India. These include (a) seed management (seed rate and spacing, and seed treatment (b) soil management, which includes soil type and field preparation, fertiliser application and (c) plant management related measures (d) appropriate cropping systems and crop rotations and e) water management. The components of each of these practices have been provided below.

4.2.1 Seed Rate, Spacing and Seed Treatment

4.2.1 (a) Green Gram

- During the Kharif season 15-20 kg seed/ha should be sown in rows which are 45 cm apart.
- During Rabi and Summer, 25-30 kg seed /ha should be sown in rows 30 cm apart
- Sowing can be done behind the local plough or with the help of seed drill.
- The seed should be treated with Thirum (2gm.) +Carbendazim (1gm.) or Carbendazim & Kepton (1gm.+ 2gm) to control the soil & seed germinated disease.
- For sucking pest control, seed treatment with Imidacloprid 70 WS @ 7g/ kg seed should be undertaken.

4.2.1 (b) Black Gram

- In Kharif, 12-155 kg seed/ha, crop should be sown at a distance of 30-45 cm with 10 cm plant spacing.
- In Rabi, about 18-20 seed/ha for upland and 40 kg/ha for rice fallows with a crop geometry of 30 cm x 15 cm.
- In Summer, 20-25 g seed is required per ha. Plant to plant spacing should be kept at 5-8 cm.

4.2.2 Soil Type and Field Preparation

4.2.2 (a) Green Gram

- The best soil for its cultivation is loam soil with good drainage.
- The crop should not be raised on alkaline, saline or waterlogged soils.
- 2-3 ploughings following by planting needs to be given to keep seedbed free from clods and weeds.
- A well prepared seedbed is required for the proper germination and the establishment of the crop.
- For the summer/ spring cultivation after the harvesting of last crops, the tillage should be done after irrigation.

4.2.2 (b) Black Gram

- Black gram can be grown on a variety of soils ranging from sandy soils to heavy cotton soils.
- The most ideal soil is a well-drained loam with pH of 6.5 to 7.8.
- Cannot be grown on alkaline or saline soils.
- During summer, the crop requires a through preparation to give a pulverized free from stubbles and weeds.

4.2.3 Sowing time

4.2.3 (a) Green Gram

- Should be sown during the last week of June to mid or first week of July.
- For the summer/ spring crop, first fortnight of March is most suitable for cultivation.

- In Kharif season, sowing should be done by ridge & furrow method.

4.2.3 (b) Black Gram

- In Kharif, sowing is done with the onset of monsoon in late June or early July.
- In Rabi, sowing is done in the second fortnight of October (upland) or November (rice fallow).
- In Summer, sowing could be done from the third week of February third week to the first week of April.
- Sowing should be done in furrow opened at a distance of 20-25 cm, seed drill could be used for this purpose.

4.2.4 Appropriate Cropping Systems and Crop Rotations

4.2.4 (a) Green Gram

- For the summer/ spring crop, green gram should be sown after the harvest of the last crop (potato, sugarcane, mustard and cotton, etc).
- As a companion crop with sugarcane seed rate should be 7-8 kg/ha. The plant-to-plant distance should be maintained (atleast 5 cm).

4.2.5 Fertiliser and Manure Application

4.2.5 (a) Green Gram

- 8-10 tonnes of compost or farmyard manure should be applied before 15 days of sowing.
- 15-20 kg nitrogen, 30-40 kg phosphorus should be applied at the sowing time.
- It is advisable to use of fertilisers on the basis of soil test and recommendations.

4.2.5 (b) Black Gram

- For sole crop 15-20 kg/ha Nitrogen, 40-50 g/ha Potash, 20kg/ha sulphur should be applied at time of last ploughing.
- Phosphatic and potassic fertilizer should be applied as per the soil test value.
- Fertiliser should be applied by drilling either at the time of sowing or just before sowing in such a way that they are placed 5-7 cm below the seed.
- Application of fertiliser should be based on soil test value.

4.2.6 Water Management

4.2.6 (a) Green Gram

- Generally, the kharif crop requires one life saving irrigation, which may be applied during the early pod formation stage.
- For the summer/spring crop, 3–4 irrigations are required.
- The first irrigation needs to be applied after 20-25 days of sowing and repeated after 10-15 days as per need. One irrigation before flowering and another at pod-filing stage would ensure healthy seeds.
- No irrigation should be given when the crop is in full bloom stage.

4.2.6 (b) Black Gram

- In Kharif, if the rainfall is normal, irrigation is not required. If there is moisture deficit at pod formation, irrigation should be applied.

- Summer: 3-4 irrigation according to crop requirement. Crop should get irrigation at an interval of 10-15 days.
- There is a need of sufficient moisture from flowering to pod development stage.

4.2.7 Plant Protection

4.2.7 (a) Green Gram

- Two weedings should be given to keep the crop free from harmful weeds.
- During the spraying of weedicide, a flat nozzle is always to be used.
- Awareness of diseases such as mung, yellow mosaic, lea crinkle, leaf curl, anthracnose, cercospora leaf spot and control measures.

4.2.7 (b) Black Gram

- One or two hand weedings should be done up to 40 days of sowing depending on the weed intensity.
- Weeds can be controlled by the use of chemicals too; pendimethalin 30% EC @ 0.75-1.00 kg a.i. per ha in 400-600 litres of water can be applied.
- Awareness of diseases such as yellow mosaic virus, powdery mildew, leaf blight etc and their control measures.

4.3 Conceptual and Econometric Framework

Similar to existing studies on agricultural technology adoption behaviour, the present study makes use of a random utility theory to explain adoption where the utility of a farm household is specified as a linear function of the household and farm specific characteristics, institutional factors, attributes of technology as well as a stochastic component (Marenya and Barrett, 2007). Farmers will adopt a practice or a combination of a practice that can provide maximum utility to them.

The probability of choosing a specific practice or a combination of practices is equal to the probability that the utility of that particular alternative is greater than or equal to the utilities of all other alternatives in the choice set. In order to maximise the utility U_{ij}, an $_i$th farmer will compare alternative practices and combinations. Accordingly, an ith farmer will choose a practice j, over any alternative practice, k, if $U_{ij}>U_{ik}$, $k\neq j$.

In our present study, farmers' choice of different agronomic practices is modelled using a multivariate probit model (MVP) and the factors influencing the extent of combinations of various agronomic practices adopted is modelled using an ordered probit model. The estimation of both the models is undertaken using conditional (recursive) mixed process estimator developed by Roodman (2011). This method has been widely adopted in several empirical studies.[12]

4.3.1 Multivariate Probit Model

Decision to adopt different practices or components is inherently a multivariate decision. In single equation statistical models, farmers' inability to access one set of services does not alter the likelihood of them accessing another set of services. However, the multivariate probit model (MVP) simultaneously models the influence of the set of explanatory variables on each of the different technology practices, while allowing for the potential correlation between unobserved disturbances as well as the relationship between the access to different practices (Teklewold et al, 2013). The MVP recognizes the correlation in the error terms of adoption equations and

[12]See for example, 1. Ruppert, et al., (2009), and Rosa Dias, P. (2010), Varma (2018).

estimates a set of binary probit models simultaneously. The possibility for correlation is due to the fact that the same unobserved characteristics of farmers could influence the adoption of agronomic practices (Kassie et al., 2015). Failure to capture the interdependence of adoption might lead to inconsistent parameter estimates (Kassie et al., 2015).

The farmer decides to adopt a k_{th} agronomic practice with a latent (unobservable) dependent variable (Y_{ik}) as a function of a set of observable household, farm, institutional and other relevant factors and multivariate normally distributed error terms (ϵ_i) (Teklewold et al., 2013; Kassiet et al., 2015). The same can be expressed as;

$$Y_{ik} = X_{ik}\beta_k + \epsilon_{ik}, \text{ (k=1..E)} \quad (1)$$

Where Y_{ik} denotes the latent dependent variables which can be represented by the level of expected benefit and/or utility derived from adoption. X represents a set of household, farm and institutional factors and β is the parameter that needs to be estimated. $\epsilon_{ik,}$ k=1..E are the multivariate normally distributed error terms. 1 to E practices are seed management(A), soil management (B), cropping system and crop rotation (C), plant management (D), and water management (E).[13]

The second system of equations describing the observable binary outcome equation variables for each of the agronomic practices choice of households is given as:

$$Y_{ik} = \begin{cases} 1 \ if \ Y_{ik} > 0 \\ 0 \ otherwise \end{cases} \quad (2)$$

Similar to Teklewold et al., 2013 and Kassie et al., 2015, we describe a multivariate model, with the error terms jointly following a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity for identification of parameters. This can be expressed as;

(uA, uB , uC, uD, uE ,)˜.MVN (0, Ω) and the symmetric variance–covariance matrix Ω is given by;

$$\Omega = \begin{bmatrix} 1 & PAB & PAC & PAD & PAE \\ PBA & 1 & PBC & PBD & PBE \\ PCA & PCB & 1 & PCD & PCE \\ PDA & PDB & PDC & 1 & PDE \\ PEA & PEB & PEC & PED & 1 \end{bmatrix}$$

Where A to E are the various agronomic practices and P denotes the pairwise correlation coefficient of the error terms with respect to any two agronomic practice adoption equations. In the presence of the correlation of error terms, the off-diagonal elements in the variance–covariance matrix of adoption equations become non-zero and Eq. (2) becomes an MVP model (Kassiet et al., 2013).

4.3.2 Ordered Probit Model

The MVP model specified above only considers the probability of adoption of different agronomic practices, with no distinction made between, for example, those farmers who adopt one practice and those who adopt multiple practices in combination. Therefore, an ordered probit analyses the factors that influence the adoption of a combination of practices (in terms of total number of practices adopted). Additionally, the variables that affect the adoption of a single agronomic practice may differently affect the intensity of adoption of all the relevant agronomic practices (Teklewold et al, 2013). The probability for adopting first practice can differ from the probability

[13] For black gram we do not have cropping system and crop rotation as this is not under the recommended practice for black gram.

of adopting a second practice or a third practice and so on. The farmers who adopt greater number of practices are definitely superior in terms of the intensity of adoption.

4.4 Descriptive Statistics: Description of Dependent and Explanatory Variables

Descriptive statistics for all the agronomic practices as dependent variables and all explanatory variables are presented in Appendix A 4.1.

4.4.1 The dependent variables

The total number of adopters of agronomic practices (at least one of the four practices) among black gram farmers were 287 out of 390. 148 farmers adopted soil management practice, 126 farmers adopted seed management practice, 230 farmers adopted plant management practice and 86 farmers adopted water management practice. Similarly, the adopters among green gram was 311 out of 399. 213 farmers adopted soil management practice, 140 farmers adopted seed management practice, 222 farmers adopted plant management practices, 273 farmers adopted cropping system and crop rotation practice, 322 farmers adopted water management practice. The adoption of agronomic practice was generally higher among the green gram farmers. Among green gram farmers 130 farmers adopted all practices, whereas among black gram farmers only 40 farmers adopted all practices.

4.4.2 Explanatory variables

The model specification draws on the adoption literature (Feder et al., 1985; Adesina and Zinnah, 1993; Moser and Barrett, 2003; Langyintuo and Mungoma, 2008; Pender and Gebremedhin, 2008; Uaiene, 2011; Meshram et al, 2012; Kassie et al., 2013; Teklewold et al., 2013; Ogada et al, 2014; Manda et al., 2015; Kassie et al., 2015 etc.).

We control for household heterogeneity by including variables such as size of the household and education level of the household. **Education of the household** is taken in the form of years of education of the household members. Several studies find a positive relationship between education of the household members and adoption decisions (Moser and Barrett, 2003; Pender and Gebremedhin, 2008; Langyintuo and Mungoma, 2008; Haldar et al., 2012).

We also include a variable called **no of years in agriculture** to capture relationship between experience in agriculture and adoption. The **household size** is used as a proxy to capture labour endowment (Pender and Gebremedhin, 2008). We proxy the household wealth through **farm size** (Kassie et al., 2015). Previous studies found a negative and significant relationship between farm size and the intensity of adoption of new technologies (Langyintuo and Mungoma, (2008; Kassie et al., 2015). However, there is also a view that farmers with larger farms will be more willing to devote portions of the land to an untried variety compared with those with smaller ones (Adesina and Zinnah, 1993). Majority of the farmers in our sample was marginal and small farmers with acres less than one hectare of land.

Agricultural extension services are an important channel for wider dissemination and adoption of technology (Langyintuo and Mungoma, 2008; Kassiet et al., 2015). The study by Devi and Ponnarasi (2009) showed that lack of awareness, training on new technology etc. as the determinants for adoption behaviour of farmers. **Access to seed varieties can also** play a significant role in adoption decisions in general (Langyintuo and Mungoma, 2008; Mazvimavi & Twomlow, 2009; Shiferaw et al., 2015). We take three major sources of seed-own stock, private companies and government to see the differential impact of each of the seed source on adoption decision. We give a dummy variable equal to 1 for those who have access to seed from each sources (government, private and own stock).

Market access also has huge bearing on transaction cost in accessing information and technology (Kassie et al., 2015). Similar to Kassie et al., 2015, we consider the **distance to main market** as a proxy for market access.

The literature has recognized the importance **of access to off-farm and non-farm employment** opportunities in influencing the adoption decision; the impact can be either positive or negative in the adoption of sustainable agricultural and natural resource management practices (Lee, 2005). There are studies that shows both a positive (Mutyasira et al., 2018) as well as a negative impact of access to off-farm activities on the adoption decisions (Beshir, 2014). We give a dummy variable equal to 1 for those who have access to off-farm activities and income.

Credit access is also important factor in deciding technology adoption (Simtowe, and Zeller,2006; Shiferaw et al., 2015; Gupta et al., 2019). The present study incorporates variables such as knowledge of Kisan Credit Card (KCC)[14] and loan availed under KCC as the variables to capture the knowledge and access to credit. For both the variables, a dummy equal to 1 is given for those who have knowledge and availed loan under KCC.

Risk and uncertainty are another important risk variable that may affect the adoption decisions (Johnson and Vijayaraghavan, 2011; Barham et al., 2014; Brick and Visser, 2015; Kemeze et al., 2020; Sagemuller and Musshof, 2020). Farmers' attitude towards risk play a crucial role in deciding whether to adopt a new agricultural technology or not (Hardaker et al., 2015). To capture this, we include variables such as experience of crop failure in the last 5 years and access to crop insurance in our model. The **information pertaining to MSP** is also added as a variable in the access to MSP model to see how the availing of MSP and thereby less price uncertainity is affecting the adoption decision.

Membership in certain farmer organization has also been highlighted in the literature as a major factor influencing the adoption decisions. Some studies find a positive relationship between membership in such farmer organizations and the adoption decisions (Quinion et al., 2010; Barrett et al., 2004; Khonje et al., 2015; Manda et al., 2016; Mutyasira et al., 2018; Varma, 2018). In our study we select the membership in input supply cooperatives as a proxy for membership.

Table 4.1. Variable Definitions

Variables	
Years of experience in farming	**No of years in farming by the farmer.**
Number of Years of Education	No of years of education of the members of the household
Number of Family Members	Number of the family members in the household including children.
Farm Size (Acres)	Total size of land owned by household in acres.
Walking Distance to Main Market (Km)	Distance to the nearest main market (in kilometres).
Price at which Black crop is sold (Per Quintal)	Price at which Black crop is sold (Per Quintal)

[14]The Kisan Credit Card (KCC) scheme was introduced by the Government of India in the year 1998 for issue of Kisan Credit Cards to farmers on the basis of their land holdings. The purpose of such a scheme was to provide adequate and timely credit support with flexible and simplified procedures.

Variables	
Years of experience in farming	**No of years in farming by the farmer.**
Availing MSP for Black Gram	Whether the farmer is selling the crop at MSP or not. A dummy variable equal =1 is yes, 0 otherwise.
Contact with Government Extension Agents	Whether the farmer has contact with government extension agents or not. A dummy variable equal =1 is yes, 0 otherwise.
Access to Off Farm Activities	Whether the household has access to off-farm activities, dummy variable equal=1 if any of the family member had access to off-farm activities, =0 otherwise.
Crop Insurance	Whether the farmer is getting crop insurance, dummy variable equal=1 if the farmer is getting crop insurance, =0 otherwise.
Seed Source Own Stock	Dummy variable equal =1 if the source for seed is own stock from previous years, =0 otherwise.
Seed Source -Government	Dummy variable equal =1 if the source for seed is government, =0 otherwise.
Seed Source Private Stock	Dummy variable equal =1 if the source for seed is private companies, =0 otherwise.
Member of Input Supply Cooperatives	Membership of any of the family member in input supply cooperatives, dummy variable = 1 if any of the family member has membership, = 0 otherwise
Knowledge of Kisan Credit Card (KCC)	Dummy variable equal =1 if the farmer had the knowledge about KCC, =0 otherwise.
Procurement Centre as APMC	Dummy variable equal =1 if the procurement centre or the market where the farmer sells the crop is APMC, =0 otherwise.
Procurement by Miller and Traders	Dummy variable equal =1 if the procurement or purchase of the crop is done by the miller or and traders. =0 otherwise.
Experience of Crop Failure	No of times the farmer experienced crop failure in the last 5 years.

4.5 Results and Discussion

The results for MVP are presented in table 4.2 and 4.3.

4.5.1 Black Gram

The results from the multivariate probit model shows that the model fits the data reasonably well – the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. As expected, the likelihood ratio test [chi2(95) = 588.47, p=0.000)] of the null hypothesis that the covariance of the error terms across equations are not correlated is also rejected.

The results showed that the number of family members, size of the farm, distance to the main market, price at which the crop is sold, membership in input supply co-operatives and APMC as procurement place have significant impact on the adoption of soil management practices such as see rate, seed spacing and seed treatment. Number of family members used to capture the household size, membership in input supply co-operatives and procurement centre as APMC reduced the likelihood of adopting seed management practices where as the price at which the crop is sold, distance to market and size of the farm increased the likelihood of adopting seed management practices.

Similarly, price at which the crop is sold, own stock as seed source, membership in input supply co-operatives and APMC as procurement came out to be statistically significant as far as the adoption of seed management is concerned. Similar to the soil management practice adoption, APMC as procurement centre and membership in input supply co-operatives reduced the likelihood of adopting seed management practice. Whereas the price at which the crop is sold and own stock as seed source increased the likelihood of adopting seed management practice.

Education of the household came out to be significant in adopting plant protection measures. Distance to main market, availing of MSP, access to off-farm activities, price at which the crop is sold also came out to be significant and positive in affecting the adoption of plant management practice. Whereas procurement centre as APMC and fear of crop failure reduced the likelihood of adoption.

Size of the household, price at which the crop is sold, distance to main market, knowledge of KCC and membership in input supply co-operatives came out to be significant in the water management practice adoption. Except the knowledge of KCC and the price at which the crop is sold, all other variables reduced the likelihood of adopting the water management practice.

The results from ordered probit model was also somewhat similar to MVP. Size of the household, price at which the crop is sold, distance to main market, farm size, contact with government extension agents, access to off farm activities, own stock as source of seed, private company as source of seed, membership in input supply co-operatives, procurement centre as APMC and crop failure came out to be statistically significant in the ordered probit model. Price at which the crop is sold, distance to main market, farm size, contact with government extension agents, access to off farm activities, own stock as source of seed increased the likelihood of adoption whereas APMC as procurement centre, membership in input supply co-operatives, crop failure, private company as source of seed, size of the family reduced the likelihood of adoption.

4.5.2 Green Gram

The results from the multivariate probit model shows that the model fits the data reasonably well – the hypothesis that all regression coefficients in each equation are jointly equal to zero is rejected. As expected, the likelihood ratio test [chi2(95) = 398.05, p=0.000)] of the null hypothesis that the covariance of the error terms across equations are not correlated is also rejected.

Education, number of family members, walking distance to main market, price at which the crop is sold, availing of MSP, contact with government extension agents, membership of input supply co-operatives and procurement agency as village trader came out to be statistically significant in the case of seed rate, spacing and seed treatment adoption. Out of these number of family members, price at which the crop is sold, availing of MSP, distance to main market, contact with government extension agents, membership in input supply co-operatives increased the likelihood of adoption.

Years of experience in farming, Farm size, distance to main market, availing of MSP and all three seed sources came out to be statistically significant in the case of soil management adoption. Out of which farm size, distance to main market, seed source as government reduced the likelihood of adopting soil management whereas the other variables increased the likelihood of adopting soil management practice adoption.

Distance to main market, seed source as government reduced the likelihood of adopting cropping system and rotation practice whereas the availing of MSP increased the likelihood of adopting cropping system and rotation practice. Similarly availing MSP, own stock as seed source, and seed from private increased the likelihood of adopting plant protection measures. As far as water management practice is concerned, only own seed source came out to be significant and positive in influencing the adoption.

The results from ordered probit model for green gram showed that number of family members, seed source as private, procurement centre as APMC and crop failure reduced the likelihood of adoption of all agronomic practices. Distance, size of the farm, walking distance to main market, contact with government extension agents, access to off farm activities, own stock as seed source, price at which the crop is sold increased the likelihood of adopting all agronomic practices.

Table 4.2: Results for Multivariate Probit Model – Green Gram

Variables	Coefficient	Marginal Effects
A. Seed Rate, Spacing and Seed Treatment		
Years of experience in farming	.002 (.008)	.000 (.001)
Number of Years of Education	**-.051 (.029)***	**-.009 (.005)***
Number of Family Members	**.110 (.044)****	**.020 (.007)***
Farm Size (Acres)	-.027 (.017)	-.005 (.003)
Walking Distance to Main Market (Km)	**.020 (.009)****	**.003 (.001)****
Price at which Green Gram is sold (Per Quintal)	**-.000 (.000)****	**-.000 (.000)****
Availing MSP for Green Gram	**1.067 (.283)*****	**.197 (.049)*****
Contact with Government Extension Agents	**.787 (.383)****	**.146 (.069)****
Access to Off Farm Activities	.223 (.248)	.041 (.045)
Crop Insurance	-.132 (.328)	-.024 (.060)
Seed Source Own Stock	1.049 (.559)*	.194 (.102)*
Seed Source -Government	-.536 (.571)	-.099 (.105)
Seed Source-Private Stock	-.090 (.583)	-.016 (.108)
Member of Input Supply Cooperatives	**.561 (.301)***	**.104 (.055)***
Knowledge of Kisan Credit Card (KCC)	.173 (.321)	.032 (.059)
Procurement Centre as APMC	.434 (.303)	.080 (.055)
Procurement Agency as Government Agency	.234 (.303)	.043 (.070)
Procurement Agency as Village Trader	**-.691 (.382)***	**-.128 (.070)***
Experience of Crop Failure	-.295 (.205)	-.054 (.037)
Constant	-1.025 (1.174)	
B. Soil		
Years of experience in farming	**.012 (.007)***	**.003 (.001)***
Number of Years of Education	-.040 (.026)	-.010 (.006)
Number of Family Members	.051 (.039)	.013 (.009)
Farm Size (Acres)	**-.021 (.011)***	**-.005 (.002)***
Walking Distance to Main Market (Km)	**-.020 (.008)****	**-.005 (.002)****
Price at which Green Gram is sold (Per Quintal)	-.000 (.000)	-.000 (.000)
Availing MSP for Green Gram	**.616 (.269)****	**.155 (.066)****
Contact with Government Extension Agents	.337 (.237)	.085 (.059)

Variables	Coefficient	Marginal Effects
Access to Off Farm Activities	.272 (.232)	.068 (.058)
Crop Insurance	-.052 (.244)	-.013 (.061)
Seed Source Own Stock	**1.019 (.395)*** **	**.256 (.096)*** **
Seed Source -Government	**-.709 (.416)***	**-.178 (.103)***
Seed Source Private Stock	**.792 (.408)***	**.199 (.101)** **
Member of Input Supply Cooperatives	-.450 (.264)	-.113 (.066)*
Knowledge of Kisan Credit Card (KCC)	.151 (.225)	.038 (.056)
Procurement Centre as APMC	.119 (.268)	.030 (.067)
Procurement Agency as Government Agency	.287 (.295)	.072 (.074)
Procurement Agency as Village Trader	-.536 (.330)	-.135 (.082)
Experience of Crop Failure	.010 (.169)	.002 (.042)
Constant	-.041 (.902)	
C. Cropping System and Rotation		
Years of experience in farming	.008 (.006)	.002 (.001)
Number of Years of Education	-.023 (.024)	-.006 (.006)
Number of Family Members	.055 (.039)	.015 (.010)
Farm Size (Acres)	-.009 (.009)	-.002 (.002)
Walking Distance to Main Market (Km)	**-.019 (.007)** **	**-.005 (.002)** **
Price at which Green Gram is sold (Per Quintal)	-.000 (.000)	-.000 (.000)
Availing MSP for Green Gram	**.435 (.243)***	**.122 (.067)***
Contact with Government Extension Agents	.093 (.236)	.026 (.066)
Access to Off Farm Activities	.090 (.215)	.025 (.060)
Crop Insurance	-.107(.239)	-.030 (.067)
Seed Source Own Stock	.314 (.379)	.088 (.106)
Seed Source -Government	**-.670 (.378)***	**-.188 (.104)***
Seed Source Private Stock	.041 (.395)	.011 (.111)
Member of Input Supply Cooperatives	-.215 (.236)	-.060 (.066)
Knowledge of Kisan Credit Card (KCC)	.418 (.222)*	.117 (.061)
Procurement Centre as APMC	-.310 (.260)	-.087 (.072)
Procurement Agency as Government Agency	-.054 (.288)	-.015 (.080)
Procurement Agency as Village Trader	-.391 (.308)	-.109 (.086)
Experience of Crop Failure	.117 (.137)	.032 (.038)
Constant	1.197 (.846)	
D. Plant Protection Measures		
Years of experience in farming	-.000 (.006)	-.000 (.001)
Number of Years of Education	-.025 (.025)	-.006 (.006)
Number of Family Members	.029 (.038)	.008 (.010)
Farm Size (Acres)	-.002 (.009)	-.000 (.002)

Variables	Coefficient	Marginal Effects
Walking Distance to Main Market (Km)	.007 (.007)	.002 (.002)
Price at which Green Gram is sold (Per Quintal)	-.000 (.000)	-.000 (.000)
Availing MSP for Green Gram	**.682 (.252)*** **	**.188 (.068)*** **
Contact with Government Extension Agents	.287 (.222)	.079 (.061)
Access to Off Farm Activities	.203 (.212)	.056 (.058)
Crop Insurance	-.110 (.225)	-.030 (.062)
Seed Source Own Stock	**.717 (.377)***	**.198 (.103)***
Seed Source -Government	-.621 (.391)	-.172 (.107)
Seed Source Private Stock	**.881 (.390)** **	**.243 (.106)** **
Member of Input Supply Cooperatives	.129 (.249)	.035 (.068)
Knowledge of Kisan Credit Card (KCC)	.040 (.209)	.011 (.058)
Procurement Centre as APMC	.314 (.250)	.087 (.069)
Procurement Agency as Government Agency	.082 (.273)	.022 (.075)
Procurement Agency as Village Trader	-.313 (.301)	-.086 (.083)
Experience of Crop Failure	.005 (.146)	.001 (.040)
Constant	.077 (.857)	
E. Water Management		
Years of experience in farming	.000 (.007)	.000 (.001)
Number of Years of Education	.017 (.027)	.004 (.006)
Number of Family Members	.033 (.036)	.007 (.008)
Farm Size (Acres)	-.015 (.009)	-.003 (.002)
Walking Distance to Main Market (Km)	-.000 (.008)	-.000 (.001)
Price at which Green Gram is sold (Per Quintal)	.000 (.000)	.000 (.000)
Availing MSP for Green Gram	-.590 (.256)	-.142 (.060)**
Contact with Government Extension Agents	207 (.245)**	.050 (.058)
Access to Off Farm Activities	. -.215 (.217)	-.051 (.052)
Crop Insurance	.014 (.240)	.003 (.057)
Seed Source Own Stock	-.246 (.395)	-.059 (.095)
Seed Source -Government	**.826 (.442)***	**.198 (.105)***
Seed Source Private Stock	-.003 (.415)	-.000 (.099)
Member of Input Supply Cooperatives	.435 (.262)	.104 (.062)*
Knowledge of Kisan Credit Card (KCC)	-.156 (.229)	-.037 (.055)
Procurement Centre as APMC	.080 (.258)	.019 (.062)
Procurement Agency as Government Agency	-.163 (.284)	-.039 (.068)
Procurement Agency as Village Trader	.147 (.334)	.035 (.080)
Experience of Crop Failure	-.149 (.177)	-.035 (.042)
Constant	.534 (.884)	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors in parentheses

Table 4.3: Ordered Probit Estimation for Total Practices – Green Gram

Variables	Coefficient	Marginal Effects P(Y=4/X)
Years of experience in farming	.003 (.005)	.001 (.001)
Number of Years of Education	**-.038 (.019)****	**-.012 (.006)****
Number of Family Members	.070 (.029)**	.023 (.009)**
Khariff Total Area (Acres)	-.010 (.007)	-.003 (.002)
Walking Distance to Main Market (Km)	.002 (.005)	-.000 (.001)
Price at which Green Gram is sold (Per Quintal)	.000 (.000)	-000 (.000)
Availing MSP for Green Gram	**.638 (.191)*****	**.203 (.059)*****
Contact with Government Extension Agents	.257 (.172)	.079 (.050)
Access to Off Farm Activities	.249 (.163)	.082 (.054)
Crop Insurance	-.035 (.174)	-.011 (.057)
Seed Source Own Stock	**.802 (.290)*****	**.262 (.093)*****
Seed Source -Government	-.542 (.298)	-.163 (.081)**
Seed Source-Private Stock	.455 (.301)	.159 (110)
Member of Input Supply Cooperatives	-.025 (.190)	-.008 (.062)
Knowledge of Kisan Credit Card (KCC)	.155 (.162)	.049 (.050)
Procurement Centre as APMC	.089 (.196)	.029 (.064)
Procurement Agency as Government Agency	-.008 (.208)	-.002 (.068)
Procurement Agency as Village Trader	**-.514 (.236)****	**-.149 (.060)****
Experience of Crop Failure	.068 (.236)	.022 (.037)
No of observations	399	LR chi2(19) 202.92
Log Likelihood	-567.673	Prob>chi2 0.000

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors in parentheses

Table 4.4: Results for Multivariate Probit Model – Black Gram

Variables	Coefficient	Marginal Effects
A. Soil		
Years of experience in farming	-.009 (.007)	-.002 (.001)
Number of Years of Education	.018 (.026)	.004 (.006)
Number of Family Members	**-.070 (.035)*****	**-.017 (.008)****
Farm Size (Acres)	**.021 (.011)****	**.005 (.002)***
Walking Distance to Main Market (Km)	**.024 (.011)****	**.006 (.002)****
Price at which Black Gram is sold (Per Quintal)	**.000 (.000)****	**.000 (.000)****
Availing MSP for Black Gram	-.207 (.258)	-.052 (.065)
Contact with Government Extension Agents	.225 (.256)	.057 (.065)
Access to Off Farm Activities	-.086 (.240)	-.022 (.061)
Crop Insurance	.485 (.330)	.123 (.083)

Variables	Coefficient	Marginal Effects
Seed Source Own Stock	.389 (.345)	.099 (.087)
Seed Source -Government	.479 (.447)	.121 (.113)
Seed Source-Private Stock	-.234 (.326)	-.059 (.082)
Member of Input Supply Cooperatives	**-.532 (.262)****	**-.135 (.065)****
Knowledge of Kisan Credit Card (KCC)	-.162 (.310)	-.041 (.078)
Procurement Centre as APMC	**-.792 (.273)****	**-.201 (.066)*****
Experience of Crop Failure	.163 (.206)	.041 (.052)
Constant	-1.304 (.765)*	
B. Seed		
Years of experience in farming	-.009 (.008)	-.001 (.001)
Number of Years of Education	.011 (.031)	.002 (.005)
Number of Family Members	-.023 (.038)	-.004 (.007)
Farm Size (Acres)	-.001 (.013)	-.000 (.002)
Walking Distance to Main Market (Km)	.013 (.014)	.002 (.002)
Price at which Black Gram is sold (Per Quintal)	**.000 (.000)*****	**.000 (.000)*****
Availing MSP for Black Gram	.090 (.348)	.016 (.063)
Contact with Government Extension Agents	.337 (.308)	.061 (.055)
Access to Off Farm Activities	-.342 (.298)	-.062 (.053)
Crop Insurance	-.293 (.349)	-.053 (.063)
Seed Source Own Stock	**.815 (.413)****	**.148 (.074)****
Seed Source -Government	.533 (.509)	.096 (.092)
Seed Source Private Stock	-.345 (.408)	-.062 (.074)
Member of Input Supply Cooperatives	**-1.189 (.284)*****	**-.216 (.048)*****
Knowledge of Kisan Credit Card (KCC)	.430 (.344)	.078 (.062)
Procurement Centre as APMC	**-.692 (.309)****	**-.125 (.055)****
Experience of Crop Failure	-.284 (.222)	-.051 (.040)
Constant	-1.901 (.938)**	
C. Plant Protection Measures		
Years of experience in farming	.000 (.008)	.001 (.001)
Number of Years of Education	**.080 (.030)****	**.015 (.005)*****
Number of Family Members	-.064 (.042)	-.012 (.007)
Farm Size (Acres)	.025 (.022)	.004 (.004)
Walking Distance to Main Market (Km)	**.057 (.015)*****	**.011 (.002)*****
Price at which Black Gram is sold (Per Quintal)	0.000 (.000)	0.000 (.000)
Availing MSP for Black Gram	**.889 (.285)*****	**.169 (.052)*****
Contact with Government Extension Agents	**.948 (.259)*****	**.180 (.046)*****
Access to Off Farm Activities	**1.608 (.298)*****	**.306 (.049)*****
Crop Insurance	-.156 (.331)	-.029 (.063)

Variables	Coefficient	Marginal Effects
Seed Source Own Stock	.538 (.366)	.102 (.069)
Seed Source -Government	.026 (.482)	.005 (.091)
Seed Source Private Stock	-.537 (.352)	-.102 (.066)
Member of Input Supply Cooperatives	-.037 (.308)	-.007 (.058)
Knowledge of Kisan Credit Card (KCC)	-.005 (.335)	-.001 (.063)
Procurement Centre as APMC	**-.891 (.333)*** **	**-.169 (.061)*** **
Experience of Crop Failure	**-.524 (.251)** **	**-.099 (.046)** **
Constant	-1.603 (.922)*	
D. Water Management		
Years of experience in farming	-.010 (.009)	-.001 (.001)
Number of Years of Education	-.033 (.037)	-.004 (.005)
Number of Family Members	**-.099 (.055)***	**-.014 (.007)***
Farm Size (Acres)	.008 (.019)	.001 (.002)
Walking Distance to Main Market (Km)	**.062 (.016)*** **	**.009 (.002)*** **
Price at which Black Gram is sold (Per Quintal)	**.000 (.000)***	**.000 (.000)***
Availing MSP for Black Gram	-.367 (.424)	-.053 (.061)
Contact with Government Extension Agents	.108 (.317)	.015 (.046)
Access to Off Farm Activities	-.109 (.425)	-.016 (.062)
Crop Insurance	-.183 (.385)	-.026 (.056)
Seed Source Own Stock	.017 (.485)	.002 (.070)
Seed Source -Government	.406 (.554)	.059 (.080)
Seed Source Private Stock	-.614 (.470)	-.089 (.068)
Member of Input Supply Cooperatives	**-1.673 (.408)*** **	**-.243 (.055)*** **
Knowledge of Kisan Credit Card (KCC)	**.617 (.366)***	**.089 (.052)***
Procurement Centre as APMC	-.014 (.357)	-.002 (.051)
Experience of Crop Failure	-.004 (.264)	-.000 (.038)
Constant	-1.830 (1.107)*	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors in parentheses

Table 4.5: Ordered Probit Estimation for Total Practices – Black Gram

Variables	Coefficient	P(Y=4/X)
Years of experience in farming	-.004(.006)	-.000(.000)
Number of Years of Education	.025(.019)	.001(.001)
Number of Family Members	-.078(.026)***	-.003(.001)**
Farm Size (Acres)	.014(.008)*	.001(.0003)*
Walking Distance to Main Market (Km)	.050(.009)***	.002(.001)***
Price at which Black Gram is sold (Per Quintal)	.0002(.000)***	.000(.000)**
Availing MSP for Black Gram	.227(.205)	.009(.009)

Variables	Coefficient	P(Y=4/X)
Contact with Government Extension Agents	.664(.199)***	.018(.006)***
Access to Off Farm Activities	.470(.184)**	.025(.013)*
Crop Insurance	.115(.230)	.004(.008)
Seed Source Own Stock	.658(.271)**	.030(.015)**
Seed Source -Government	.593(.354)*	.044 (.041)
Seed Source-Private Stock	-.425(.265)*	-.017 (.010)
Member of Input Supply Cooperatives	-.999(.195)***	-.061 (.020)***
Knowledge of Kisan Credit Card (KCC)	.257(.242)	.009 (.020)
Procurement Centre as APMC	-1.08(.215)***	-.072 (.025)**
Experience of Crop Failure	-.264 (.148)*	-.012 (.007)
No of observations	390	LR chi2(17) 355.17
Log Likelihood	-417.60	Prob>chi2 0.000

Note: Standard errors in parentheses

4.6 Conclusion

The present chapter analysed the determinants of various agronomic practices separately employing a multivariate probit model and taking all agronomic practices together employing an ordered probit model. The results generally showed that the contact with government extension agents, access to off-farm activities, availing of MSP, price at which the crop is sold and own stock of seed increased the likelihood of adopting several practices for both black gram and green gram. While these results were not counter-intuitive the results for membership in input supply co-operatives and distance to main market was counter-intuitive. As per the literature one would expect a positive relationship between the membership in input supply co-operatives and the adoption of agronomic practices. Similarly, one would expect a negative relationship between the distance and the adoption. However, the findings are just opposite.

The negative relationship between membership in input supply co-operatives and adoption could be due to the fact the membership in input supply co-operatives means better farming situation of farmers and they cultivate more market oriented and less risky crops. This could be the reason for a positive relationship between the distance and adoption. It indicates that the agronomic practices are mainly adopted by farmers who are less market oriented but resource poor farmers as a livelihood maximisation strategy.

The results from size of the farm and education are also mixed. These results also point out that the adoption of agronomic practices are undertaken by resource poor farmers. Also the availing of MSP had a significant and positive impact in influencing the adoption of most practices.

CHAPTER 5

IMPACT OF MSP ON THE ADOPTION OF VARIOUS AGRONOMIC PRACTICES

5.1 Introduction

The present chapter will analyse the impact of MSP in encouraging the adoption of various agronomic practices among black Gram and green Gram farmers. Numerous studies have analysed the impact of risk and uncertainty in farm level decision making (Barham et al., 2014; Brick and Visser, 2015; Kemeze et al., 2020; Sagemuller and Musshof, 2020), and ascertain that farmers' attitude towards risk play a crucial role in deciding whether to adopt a new agricultural technology or not (Hardaker et al., 2015). There are two contrasting strands of findings in this context; while one group of studies show that the likelihood of agriculture technology adoption increases as risk aversion increases (Liu, 2013; Brick and Visser, 2015) another group of findings indicate that risk-averse farmers are less likely to adopt new technologies, emphasising the importance of context specificity (Pannell and Burton, 2005; Begho, 2021). In contrast, Tran, et al., (2020) finds that farmers who are more willing to take risks are more likely to adopt climate smart agriculture. As per Kaan (1998), uncertainties in prices are the most significant risks, while Ulla, Shivakoti and Kamran (2016) ascertain that the relative importance of these risks is dependent on factors such as government policies and legislations, the type of agricultural product, the geographical location, and the presence of formal/ traditional risk coping tools.

Kim et al., (1992) concludes that that the introduction of a price-stabilisation policy would encourage producers to adopt yield-increasing technologies, while the discontinuation of such a policy would encourage the adoption of cost-reducing technologies. Yet there is a dearth of studies that exclusively draw a link between price-stabilisation policies and the impact on technology adoption.

In this context, there has been increased policy impetus on the enhancing productivity of pulses over the years; for example, the National Food Security Mission-Pulses is a significant intervention wherein the target has been to achieve 3 million tonnes of additional pulses production by 2019-20 across 29 states and 638 districts. In addition to this, the government increased the minimum support price (MSP) for pulses to increase price security and incentivise the farmers to adopt modern technology. The government has also come up with a list of crop specific recommended agronomic practices such as climate management, soil management, irrigation management, and plant management that seeks to ensure that producers can maximise yield potential by adhering to these specified practices. Though there has been an increase in number of studies that describe the benefits of adopting such agronomic practices (Bantilan and Parthasarthy, 1998; Ali and Gupta, 2012; Tripathi, 2019), our understanding of what drives a farmer to adopt different agronomic practices remains limited.

Specifically, to the best of our knowledge, there have not been any study explicitly analysing the impact of market price assurance in the form of government's MSP in encouraging the adoption of various agronomic practices. A better understanding of factors that influence farmer's adoption of multiple agronomic practices, especially when the output price uncertainty is minimised through a guaranteed support price is therefore play a crucial role in designing policies that could stimulate the adoption and thereby pulse productivity and farm income.

The remainder of the chapter is organised as follows. Section 5.2 provides the conceptual and econometric framework for the analysis along with variable description. Section 5.3 presents the main analytical results. Concluding observations and policy implications are presented in Section 5.4.

5.2 Conceptual and Econometric Framework

In line with existing studies on agricultural technology adoption behaviour, the present study makes use of a random utility theory to explain adoption, wherein the utility of a farm household is specified as a linear function of the household and farm specific characteristics, institutional factors, attributes of technology as well as a stochastic component (Marenya and Barrett, 2007). Farmers will adopt a practice or a combination of a practice that can provide maximum utility to them (Rahm and Huffman, 1984; Shiferaw *et al.*, 2015; Varma, 2018).

The probability of choosing a specific practice or a combination of practices is equal to the probability that the utility of that alternative is greater than or equal to the utilities of all other alternatives in the choice set. In order to maximise the utility U, an $_i$th farmer will compare alternative practices and combinations. Accordingly, the $_i$th farmer will choose a practice j, over any traditional practice, k, if $U_{ij}>U_{ik}$, k≠j.

The probability that the farmer adopts a superior agricultural practice j depends on a set of explanatory variables Z. By denoting A_j=1 for adoption of j we can write:

$$P_i = P_r(A_j = 1) = P_r(U_{ij} > U_{ik}) \quad (1)$$

$$1 - P_i = P_r(A_j = 0) = P_r(U_{ij} < U_{ik}) \quad (2)$$

With random utility in equation 1, the probability that the farmer will choose the technology as expressed in the first equation as:

$$P_i = P_r(A_j = 1) = P_r(U_{ij} > U_{ik}) = P_r[U_{ij} + e_{i1} > +U_{i0} + e_{i0}] \quad (3)$$

$$= P_r[\beta_1 F_i(K_i L_i) + e_{i1} > \beta_0 F_i(K_i L_i) + e_{i0}] \quad (4)$$

$$= P_r[e_{1i} - e_{0,i} > F_i(K_i, L_i)(\beta_1 - \beta_0)] \quad (5)$$

$$= P_r[e_{0i} - e_{1i} < U_{ij} - U_{i0}] \quad (6)$$

$$P_r\{\mu_i > -F_i(K_i L_i)\delta\} \quad (7)$$

$$P_i = F_i(Z_i\beta) \quad (8)$$

Where Z is the *n* x *k* matrix of the explanatory variables and *β* is the *k* x *1* vector of parameters to be estimated, *Pr (.)* is the probability function, μ_i is the random error term, and $F_i(Z_i\beta)$ is the cumulative distribution function for μ_i evaluated at $Z_i\beta$. The probability for a farmer to choose a specific agronomic practice over the traditional practice is a function of the vector of Z and of the unknown parameters and error term.

The expected utility of the new technology depends on the farmer's risk aversion and (perceived) uncertainty pertaining to output price and yield. The risk aversion by the farmers, especially in developing countries is cited to serve as a reason for low uptake of several technologies despite the proven yield advantages. As mentioned earlier, when the prices are certain, the farmers will go for the adoption of yield enhancing technology.

Let $\pi_{ij} = (A_{ij,}Z_{ij,}\varepsilon_{ij}^{A})$ denote the random profit obtained by the farmer i by adopting the $_{j}$th practice. A_{ij} denotes the adoption of the $_{j}$th practice by the $_{i}$th farmer. Z_{ij} denotes the $_{i}$th farmer's household and farm level characteristics, and ε_{ij}^{A} refers to the uncertainty (price and yield) pertaining to the adoption of j.

The farmer's utility maximization can then be written as:

$$max_{\,A_{ij}} E[U(\pi_{ij}\left(\left(A_{ij,}Z_{ij,}\varepsilon_{ij}^{A}\right)\right)] \quad (9)$$

In the above equation E is the expectation operator and U is the "von Neumann-Morgenstern" utility function of the farmer. Furthermore, given that the recommended agronomic practices aim towards the enhancement of the yield for the farmer, we can re-write the above equation as:

$$A_{ij}^{Y} = max_{\,A_{ij}} E[U(\pi_{ij}\left(\left(A_{ij,}Z_{ij,}\varepsilon_{ij}^{A}\right) \quad (10)$$

The farmer would deviate from a yield enhancing agricultural practices adoption only when the expected utility from the yield enhancing agricultural practice is lower. The expected utility will be lower for a risk averse farmer. However, the price risk is eliminated through a guaranteed price (MSP) from the government. In such a context, the farmer will try to maximise the expected utility by adopting yield enhancing agronomic practices, assuming other factors that can influence the farmer's decision-making are constant. While assuming that the farm, farmer and household characteristics and price uncertainty are constant, the equation will become:

$$E[U(A_{ij}) = max_{\,A_{ij}} E[U\left(\pi_{ij}\left(\left(A_{ij,}\overline{Z_{\iota J,}}\overline{\varepsilon_{ij}^{A}}\right)\right)\right] > \mathrm{E}[\mathrm{U}(A_{ik}) \quad (11)$$

The farmer's demand for the new agronomic practice can be written as below:

$$A_{i}^{*} = \alpha \boldsymbol{x}_{i}' + u_{i} \quad (12)$$

Where $\boldsymbol{x}_{i}'$ is a vector of variables that determine the demand function, α is a parameter vector, u is an error term with mean 0 and variance σ_{u}. Similarly, the latent variable underlying a farmer's access to guaranteed price (MSP) can be modelled as provided below:

$$L_{i}^{*} = \beta \boldsymbol{z}_{i}' + \epsilon_{i} (\text{Access to minimum support price}) \quad (13)$$

In the above equations, $\boldsymbol{Z}_{i}'$ is the vector of variables that affect the access to minimum support price, which also includes the access to information related to MSP. And β is the parameter to be estimated; ϵ is the error term with mean 0 and variance 1. The adoption of an agronomic practice by a farmer is characterised by the interaction of models (12) and (13).

The joint probability for adoption is estimated using a conditional (recursive) mixed process estimator (CMP) developed by Roodman (2009, 2011). [15] The first set of equations are estimated using probit models, and the second set of equations is estimated using probit and ordered probit models. The first set of probit models only considers the probability of adoption of different agronomic practices separately, with no distinction made between, for example, those farmers who adopt one practice and those who adopt multiple practices in combination. Therefore, an ordered probit analyses the factors that influence the adoption of a combination of practices (in terms of the total number of practices adopted). Additionally, the variables that affect the adoption of a single agronomic practice may differently affect the intensity of adoption of all the relevant agronomic practices (Teklewold et al, 2013). The probability for adopting the first practice can differ from the probability of adopting a second practice or a third practice and so

[15] The model is estimated using CMP command in Stata as it helps us to run multiple equations.

on. The farmers who adopt greater number of practices are superior in terms of the intensity of adoption.

5.3 Descriptive Statistics: Description of Dependent and Explanatory Variables

The definitions for all the dependent variables and explanatory variables are presented in Table 5.1. The descriptive statistics for both black gram and green gram are presented in Appendix A 5.1-A 5. in Supplementary Materials.

5.3.1 Dependent Variables

5.3.1.1 Adoption of Agronomic Practices-Black Gram

The number of adopters of agronomic practices pertaining to climate requirement for cultivation and sowing time was 209 (53% of the total sample), fertiliser and manure application was186 (47%), seed management was 181 (46%), plant management was 230 (58%), water management was 86 (21%), and harvesting, threshing and storage management was 175 (44%). The highest adoption of all these practices were observed in the state of Madhya Pradesh, except in the case of water management for which there were no adopters. The lowest adoption of all these practices was observed in the state of Rajasthan (for more details, see Appendix A.5.1-A5.8).

5.3.1.2 Adoption of Agronomic Practices-Green Gram

The number of adopters of agronomic practices pertaining to climate requirement for cultivation and sowing time was 308 (77% of the total sample), fertiliser and manure application was 213 (53%), seed management was 140 (35%), plant management was 222 (55%), water management was 248 (62%), and harvesting, threshing and storage management was 318 (79%) (see Appendix A.6 in supplementary materials). The highest adoption of agronomic practices pertaining to climate management and sowing time was observed in the state of Maharashtra while the lowest was observed in Madhya Pradesh. The highest adoption of soil management was observed in Madhya Pradesh, whereas the lowest was in Maharashtra. In the case of seed management, the highest adoption was observed in Rajasthan whereas the lowest was observed in Andhra Pradesh, for plant the highest was in Rajasthan whereas the lowest was in Madhya Pradesh. The highest adoption of water management practices was observed in Rajasthan, whereas the lowest was in Madhya Pradesh. Maharashtra had the highest adoption of agronomic practices pertaining to harvesting, threshing and storage, while Andhra Pradesh was characterised by the lowest adoption rates as per the survey findings (see Appendix A.9).

5.3.2 Explanatory Variables

A number of studies have identified significant determinants of the adoption of agronomic practices and agriculture technology which have been classified broadly under (a) farmer characteristics such as age, size of the household, access to credit, education, membership of an association (b) farm structure and management, for example labour, family labour, farm size and (c) knowledge, information and resource availability which includes institutional factors such as access to agriculture extension, off-farm activities and distance to market (Ghimire et al., 2015, Witcombe et al. 2017; Sanchez-Toledano et al., 2018).

Age and the experience of the farmer has been highlighted as an important factor in deciding the adoption in several studies (Feder et al., 1985; Uaiene, (2011); Teklewold et al., 2013; Ogada et al, 2014; Manda et al., 2016; Kassiet et al., 2015). One set of studies postulate a positive relationship between age/ experience and adoption decisions, (Meshram et al, 2012; Kassie et al., 2013), while the other set of studies indicate a negative or intermediate relationship between age/experience and adoption (Teklewold et al., 2013; Manda et al., 2016). In our analysis, we include **years of experience in farming** to capture the relationship between experience in agriculture and adoption. The average years of experience in our sample was twenty-six years for black gram farmers and 24 years for green gram farmers.

Another important household characteristic is the **education of the household**. Several studies find a positive relationship between education of the household members and adoption decisions (Moser and Barrett, 2003; Pender and Gebremedhin, 2008; Langyintuo and Mungoma, 2008; Haldar et al., 2012). However, some studies have found a negative relationship between education and technology adoption decisions (Nkomoki et al., 2018). The average years of education in our sample was 7.6 for black gram farmers and 6 for green gram farmers.

In several technology adoption studies, the **household size** is used as a proxy to capture labour endowment (Pender and Gebremedhin, 2008; Khonje et al., 2018). The average household size for both black gram and green gram households in our sample was 5.

Similar to existing studies, the household's wealth in this study is proxied using the **farm size** owned by the farmer and the **household income** (Kassie et al., 2015; Khonje et al., 2018; Nkomoki et al., 2018). Previous studies have found a negative and significant relationship between farm size and the intensity of adoption of new technologies (Langyintuo and Mungoma, 2008; Kassie et al., 2015). However, there is also a view that farmers with larger farms will be more willing to devote portions of the land to an untried variety compared with those with smaller ones (Adesina and Zinnah, 1993). Also, the benefits accruing from the adoption of a sustainable agricultural practice is more for farmers with larger large land holdings (Quinion et al., 2010; Nkomoki et al., 2018). The average farm size in our sample for black gram was 5 acres (2.02 hectares) and 7 acres (2.83 hectares) in the case of green gram. Therefore, a majority of farmers in our sample were small and semi-medium farmers. The average household income for both categories of farmers were around Rs. 2.2 lakhs.

Another important factor that influences the adoption decision as per the literature is **agricultural extension services** (Langyintuo and Mungoma, 2008; Kassiet et al., 2015; Manda et al., 2016). Since agronomic practices are knowledge-based innovations, extension services play even a greater role in wider adoption (Noltze et al., 2012; Varma, 2018). Around 87 percent of black gram cultivators and 81 percent of green gram cultivators had access to extension services. We give a dummy variable equal to 1 for those who have access to extension services.

Access to quality seed varieties can also play a significant role in adoption decisions in general (Langyintuo and Mungoma, 2008; Mazvimavi & Twomlow, 2009; Shiferaw et al., 2015), and in the case of pulses in particular. We use three variables to capture the source and access of seed; whether the seed source is the farmers' own stock from last year, whether it is sourced from private sources, and whether it is sourced from government agencies. Similar to extension services, we give a dummy variable equal to 1 for those who have access to each source. In our sample for black gram farmers, 49 percent of farmers were using seeds from their own stock in the previous year, 37 percent of farmers were procuring seeds from private sources, and only .06 percent of farmers were procuring seeds from government sources. The corresponding figures for green gram farmers were 47 percent, 21 percent and 28 percent respectively.

Market access also has a huge bearing on the transaction cost in accessing information and technology (Kassie et al., 2015; Varma, 2018). Drawing from existing studies, we consider the **distance to main market** as a proxy for market access. The average distance for households to the main market in our sample was 12.6 km for black gram farmers, and 14 km for green gram farmers.

The literature has recognised the importance **of access to off-farm and non-farm employment** opportunities in influencing the adoption decision; the impact can be either positive or negative in the adoption of sustainable agricultural and natural resource management practices (Lee, 2005). There are studies that shows both a positive (Mutyasira et al., 2018) as well as a negative impact of access to off-farm activities on the adoption decisions (Beshir, 2014). We give a dummy variable equal to 1 for those who have access to off-farm activities and income. Around 32 percent of households from the black gram sample had access to off-farm activities whereas around 42 percent of green gram farmers had access to off-farm activities.

It has been observed that farmer's membership in **farmer producer organisations** have a positive relationship with the adoption decisions (Quinion et al., 2010; Barrett et al., 2004; Khonje et al., 2015; Manda et al., 2016; Mutyasira et al., 2018; Varma, 2018). In our study we select the membership in input supply cooperatives as a proxy for membership. A dummy variable equal to one is assigned to those who have membership. In our sample, 62 percent of blackgram farmers and 50 percent of green gram farmers had membership in input supply cooperatives.

Studies on agricultural technology adoption have explicitly incorporated the importance of **credit access** in technology adoption (Simtowe, and Zeller,2006; Shiferaw et al., 2015; Gupta et al., 2019). The present study incorporates variables such as knowledge of Kisan Credit Card (KCC)[16] and loan availed under KCC as the variables to capture the knowledge and access to credit. For both the variables, a dummy equal to 1 is given for those who have knowledge and availed loan under KCC. In our black gram sample, 89 percent of farmers responded yes to have knowledge about KCC, while in the green gram sample, 72 percent of farmers had knowledge about KCC. 59 percent of black gram farmers and 53 percent of green gram farmers had availed a loan under the KCC scheme.

Risk and uncertainty have also been highlighted by numerous studies (Johnson and Vijayaraghavan, 2011; Barham et al., 2014; Brick and Visser, 2015; Kemeze et al., 2020; Sagemuller and Musshof, 2020) as a factor influencing adoption. Farmers' attitude towards risk play a crucial role in deciding whether to adopt a new agricultural technology or not (Hardaker et al., 2015). To capture this, we include variables such as experience of crop failure in the last 5 years and access to crop insurance in our model. Crop failure will increase the farmers' aversion towards risk and farmer may or may not adopt a new technology. The access to crop insurance however can help farmers to reduce risk, and thereby may encourage the technology adoption. For both the variables we use a dummy variable equal to 1 for those who have experienced crop failure in the last 5 years and those who have access to crop insurance. In our sample 56 percent of black gram farmers and 93 percent of green gram farmers have experienced at least one crop failure in the last 5 years. Further, 87 percent of black gram farmers and 73 percent of green gram farmers had access to crop insurance.

The **information pertaining to MSP** is also added as a variable in the access to MSP model. In our sample, 47 percent of black gram farmers and 54 percent of green gram farmers avail MSP. Around 43 percent of black gram farmers and 73 percent of green gram farmers had received information pertaining to MSP from newspapers. Similarly, around 29 percent of black gram farmers and 57 percent of green gram farmers had received information pertaining to MSP from the radio.

[16] The Kisan Credit Card (KCC) scheme was introduced by the Government of India in the year 1998 for issue of Kisan Credit Cards to farmers on the basis of their land holdings. The purpose of such a scheme was to provide adequate and timely credit support with flexible and simplified procedures.

Table 5.1: Variable Definitions

Variable	Definition
Education	Number of years of education of the respondent farmer
Household size	Number of the family members in the household including children.
Farm Size	Total area under farming in acres
Years of Experience in Farming	Number of years of experience of the respondent in farming
Access to Off Farm/non-farm Activities	Dummy variable = 1 if the respondent had access to off-farm/non-farm activity, = 0 otherwise
Experience of Crop Failure	Dummy variable = 1 if the respondent has experienced crop failure in the last 5 years, = 0 otherwise
Member of Input Supply Cooperatives	Membership of any of the family member in input supply cooperatives, dummy variable = 1 if any of the family member has membership in any input supply cooperative, = 0 otherwise
Knowledge of Kisan Credit Card (KCC)	Dummy variable = 1 if the household has knowledge of KCC, = 0 otherwise
Availed Loan under KCC	Dummy variable = 1 if the household has availed a loan using the KCC, = 0 otherwise
Have Crop Insurance	Dummy variable = 1 if the household has crop insurance, = 0 otherwise
Ln Distance	Log Distance from the household to nearest procurement centre in kilometres
Availing MSP	Dummy variable = 1 if the household is availing the minimum support price for black gram/green gram, = 0 otherwise
MSP info from Newspaper	Dummy variable = 1 if the source of information about MSP is the newspaper, = 0 otherwise
MSP info from Radio	Dummy variable = 1 if the source of information about MSP is the radio, = 0 otherwise
Ln Household Income	Log of annual family income (INR)
Seed Source Own Stock from last Year	Dummy variable = 1 if the source of seed is the household's own stock from the previous year, = 0 otherwise
Seed Source Private Stock	Dummy variable = 1 if the source of seed is private, = 0 otherwise
Seed Source Government	Dummy variable = 1 if the source of seed is government, = 0 otherwise
Contact with Government Extension Agents	Dummy variable = 1 if the household has contact with government extension agents, = 0 otherwise

5.4 Results and Discussion

5.4.1 Factors Affecting the Availing of MSP and the Impact of MSP on Adopting Agronomic Practices-The Case of Black Gram

The results of the first set of models and second set of models are presented in Table 5.2 and 3 respectively. The results show that the education (number of years), membership in input supply co-operatives, knowledge about KCC, distance to main market and information about MSP from the radio increased the likelihood of a farmer availing MSP. Educated farmers had a 1 percent greater probability to avail MSP. Similarly, membership in input supply-cooperatives increased the probability to avail MSP by 23-24 percent. The farmers who had knowledge about KCC had around 12-17 percent higher probability to avail MSP. The MSP information received from radio increased the probability to avail MSP by 31-32 percent Interestingly, the distance from main market increased the probability to avail MSP by 10- 12 percent. The field level observations showed that farmers who have a greater quantity to sell will travel to the far-off market, and as a result have a greater possibility to avail MSP. Household income reduced the probability to avail MSP by 3-4 percent.

In the second model, the results supported our hypothesis that MSP has an impact on the adoption of agronomic practices. The probability to adopt most of the agronomic practices increased when farmers avail MSP for black gram. The only exception for this was in the case of adoption of water management practices. When farmers avail MSP for black gram, the probability to adopt climate management practices increased by 28 percent, the probability to adopt soil management practices increased by 18 percent, the probability to adopt seed management practices increased by 39 percent, and the probability to adopt practices pertaining to harvesting, threshing and storage increased by 35 percent.

Apart from MSP, access to off-farm activities increased the probability of adoption of various agronomic practices. Due to the access to off-farm activities, the probability for a farmer to adopt the following agronomic practices increased in the following manner; climate and soil management practices by 21-22 percent, seed management by 17 percent, plant management by 28 percent and harvesting, threshing and storage by 23 percent. As expected, an experience of crop failure in the last 5 years (in terms of numbers) reduced the probability to adopt almost all the agronomic practices except water management. Education had a positive impact only on the plant management by increasing its probability of adoption by 1 percent. While membership in input supply co-operatives increased the likelihood to avail MSP, it reduced the likelihood to adopt most of the agronomic practices such as climate management, soil management, seed management and harvesting, threshing and storage.

The results from the probit and ordered probit models also showed that the availing of MSP increased the probability to adopt all agronomic practices by 100 percent. Like the previous models, the access to off-farm activities increased the probability to adopt all agronomic practices, which is in line with studies such as Muyasira et al., which indicate a positive impact on adoption, whereas the experience of crop failure and loan availed from KCC reduced the probability to adopt all the practices (see Table 4). Our findings related to crop failure are in line with the findings of Ghadim et al., (2005) and Begho, (2021), and show that risk is reducing the probability to adopt agricultural technologies.

The education of the household also increased the likelihood of adoption of agronomic practices. Here, our results are in line with several existing studies (Moser and Barrett, 2003; Pender and Gebremedhin, 2008; Langyintuo and Mungoma, 2008; Haldar et al., 2012).

Table 5.2: Probit Models for Black Gram

Variables	Climate	Soil	Seed	Plant	Water	Harvesting, Threshing, Storage
Availing MSP						
Years of experience in farming	.002 (.001) *	.001 (.001)	.001 (.001)	.001 (.001)	.001 (.001)	.001 (.001)
Years of education	**.014(.003) *****	**.013(.003) *****	**.014 (.003) *****	**.013(.003) *****	**.012(.004) *****	**.014(.003) *****

Variables	Climate	Soil	Seed	Plant	Water	Harvesting, Threshing, Storage
Number of family members	.001 (.006)	.000 (.006)	.001(.006)	.001 (.006)	.001 (.006)	-.001 (.006)
Farm Size (Acres)	.002 (.002)	.002 (.002)	.001 (.002)	.002 (.002)	.001 (.002)	.001 (.002)
Access to Off Farm Activities	.048 (.044)	.052 (.044)	.046 (.043)	.066 (.045)	.060 (.044)	.046 (.044)
Member of Input Supply Cooperatives	**.228 (.037) *****	**.233 (.037) *****	**.231(.036) *****	**.240(.036) *****	**.243 (.044) *****	**.244 (.035) *****
Experience of Crop Failure	-.057 (.044)	-.050 (.046)	-.047 (.043)	-.055 (.046)	-.050 (.049)	-.072 (.047)
Knowledge of Kisan Credit Card	**.145 (.059) ****	**.155 (.060) *****	**.166 (.060) *****	**.150 (.058) ****	**.122 (.062) ****	**.172 (.060) *****
Availed Loan under KCC	-.011 (.038)	-.019 (.038)	-.007 (.037)	-.017 (.038)	-.015 (.032)	-.032 (.038)
Have Crop Insurance	.020 (.056)	.017 (.057)	.017 (.057)	.004 (.058)	.004 (.056)	.024 (.057)
Ln Distance	**.124 (.029) *****	**.113 (.030) *****	**.122 (.029) *****	**.115 (.030) *****	**.118 (.030) *****	**.102 (.031) *****
MSP from Newspaper	.034 (.043)	.060 (.042)	.062 (.039)	.064 (.042)	.061 (.041)	.050 (.041)
MSP from Radio	**.333 (.062) *****	**.312 (.062) *****	**.308 (.061) *****	**.307 (.063)**	**.322 (.070) *****	**.310 (.062) *****
Ln Household Income	**-.036 (.020) ***	**-.043 (.020) *****	**-.043 (.019) ****	**-.044 (.019) ****	**-.042 (.020) ****	**-.037 (.019) ***
Constant	-3.21 (1.82) *	-2.42 (1.78)	-2.77 (1.81)	-2.28 (1.852)	-2.16 (1.82)	-2.69 (1.807)
Agronomic Practice						
Years of Experience in Farming	.000 (.001)	-.001(.002)	.000 (.001)	.000 (.001)	-.000 (.001)	.000 (.001)
Years of Education	.010 (.006) *	.010(.006)	.009 (.006)	.015 (.006) **	.000 (.006)	-.003 (.006)
Number of Family Members	-.010 (.009)	-.007(.008)	-.008 (.008)	-.013 (.008)	-.017 (.009) *	-.004 (.008)
Farm Size (Acres)	.008 (.005)	.002(.003)	-.002 (.003)	.009 (.008)	.001 (.003)	-.001 (.002)
Access to Off Farm Activities	**.212 (.065) *****	**.224(.062) *****	**.172 (.055) *****	**.279 (.071) *****	.047 (.066)	**.235 (.056) *****
Member of Input Supply Cooperatives	-.143 (.065) **	-.233(.065) ***	-.336 (.067) ***	-.066 (.073)	-.087 (.054)	-.201 (.067) ***
Experience of Crop Failure	-.103 (.049) **	-.077(.046) *	-.111 (.042) ***	-.099 (.048) **	-.007 (.042)	-.162 (.040) ***
Knowledge of Kisan Credit Card	-.100 (.073)	.231 (.083) **	.168 (.075) **	.058 (.072)	.123 (.066) *	-.041 (.074)

Variables	Climate	Soil	Seed	Plant	Water	Harvesting, Threshing, Storage
Availed Loan under Kisan Credit Card	-.117 (.050) **	-.165(.052) ***	-.068 (.048)	-.100 (.052) *	-.020 (.045)	.032 (.048)
Have Crop Insurance	.127 (.071) *	-.009(.071)	-.100 (.069)	.014 (.062)	-.008 (.062)	.031 (.067)
Ln Distance	.006 (.037)	-.091(.034) **	-.044 (.032)	.160 (.034) ***	.166 (.027) ***	-.037 (.032)
Ln Household Income	-.006 (.027)	.014(.023)	.005 (.024)	-.031 (.027)	.003 (.025)	.008 (.024)
Availing MSP for Black Gram	**.279 (.087) *** **	**.184(.107) ***	**.391 (.079) *** **	.121 (.137)	**-.353 (.065) *** **	**.355 (.085) *** **
Seed Source Own Stock from Last Year	.099 (.070)	**.235(.080) *** **	**.173 (.069) ** **	**.141 (.070) ** **	.005 (.061)	**.165 (.083) ** **
Seed Source Private Stock	-.171 (.069) **	-.044(.083)	-.148 (.071) **	-.112 (.067)	-.066 (.058)	-.084 (.085)
Seed Source Government or Others	.107 (.091)	.302(.098) ***	.073 (.093)	.036 (.091)	.063 (.077)	.137 (.103)
Contact with Government Extension Agents	**.089 (.051) ***	**.175(.054) *** **	**.139 (.050) *** **	**.180 (.046) *** **	.019 (.046)	**.140 (.053) *** **
Constant	-.231 (1.41)	-1.63 (1.46)	-.770 (1.45)	-1.49 (1.59)	-2.47 (1.69)	-1.113 (1.45)
LR chi ^{2}(31)	526.57	575.55	600.1	540.69	488.16	593.54
Prob > chi ^{2}	0.000	0.000	0.000	0.000	0.000	0.000
Number of Observations	390	390	390	390	390	390

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. The average marginal effects are reported and standard errors are in parentheses

Table 5.3: Probit and Ordered Probit Models for Black Gram

Variable	Co-efficient
Availing MSP for Black Gram	
Years of experience in farming	.002(.001)*
Years of education	.014(.004)***
Number of family members	.001(.006)
Farm Size (Acres)	.002(.002)
Access to Off Farm Activities	.049(.043)
Member of Input Supply Cooperatives	.230(.037)***
Experience of Crop Failure	-.054(.045)
Knowledge of Kisan Credit Card	.152(.060)**
Availed Loan under KCC	-.016(.038)
Have Crop Insurance	.023(.058)

Variable	Co-efficient
Ln Distance	.122(.030)***
MSP from Radio	.321(.062)***
MSP from newspaper	.047(.042)
Ln household Income	-.038(.020)**
Constant	-6.31(.984)
Total Black Gram	
Years of Experience in Farming	.001(.006)
Years of Education	.038(.022)*
Number of Family Members	-.058(.029)**
Ln Farm Size (Acres)	.009(.011)
Access to Off Farm Activities	1.37(.219)***
Member of Input Supply Cooperatives	-1.03(.217)***
Experience of Crop Failure	-.645(.164)***
Knowledge of Kisan Credit Card	.297(.259)
Availed Loan under Kisan Credit Card	-.425(.171)**
Have Crop Insurance	.133(.244)
Ln Distance	.299(.122)**
Availing MSP for Black Gram	1.003(.277)***
Seed Source Own Stock from Last Year	.828(.265) ***
Seed Source Private Stock	-.830(.260)***
Seed Source Government	.663(.349)*
Ln household Income	.037(.092)
Contact with Government Extension Agents	.900(.194)***
LR chi2(35)	616.14
Prob>chi2	0.000
No of Observations	390

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. The average marginal effects are reported and standard errors in parentheses

5.4.2 Factors Affecting the Availing of MSP and the Impact of MSP on Adopting Agronomic Practices-The Case of Green Gram

The results of the first set of models and second set of models are presented in Tables 4 and 5 respectively. The results from green gram were similar to black gram. The results showed that education, access to off farm activities, membership in input supply co-operatives, information from radio and newspaper and the distance from the main market increased the likelihood of availing MSP, whereas experience in farming, crop failure and crop insurance reduced the likelihood of availing MSP. Education of the farmer increased the probability to avail MSP by 2 percent, access to off farm activities by 14-16 percent, membership in input supply cooperatives by 33-34 percent, distance by 6 percent, information received from radio by 15 percent to 22 percent, information from newspaper by 10-14 percent. The risk factor-crop failure reduced the probability to avail MSP. It could be that higher numbers of crop failure are adversely affecting the yield, and therefore farmers are unable to avail MSP. Receiving insurance for the crop failure also is adversely affecting the availing of MSP. Perhaps crop insurance is helping farmers to mitigate the risk and crop loss, and as a result MSP is becoming redundant. Like in the case of black gram, distance increased the probability to avail MSP for green gram. As mentioned already, this could be due to the greater marketing opportunities available to farmers who are close to the market, whereas those who are far from the market are left with only the government's support price.

As hypothesised, the availing of MSP for green gram had a significant and positive impact in adopting most of the agronomic practices such as soil, seed, plant, and water management practices. The availing of MSP increased the probability to adopt soil management practices by 45 percent, seed management by 37 percent, plant management by 48 percent and water management by 38 percent (see Table 5.4).

The results from the probit and ordered probit models also supported our hypothesis that MSP can have an impact on the adoption of agronomic practices. The availing of MSP increased the probability to adopt all agronomic practices by 130 percent (see Table 5.5). The probit and ordered probit model results for MSP were similar to the probit models. Experience in farming, insurance and crop failure reduced the likelihood of availing MSP whereas education, membership in input supply cooperatives, access to off-farm activities, distance and information received from newspaper and radio increased the likelihood of availing MSP.

As far as the adoption of agronomic practices are concerned, apart from the availing of MSP, experience in farming and contact with extension agents increased the likelihood of adopting agronomic practices. Variables such as education and membership in input supply co-operatives reduced the likelihood of adopting agronomic practices.

Table 5.4: Probit Models for Green Gram

Variables	**Climate**	**Soil**	**Seed**	**Plant**	**Water**	**Harvesting, Threshing and Storage**
Availing MSP						
Years of Experience in Farming	-.003** (.001)	-.002* (.001)	-.003** (.001)	-.002* (.001)	-.002* (.001)	-.003* (.001)
Years of Education	.015** (.005)	.018*** (.005)	.018*** (.005)	.018*** (.005)	.018*** (.005)	.015*** (.005)
Household Size	.001 (.007)	-.000 (.006)	.001 (.007)	-.002 (.007)	-.001 (.007)	.001 (.007)
Farm Size (Acres)	-.002 (.003)	-.002 (.003)	-.003 (.003)	-.002 (.003)	-.002 (.008)	-.002 (.003)
Access to Off Farm Activities	.156*** (.038)	.149*** (.038)	.149*** (.038)	.139*** (.037)	.147*** (.038)	.157*** (.038)
Member of Input Supply Cooperatives	.337*** (.037)	.326*** (.035)	.329*** (.036)	.340*** (.035)	.336*** (.036)	.338*** (.037)
Experience of Crop Failure	-.104*** (.029)	-.111*** (.029)	-.104*** (.029)	-.108*** (.028)	-.106*** (.029)	-.107*** (.030)
Knowledge of Kisan Credit Card(KCC)	.016 (.052)	.015 (.048)	.007 (.049)	.024 (.048)	.017 (.050)	.014 (.051)
Availed Loan under KCC	.027 (.045)	.008 (.043)	.027 (.043)	.008 (.044)	.012 (.044)	.027 (.043)

Variables	Climate	Soil	Seed	Plant	Water	Harvesting, Threshing and Storage
Have Crop Insurance	-.107** (.048)	-.112** (.046)	-.103** (.047)	-.112** (.047)	-.112** (.048)	-.107** (.048)
Ln Distance	.056*** (.019)	**.056*** (.018)**	.056** (.019)	.058*** (.018)	**.056*** (.018)	.055*** (.019)
MSP from Radio	.157** (.057)	.217*** (.053)	**.196*** (.056)**	.202*** (.053)	.187*** (.053)	.149** (.056)
MSP from Newspaper	.126** (.052)	.099** (.049)	**.121** (.049)**	.139*** (.047)	.135*** (.047)	.134** (.049)
Ln household Income	.012 (.028)	.013 (.028)	.018 (.029)	.013 (.028)	.009 (.028)	.009 (.029)
Constant	-2.78 (2.14)	-2.89 (2.13)	-3.293 (2.163)	-3.06 (2.12)	-2.66 (2.14)	-2.55 (2.16)
Agronomic Practices						
Years of Experience in Farming	.002 (.002)	.005** (.002)	.001 (.001)	.001 (.002)	.002 (.002)	.002 (.002)
Years of Education	.021** (.007)	-.011* (.006)	-.015** (.005)	-.008 (.007)	-.012* (.007)	.010 (.007)
Household Size	-.006 (.009)	.010 (.010)	**.022*** (.007)**	.010 (.009)	.004 (.010)	-.003 (.008)
Farm Size (Acres)	.002 (.004)	-.004 (.004)	-.000 (.004)	.000 (.004)	.001 (.004)	.003 (.004)
Access to Off Farm Activities	-.025 (.072)	.000 (.056)	.058 (.051)	.018 (.057)	.003 (.062)	.102 (.068)
Member of Input Supply Cooperatives	.044 (.108)	-.311** (.064)	-.051 (.063)	-.177** (.073)	-.176** (.078)	.081 (.091)
Experience of Crop Failure	-.068 (.048)	.045 (.040)	-.019 (.037)	.048 (.039)	.054 (.042)	-.030 (.046)
Knowledge of Kisan Credit Card(KCC)	-.065 (.069)	.029 (.064)	.017 (.063)	-.026 (.065)	-.020 (.070)	-.007 (.069)
Availed Loan under KCC	.002 (.056)	-.007 (.055)	.002 (.046)	.033 (.055)	.039 (.059)	-.033 (.056)
Have Crop Insurance	-.002 (.060)	.014 (.057)	.001 (.058)	-.009 (.059)	-.008 (.063)	.100* (.059)
Ln Distance	-.011 (.020)	-.074*** (.019)	.018 (.016)	-.001 (.021)	-030 (.021)	-.005 (.020)
Availing MSP for Green Gram	-.167 (.180)	.446*** (.072)	.366*** (.072)	.483*** (.071)	.385*** (.092)	-.191 (.145)
Seed Source Own Stock from last Year	-.286** (.140)	.266** (.093)	.206** (.098)	**.204** (.097)**	.167* (.100)	-.130 (.110)
Seed Source Private Stock	-.218 (.145)	**.228** (.097)**	.006 (.103)	.270** (.101)	.173* (.104)	-.135 (.114)
Seed Source Government or Others	-.039 (.148)	-.125 (.100)	-.066 (.100)	-.120 (.102)	-.152 (.103)	.075 (.117)

Variables	Climate	Soil	Seed	Plant	Water	Harvesting, Threshing and Storage
Ln household Income	-.041 (.039)	-.015 (.037)	-.080** (.033)	-.034 (.037)	.013 (.039)	-.028 (.039)
Contact with Government Extension Agents	.086 (.063)	.064 (.054)	.155** (.064)	.081 (.056)	.042 (.060)	-.019 (.062)
Constant	3.61* (2.00)	-.399 (1.83)	1.869 (2.08) **	.038 (1.71)	-1.07 (1.68)	2.14 (1.91)
LR chi2(31)	367.19	508.06	484.59	435.36	422.97	352.92
Prob>chi2	0.000	0.000	0.000	0.000	0.000	0.000
No.of observations	399	399	399	399	399	399

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. The average marginal effects are reported and standard errors are in parentheses

Table 5.5: Probit and Ordered Probit Models for Green Gram

Variable	Co-efficient
Availing MSP for Green Gram	
Years of experience in farming	-.003 (.001)**
Years of education	.020(.005) ***
Number of family members	-.000(.007)
Ln Farm Size (Acres)	-.002(.002)
Access to Off Farm Activities	.134(.037)***
Member of Input Supply Cooperatives	.324(.034)***
Experience of Crop Failure	-.111(.028)***
Knowledge of Kisan Credit Card	.033(.048)
Availed Loan under KCC	-.003(.043)
Have Crop Insurance	-.120(.046)**
Ln Distance	.057(.018)***
MSP from Radio	.253(.056)***
MSP from newspaper	.113(.045)**
Ln household Income	.017(.028)
Constant	-3.38(2.14)
Total Green Gram	
Years of Experience in Farming	.009(.005)**
Years of Education	-.030(.018) *
Number of Family Members	.038(.024)
Ln Farm Size (Acres)	.001(.010)
Access to Off Farm Activities	.068(.158)
Member of Input Supply Cooperatives	-.745(.189)***

Variable	Co-efficient
Experience of Crop Failure	.096(.107)
Knowledge of Kisan Credit Card	-.060(.183)
Availed Loan under Kisan Credit Card	.100(.151)
Have Crop Insurance	.044(.164)
Ln Distance	-.079(.054)
Availing MSP for Green Gram	1.30(.222)***
Seed Source Own Stock from Last Year	.483(.262)*
Seed Source Private Stock	.382(.273)
Seed Source Government or Others	-.405(.266)
Ln household Income	-.131(.101)
Contact with Government Extension Agents	.296(.158)*
LR chi2(37)	403.58
Prob>chi2	0.000
No of Observations	399

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. The average marginal effects are reported and standard errors in parentheses

5.5 Conclusion and Policy Implications

This chapter examines the role of MSP in influencing the adoption of various agronomic practices by black gram and green gram farmers in India.

Extant literature suggests that several pulses farmers are exposed to the vagaries of market and quite often sell their crop below 20 percent to 30 percent of MSP (Reddy, 2021). The lack of effective procurement under MSP, in a situation wherein farmers are already exposed to production and price risk are highlighted as the main reasons for inadequate incentives for farmers to cultivate these crops (Sekhar and Bhatt, 2012; Thomas et.al., 2013). Also, there is evidence that MSP backed procurement operations have encouraged technological adoption and productivity of the two important cereal crops-paddy and wheat (Reddy, 2021). The procurement of pulse crops such as black gram and green gram is negligible as compared to cereals such as wheat and paddy. A survey conducted by the National Sample Survey Organization (NSS Report 2012-13) showed that among 1000 crop producing households, the awareness of MSP was only 5.7 percent for black gram farmers and 9.8 percent for green gram farmers, and the percentage of farmers who sold their crop at MSP was even lower. A study conducted by NITI Aayog in 2016 also highlighted the poor awareness level among farmers and lack of effective procurement under MSP (Subramanian, 2016).

The results from the availing of MSP model showed that information about MSP received from radio was more important than newspaper and this was especially true in the case of black gram farmers. Similarly, crop failure and crop insurance resulted in the lowering of availing of MSP. This could be due to the insurance coverage that the farmers receive during crop loss, or the lack of enough crops to be sold when there is a crop loss. As expected, membership in input supply co-operatives, education, knowledge of KCC and access to off-farm activities generally increased the likelihood of availing MSP. Household income lowered the probability in the case of black gram farmers and shows the importance of MSP as a risk mitigating strategy. for resource poor farm households, especially when they experience crop failure.

Availing of MSP came out to be statistically significant and positive in increasing the likelihood of adopting 4 out of 6 agronomic practices in the probit models for both the crops. Availing of MSP came out to be positive and significant in increasing the likelihood of all agronomic practices, when we take these practices together, in both the cases. The results show that those farmers who avail MSP are more enthusiastic in adopting agronomic practices which are perceived to be yield enhancing. The results support the argument that price-stabilisation policies would encourage farmers to adopt yield enhancing technologies (Kim et al.,1992). In conclusion, the chapter highlights that MSP combined with effective procurement can increase the adoption of agronomic practices. Thus, appropriate actions need to be taken to increase the awareness of MSP among farmers, scale up the procurement operations, and make the procurement more effective in order to encourage the uptake of recommended yield-enhancing agronomic practices for black gram and green gram.

CHAPTER 6

IMPACT OF ADOPTION OF AGRONOMIC PRACTICES ON YIELD – THE CASE OF BLACK GRAM

6.1 Introduction

The present chapter analyses the impact of adoption of various agronomic practices on the crop yield. As per extant studies, a number of factors have contributed to the low productivity of black gram; these include erratic or below normal monsoons which lead to moisture stress at phases of critical growth, biotic stresses such as root rot, sucking insect pests and abiotic stresses such as low temperature, salt stress, waterlogging across seasons, with the technological breakthrough in terms of crop protection to decrease the incidence of such stresses being yet to be realised (Reddy, 2010; Directorate of Pulses Development, 2016). The genetic potential for high yields is also limited, and as a result the gap between actual and potential yield remains to be very high. Additionally, studies have noted that supply side impediments include inadequate institutional support, non-availability or low distribution of location specific recommended high varieties, lack of price security and scientific storage facilities etc (Thomas et al., 2013).

In India, there is limited empirical evidence on the determinants of adoption of agronomic practices. This is especially true for agronomic practices specifically recommended for black gram and/or their impacts on yield received by farmers. Additionally, there are hardly any studies analysing the factors that affect the decisions to adopt individual as well as the combinations of agronomic practices and their impact using a multinomial selection framework. This chapter examines specific factors that affect the decision to adopt major practices—(a) seed management, (b) soil management and (c) plant management—as well as the combination of these practices and their impact on the yield received. The chapter makes use of the multinomial endogenous treatment effects model that is useful in addressing selection bias due to observed and unobserved heterogeneity (Deb and Trivedi, 2006b: Manda et al.,2015: Varma, 2019). Such a framework is quite helpful in incorporating the interdependency between different types of agronomic practices.

The next section (6.2) presents the conceptual and econometric framework of the study. Section 6.3 discusses the variables and hypothesis, followed by Section 6.4 which presents the empirical results. The last section is the conclusion.

6.2 Conceptual and Econometric Framework

It has been widely recognised in the literature that adoption of any agricultural technologies is not a simple binary decision (Varma, 2019). This is especially true in the case of agronomic practices which are mainly natural resource management practices, and they are mostly adapted to various situations. The flexibility in adoption encourages farmers to adopt only a part of the practise or to apply a combination of the practices (Smale et al., 1995; Varma, 2018). Recently empirical analysis has become increasingly multivariate and attempts to model the inter-relationship between each practice (Teklewold et al, 2013; Manda et al., 2015; Varma, 2019).

By treating the adoption of various agronomic practices as a choice of over eight combinations comprising of three major principles of soil management, plant management and seed management, the chapter utilises the multinomial endogenous treatment effects model to understand the adoption and its impact. The generation of mutually exclusive combinations helped us in coming up with 8 groups which include (a) non-adopters, (b) seed management, (c) plant management, (d) soil management, (e) plant management plus seed management, (f) soil management plus plant management, (g) soil management plus seed management and (h) soil management plus plant management plus seed management. On the basis of this, in our sample, we observed that 188 farmers were non-adopters, 2 farmers followed only the practices of seed management, 7 farmers followed only the practice of soil management, 29 farmers followed only the practice of plant management, 23 farmers followed both the practices of plant management and seed management, 9 farmers followed both the practices of soil management and seed management, 40 farmers followed both the practices of soil management and plant management, and 92 farmers followed the practices of soil management, plant management and seed management.

Since the focus of the present study is to analyse the adoption of combinations of various agronomic practices and its impact on yield, the model may suffer from endogeneity as adoption decisions are likely to be influenced both by observed and unobservable characteristics that may be correlated with the outcome variable (Kassie et al., 2014). In such a situation, an analysis using a joint framework is quite useful as it might be helpful in separating the outcomes of adoption from the factors influencing the adoption. Therefore, we adopt a multinomial endogenous treatment effects model proposed by Deb and Trivedi (2006a). Thus, we are able to analyse the impact of individual practices and a combination of practices and its impact while capturing the interactions between adoptions of alternative practices (Wu and Babcock, 1998; Mansur et al., 2008).

6.2.1 Model Specification

There are two stages in the multinomial endogenous treatment effects model. The first stage of the model will analyse the factors affecting the farmer's selection of one of the eight bundles mentioned above (Deb and Trivedi 2006a,b; Manda et al., 2015, Varma, 2019). Assuming that the farmer i will try to maximise the utility U associated with the kth practice, the indirect utility associated with the k^{th} agronomic practice, k = 0, 1, 2 …, k for farmer i can be written as:

$$U_{ik}^{*} = X_i' \beta_k + \sum_{m=1}^{k} \delta_{km} l_{ik} + \eta_{ik} \quad (1)$$

Where X_i denotes the vector of explanatory variables that are relevant at the farm level decision making and β_k is the corresponding parameters to be estimated. η_{ik} are independently and identically distributed error terms. Also U_{ik}^{*} includes a latent factor l_{ik} that incorporates unobserved characteristics common to farmer i's treatment choice and outcome variables. The outcome variables in our analysis are soil management, plant management and seed management practices, whereas the unobserved characteristics that may have an impact on outcome variables are the enterprising nature of farmers, management and technical abilities of farmers or any institutional factors (Manda et al., 2015). The l_{ik} are assumed to be independent of n_{ik}. Following Deb and Trivedi (2006b), let $k = 0$ denote the control group and $U_{i0}^{*} = 0$. The control group in our analysis are the non-adopters of agronomic practices.

Let k_j be binary variables representing the observed treatment choice where $k_i = k_{i1}, k_{i2} \ldots k_{ij}$. Also let $l_i = l_{i1}, l_{i2} \ldots l_{ij}$, the probability of treatment therefore can be written as:

$$P_r(k_i | \mathrm{x}_i l_i) = g(x_i'\beta_1 + \delta_1 l_{i1,} x_i'\beta_2 + \delta_2 l_{i2,} \ldots \ldots \ldots x_i'\beta_j + \delta_j l_{ij} \quad (2)$$

In the above equation, g is a multinomial probability distribution. Like Deb and Trivedi (2006b), let us also assume that g has a mixed multinomial logit (MMNL) structure in the following form:

$$P_r(k_i|x_i l_i) = \frac{\exp(x_i'\beta_j+\delta_j l_{ij})}{1+\sum_{m=1}^{k}\exp(x_i'\beta_m+\delta_m l_{im})} \quad (3)$$

The analysis of the impact of adoption of agronomic practices on crop yield received is undertaken in the second stage. The expected outcome from the adoption of different bundles of agronomic practices can be specifies as:

$$E(O_i|d_i x_i l_i) = x_i'\beta + \sum_{k=1}^{K}\lambda_k d_{ik} + \sum_{k=1}^{K}\Upsilon_k l_{ik} \quad (4)$$

Where x is a vector of exogenous variables with associated parameter vectors as β and λ_k denote the treatment effects relative to the control group. $E(O_i|d_i x_i l_i)$ is the function of each of the latent factors l_{ik} and shows that the outcome may be affected by unobserved factors that also affects selection into treatment. This is captured by factor loading parameter Υ_k. When Υ_k is positive, treatment and outcome are positively correlated, when Υ_k negative, treatment and outcome and negatively correlated. In other words, there can be a positive or negative selection bias associated with parameters vectors. Since our outcome variable- yield is a continuous variable, we assume a normal distribution function and the model is estimated using Maximum Simulated Likelihood (MSL) method using 200 simulation draws.

In order to get robust estimates, we can include an instrument variable in the equation, though the equations can be estimated with the same set of explanatory variables both in the treatment equation and outcome equation (Deb and Trivedi, 2006b). The selected instrument variable should not be correlated with the outcome variable-yield. We use membership in input supply cooperatives as our instrument variable. The membership in input supply cooperatives can have an impact on the adoption decisions of agronomic practices but is hardly expected to influence the yield. Existing studies on adoption and impact of technology have utilised such social network variable as an instrument variable (Wossen, et al. (2017). We also ran a test to see the validity of instrument and the results are presented in Table A6.1 in the Appendix. The instrument variable that we selected membership in input supply cooperatives has an impact on the adoption decision by farmers in most cases but does not have any impact on the outcome variable of the non-adopters.

6.3 Description of Variables and Hypothesis

The adoption models include several explanatory variables based on economic theory and empirical literature on adoption. The definition of the variables used in the current econometric analysis is presented in Table 6.1. The details of the explanatory variables are as follows.

Several studies have included household characteristics such as education, access to extension services, organisational membership, size of the landholding, etc. as the important factors influencing the adoption decision of agronomic practices by farmers. For example, Rao, et al. (2007) finds that education and farm size influences the adoption decision of integrated pest management in cotton, groundnut and pigeon pea significantly in the state of Andhra Pradesh. Exposure to education has also been used as a variable to capture human endowment, wherein it is hypothesised that exposure to education will increase the ability of farmers to obtain information, and subsequently process and use the same. Barrett et al. (2004), Pender and Gebremedhin (2008), and Langyintuo and Mungoma (2008) have found a positive relationship between education and adoption. Further, Issahaku and Abdulai (2020) and Zakaria et al. (2020) have demonstrated that the education of the household head influences the likelihood of farmers adopting climate-smart agricultural practices. We also include a variable called no of years in agriculture to capture the relationship between experience in agriculture and adoption.

The impact of total farm size in the adoption decisions of agronomic practices has been mixed (Langyintuo and Mungoma, 2008). Bonabana-Wabbi (2002) suggested that integrated pest management strategies are scale neutral, and the size of the farmers' land holdings does not impact integrated pest management adoption. Langyintuo and Mungoma, (2008) found a negative and significant relationship between farm size and the intensity of adoption of improved maize varieties. Simtowe (2011) also finds that there is a negative relationship between landholdings and adoption of high yielding pigeonpea; farmers facing land pressure intensify pigeonpea adoption through the adoption of improved varieties. The relationship between total farm size and the adoption of new practices also depends on factors such as fixed adoption costs, risk preferences, credit constraints and labour requirements etc. (Just and Zilberman, 1983; Feder et al., 1985).

The extant literature investigates the role played by institutional variables, such as distance to market and access to information, role of government extension agents in adoption of agronomic services across the world. Agricultural extension services are an important channel for wider dissemination and adoption of technology (Langyintuo and Mungoma, 2008; Kassiet et al., 2015). The study by Devi and Ponnarasi (2009) showed that lack of awareness, training on new technology etc. acted as the determinants for adoption behaviour of farmers. Few studies have postulated that the adoption of recommended agronomic practices is constrained by information asymmetries arising from a lack of effectiveness and frequency of public extension services. Reddy (2010) observes that the presence of inadequate and incorrect information regarding pulse production technology can serve as a constraint to adoption. The study by Devi and Ponnarasi (2009) showed that lack of awareness, training on new technology etc. serve as determinants for adoption behaviour of farmers. Kaliba et al. (2000) found that extension services and on farm field trials are two of the most important factors influencing uptake of improved varieties and fertiliser usage in the case of maize. Mitschke (2017) found that the provision of relevant information and relevant guidance to the farmers, along with the provision of agricultural inputs had the potential to enhance adoption and yields of beans. Uzonna and Quijie (2013) found that there was a significant corelation between adoption of improved crop practices and timeliness of training, as well as method of training. We seek to examine the impact of access to information and the role of the institutional factors by considering variables such as contact with government extension agents, government training, knowledge about production techniques in the last five years and availing of credit under the kisan credit card government scheme.

Studies such as Mekonen et al., (2018) suggest that the information exchange among farmers are more effective, or the learning effect is larger with a membership in social groups, or voluntarily formed groups for exchanging agricultural information. However, other studies such as Bandiera and Rasul (2006), Conley and Udry (2010) and Matsumoto et al. (2014) indicate that adoption is more likely to be accentuated by having a benefiting adopter in a network, especially for knowledge intensive technologies and farmers do not seem to rely on all members of the village in order to obtain agricultural information. Caviglia-Harris (2003) have found that in Brazil, as the number of farm-related unions or agricultural cooperatives increases, so does the likelihood of adoption. We seek to capture the productivity spillovers on account of membership to a particular group by examining membership to input supply cooperatives.

Table 6.1: Variable Definitions

Variable	Definition
Farm Size	Total size of land owned by household in acres.
No. of family members	Number of the family members in the household including children.
Education	No of years of education of the members of the household
Government or NGO training	Government or NGO training frequency per year in numbers
Rainfall satisfactory	Whether the farmer is receiving required rainfall during the crop season, dummy variable 1 for yes and 0 otherwise.
Knowledge about production techniques in last five years	Knowledge in the number of new production techniques by the farmer.
Experience in farming	No of years in farming by the farmer.
Contact with government extension agents	Dummy variable=1 if the household had contact with government extension agents, =0 otherwise
Access to credit	Dummy variable =1 if the household had access to formal sources of finance (we define formal sources as commercial banks and cooperative banks), =0 otherwise.
Availed loan under KCC scheme	Dummy variable=1 if the farmer has availed loan under the Kisan Credit Card scheme, 0 otherwise.
Family members working fulltime in own farm	Number of family members (>14) working full time in the farm.
Membership in input supply cooperatives	Membership of any of the family member in input supply cooperatives, dummy variable = 1 if any of the family member has membership, = 0 otherwise
Distance	Distance to the nearest main market (in kilometres).

6.4 Estimation Results and Discussion

6.4.1 Descriptive Statistics

Descriptive statistics of the explanatory variables that are hypothesised to influence adoption as well as outcome variable are presented in Table 6.2. As mentioned earlier, here we focus on adoption as a choice over eight alternatives involving three major agronomic principles. The first group is non-adopters which had 188 cultivator households. The total number of adopters of agronomic practices is 202. Among the adopters, around 92 households (45.54%) have adopted all three agronomic practice categories. Plant management and seed management is adopted by around 23 households (11.38%), soil management and seed management are adopted by around 9 households (4.45%) and similarly, 38 households (20%) have adopted plant management alone and 19 households (10%) have adopted plant management and soil management alone.

The descriptive statistics show that the average of farm size (i.e., the total size of land owned by the household) was higher among adopters in almost all cases as compared to non-adopters (except for adopters of soil management techniques only). The average of government/ NGO training received with respect to agriculture was higher among adopters as compared to non-adopters. The average yield was observed to be lower amongst the non-adopters as opposed to the adopters; the highest average yield was observed in the case of adopters of seed management practices only.

Surprisingly, the average years of education was higher among the non-adopters than among adopters of most of the practices/ combination of practices. The average years of education was highest among adopters of plant management measures, followed by soil and plant management. The membership in input supply cooperatives was generally higher among non-adopters as opposed to adopters, except in the case of adopters of plant management measures.

Table 6.2: Descriptive Statistics for Variables used in the Model

Variable	Non-adopters	Seed	Plant	Plant and Seed	Soil	Soil and Seed	Soil and Plant	Soil, Plant and Seed
Farm Size	4.068 (5.674)	9 (8.485)	8.124 (6.798)	4.899 (2.499)	3.562 (3.176)	5.492 (4.847)	9.584 (14.913)	5.782 (5.503)
No. of family members	6.244 (2.750)	3.5 (.707)	5.448 (1.919)	4.130 (1.391)	4.857 (2.267)	3 (1)	4.4 (1.549)	4.5 (2.388)
Years of Education	8.877 (3.954)	1 (1.414)	10.068 (4.479)	4.217 (4.870)	6.571 (3.644)	2.222 (2.587)	9.425 (5.310)	4.902 (5.042)
Government or NGO training	.755 (.499)	1 (0)	1.724 (1.065)	1.478 (.730)	1.142 (.690)	1.111 (.333)	1.725 (1.012)	1.347 (.670)
Walking distance from the market (km)	8.143 (4.084)	17.5 (3.535)	23.379 (8.953)	15.086 (7.543)	11.142 (6.593)	10.222 (7.361)	21.375 (10.080)	14.043 (7.802)
Experience in farming	27.36 (11.52)	40 (0)	23.724 (14.616)	33.173 (11.811)	31.428 (7.480)	29.888 (6.697)	25.925 (13.035)	23.586 (11.135)
Membership in input supply cooperatives	.819 (.385)	0 (0)	.896 (.309)	.260 (.448)	.857 (.377)	0 (0)	.775 (.422)	.184 (.390)
Total Yield	2.171 (.698)	7.25 (6.717)	3.948 (2.139)	4.717 (2.700)	4.297 (4.730)	4.804 (4.620)	3.870 (2.276)	5.122 (3.615)

Note: Standard deviation is given in parentheses.

6.4.2 Factors Influencing the Adoption of Various Agronomic Practices

The results for the mixed multinomial logit model are presented in Table 6.3. This is the result from the first stage of our multinomial endogenous treatment effects model. The model is estimated selecting one category as the base category, against which the results are compared. The non-adoption of agronomic practices is selected as the base category. The results show that the model fits the data very well with the Wald test, chi2 = 1553; P > chi2 = 0.00 implying that the null hypothesis that all the regression coefficients are jointly equal to zero is rejected.

The results show that the size of the farm had a statistically significant and positive impact on the adoption of 4 out of 7 agronomic practices combinations. However, the literature on the impact of farm size on adoption of agronomic practices is quite mixed as some argue that management practices are scale neutral (Bonabana-Wabbi, 2002), while some studies find a negative relationship (Langyintuo and Mungoma, 2008; Simtowe (2011) and some studies finds a positive relationship (Rao et al., 2007). The study by Rao et al., (2007) is undertaken in the Indian context and our findings are consistent with this study. This could be attributed to farmers with larger land holdings having a greater degree of risk resistance, more capital and better credit as opposed to smaller-scale farmers, which incentivises uptake of adoption and investment into agronomic practices management (Hu et al, 2022).

The size of the household, which is used as a proxy to capture labour endowment, had a negative and significant impact on the adoption of agronomic practices in our analysis. This was evident from 4 out of seven agronomic practices combinations. The size of the household reduced the adoption of seed, seed and soil, soil and plant and seed and plant management practices. This contradicts the findings by Noltze et al., (2012) and Teklewold et al., (2013), which signify that a large family size may encourage investment into and maintainence of these agronomic practices. It is quite possible that larger households have lesser resources to spent on farming, or there is diversion of labour into non-farm activities as indicated by study findings of Bekele and Drake (2003), which was adversely impacting the adoption of agronomic practices.

The education of farmers in general is expected to influence the adoption (Moser and Barrett, 2003; Barrett et al. 2004; Pender and Gebremedhin 2008; Langyintuo and Mungoma, 2008; Manda et al., 2015; Issahaku and Abdulai, 2020; Zakaria et al. 2020). However, in our analysis education came out to be insignificant in most combinations and negative and significant for 2 out of 7 combinations. The statistically significant and negative result for adoption of all agronomic practices (the 7th combination) shows that the education has negative impact on the adoption of agronomic practices. It is possible that educated farmers are gradually moving away from farming and to other profitable ventures. The results therefore are more consistent with the findings of studies such as Uematsu et al. (2010), Khanna (2001), Banerjee et al. (2008) which have concluded that the impact of education could either be negative or there could be no impact, justified by reasons such as farmers earning a greater amount through off-farm activities as opposed to agricultural operations.

The selling price had a positive and significant impact on the adoption of three out of seven practices (soil management, plant management, and soil and plant management) implying that a better price received by farmers is encouraging the adoption of agronomic practices. The results from access to off-farm activities were mixed with access to off-farm activities increasing the adoption of all agronomic practices (the 7th combination) but reducing the adoption of some of the combinations such as soil management, and seed and plant management.

The training received from government or NGOs also had a positive and significant impact on four out of seven combinations of practices. These findings are in line with the existing studies (Devi and Ponnarasi, 2009; Uzonna and Quijie, 2013; Mitschke , 2017). Similarly, years of experience in farming had a positive and significant impact on the adoption of seed management, soil and plant management and seed and plant management practices. The results are consistent with studies done by Meshram et al, 2012 and Kassie et al., 2013.

Membership in input supply co-operatives discouraged farmers from adopting 3 out of 7 practices. The results for seed and soil management, seed and plant management, seed, soil and plant management came out to be negative and statistically significant in our model. However, membership had a positive and significant impact on the soil management practice. Although there are several studies that highlight membership in farmer organisation as one of the important factors in affecting the agronomic practice adoption decisions due to them serving as important channels for dissemination of information and peer impact (Barrett et al., 2004; Matuschke & Qaim, 2009; Khonje et al., 2015), our results show the contrary, consistent with Ahmed (2019), who has empirically demonstrated lower adoption in the case of maize. These findings could be due to the fact that farmers with membership in such farmer organisations already having better crop cultivation and marketing prospects, due to which they are not incentivised to adopt yield enhancing agronomic practices specific to black gram. The results for soil management further strengthens this view as soil management is not specific to black gram and can be relevant to other crops as well, whereas seed and plant management are black gram-specific.

Interestingly, distance from the main market increased the adoption of all the practices and the results for 4 out of 7 practices, which indicates that farmers who are far away from the market with less marketing opportunities adopted several of these practices. As mentioned already, more than 50 percent of farmers in our sample are small and marginal farmers and therefore, it is possible that farmers who are remotely located from the market are more encouraged to adopt agronomic practices relevant to black gram than farmers who cultivate other crops and marketable crops, and are located close to main market.

Table 6.3: Mixed Multinomial Logit Model Estimates of Adoption of Agronomic Practices (Baseline Category is Non-Adoption of Agronomic Practices)

Variable	Soil	Seed	Seed and Soil	Plant	Soil and Plant	Seed and Plant	Seed, Soil and Plant
Farm Size	.008 (.059)	.494** (.228)	.077 (.087)	.107*** (.034)	.126*** (.034)	.040 (.057)	.074* (.039)
No. of family members	-.332 (.231)	-.717*** (.208)	-.681** (.237)	-.057 (.128)	-.472** (.191)	-.328** (.114)	-.132 (.111)
Education	-.108 (.118)	-.469 (.431)	-.203* (.116)	-.078 (.087)	-.046 (.075)	-.043 (.083)	-.109** (.053)
Selling Price	-7.65** (3.16)	.115 (7.27)	1.05 (6.57)	6.86** (3.09)	7.28** (3.04)	11.07** (4.05)	2.62 (2.55)
Access to off- farm activities	-47.30*** (3.08)	57.44 (61.41)	2.11 (2.23)	.159 (.687)	-.189 (.675)	-42.7*** (.608)	1.12* (.658)
Distance to market	.050 (.084)	.659*** (.157)	.077 (.104)	.254*** (.048)	.239*** (.049)	.148** (.057)	.135** (.052)
Years of experience in farming	.043 (.027)	.254*** (.071)	.008 (.030)	.019 (.025)	.041* (.025)	.084** (.029)	-.031 (.019)
Government of NGO training frequency per year	1.56* (.928)	-20.62 (62.64)	1.12 (1.01)	.641 (.465)	.879** (.404)	1.14* (.610)	1.10** (.410)
Membership in input supply cooperatives	2.18* (1.16)	-67.27 (64.15)	-45.30*** (1.30)	.824 (.930)	-.181 (.694)	-2.32*** (.647)	-3.18*** (.464)
Constant	60.16 (26.8)**	-1.84	-10.06 (55.80)	-66.42** (26.34)	-67.9** (26.6)	-100.2** (34.9)	-22.8 (21.7)
No of Observations 387 Wald chi2=1553, P>chi2=0.0000							

Notes: Sample size is 390 and 200 simulation draws were used. ***P < 0.01, **P < 0.05, *P < 0.1. Robust standard errors are given in parentheses.

6.4.3 Average Treatment Effects of Single as well as Different Combinations of Agronomic Practices

The results from the average treatment effects of different combinations of agronomic practices are given in Table 4. The impact of adoption of various combinations of agronomic practices on crop yield were estimated considering the yield as both an endogenous outcome variable as well as an exogenous outcome variable. The results from the exogenous model assuming yield as exogenous showed that the adoption of all the agronomic practices had a positive impact but was statistically significant only for 3 combinations of practices. They are (a) plant management, (b) seed and plant management, and (c) seed, soil and plant management practices. The highest number of adopters have adopter all three practices; seed, soil and plant management-92 households (45.54%). The results therefore indicate that the yield benefits increased for those farmers who adopt all practices as compared to partial adopters. The adoption of plant management alone increased the yield by 105 units, seed and plant management by 143 units and seed, soil, and plant management by 184 units.

However, the inferences from the exogenous model considering yield as an exogenous variable may lead to inconsistent results as it ignores the effects of unobserved factors (Manda *et al*., 2015). The unobserved characteristics such as superior managerial ability and enterprising nature of households can affect the yield. Therefore, a multinomial endogenous treatment effects model is estimated to overcome this issue by treating yield as an endogenous outcome.

The average adoption effects after controlling for unobserved heterogeneity show that the yield impact of agronomic practices is indeed much higher when we treat yield as endogenous. The results showed that adoption of five combinations of agronomic practices had a statistically significant and positive impact on yield. They were (a) seed management, (b) seed and soil management, (c) plant management, (d) soil and plant management and seed, (e) soil and plant management practices. The yield benefits were 311 units, 208 units, 99 units, 98 units and 253 units respectively. As mentioned already, the adoption of all agronomic practices provides much higher yield benefits.

In terms of other variables that affect yield are concerned, the results from the endogenous model showed that size of the farm had a positive and significant impact on the yield. The yield will increase by 11 units if the size of the farm increased by 1 unit. Education and access to off-farm activities had a statistically significant and negative impact on yield, indicating that better opportunities are preventing farmers from investing in yield improvement of crop. Education of the farm households reduced the yield by 11 units and access to off-farm activities by 59 units. The results were similar to the exogenous model, though in the exogenous model, the farm size was positive but insignificant. However, the results for the other two variables-education and access to off-farm activities were similar. Apart from these variables, years of experience in farming was also negative and significant in the exogenous model indicating that experience in farming had a negative impact on yield. Experience in farming reflects the age of the farmer and the results indicate that the younger farmers are more enthusiastic and enterprising, and therefore positively affect the yield as compared to older farmers.

In addition, most of the factor loadings (k) show evidence of negative selection bias as the results for seed management, seed and soil management, soil and plant management and seed, soil and plant management were statistically significant and negative. The results therefore suggest that unobserved factors that increase the likelihood of adopting different combinations of agronomic practices for black gram are associated with lower levels of yield than those expected under random assignment to the different combinations of agronomic practices adoption status. Positive selection bias is also seen in the case of seed and plant management practice, suggesting that unobserved variables increasing the likelihood of adopting this practice is associated with higher levels of yield.

Table 6.4: Multinomial Endogenous Treatment Effects Model Estimates of Agronomic Practices Impacts on Crop Yield

Practice	Crop yield
Exogenous	
Soil	1.56 (1.43)
Seed	3.25 (2.83)
Seed and Soil	1.26 (1.32)
Plant	1.05** (.441)
Soil and Plant	.670 (.479)
Seed and Plant	1.43** (.561)
Seed, Soil and Plant	1.84*** (.361)
Farm Size	.107 (.030)
No. of family members	-.052 (.037)
Education	-.123*** (.026)
Selling Price	.778 (.786)
Access to off-farm activities	-.561*** (.191)
Distance to market	.006 (.020)
Years of experience in farming	-.016* (.010)
Government of NGO training frequency per year	.040 (.156)
Constant	-2.87 (6.72)
Wald chi2	191.18
P>chi2	0.000
Endogenous	
Soil	1.69 (1.73)
Seed	3.11* (1.80)
Seed and Soil	2.08* (1.21)
Plant	.989** (.501)
Soil and Plant	.983** (.477)
Seed and Plant	.671 (.564)
Seed, Soil and Plant	2.53*** (.443)
Farm Size	.105*** (.022)
No. of family members	-.039 (.038)
Education	-.105*** (.026)
Selling Price	.724 (.990)
Access to off-farm activities	-.593** (.208)
Distance to market	.006 (.019)
Years of experience in farming	-.012 (.010)
Government of NGO training frequency per year	.000 (.160)
Constant	-2.83 (8.53)

Practice	Crop yield
Wald chi2	44850
P>chi2	0.000
Selection terms (λ)	
Soil	.833 (.581)
Seed	-.459* (.224)
Seed and Soil	-.889*** (.214)
Plant	.125 (.246)
Soil and Plant	-.439** (.170)
Seed and Plant	.740** (.286)
Seed, Soil and Plant	-1.16*** (.275)

Notes: The baseline is non adopters of agronomic practices. Sample size is 387 and 200 simulation draws were used. ***P < 0.01, **P < 0.05, *P < 0.1. Robust standard errors are given in parentheses.

6.5. Conclusion

The literature analysing the determinants of adopting various agronomic practices and its impact on yield is rich. However, empirical studies that analyse the different combinations of agronomic practices and its impact on yield in a multinomial selection framework are relatively scarce. The factors affecting each and every combination of agronomic practices can be different from each other. Similarly, the factors that encourage the adoption of agronomic practices can also be correlated with the outcome variable. For example, size of the farm can also influence the adoption as well the yield impact. As a result, the single equation modelling techniques will provide inconsistent results. This paper contributes to the empirical literature by analysing the determinants of adoption of seven mutually-exclusive combinations of agronomic practices among black gram farmers and its impact on crop yield. The analysis is undertaken using a multinomial endogenous treatment effects model. Farm household survey data is collected from a sample of 387 households from four major black gram producing states of India—Andhra Pradesh, Madhya Pradesh, Rajasthan and Maharashtra.

The examination of the factors impacting adoption of agronomic practices indicated several results consistent with the available literature, as well as some interesting deviations. For instance, our results regarding the positive impact of farm size, training from government or NGOs, selling price on agronomic practice adoption were in line with studies undertaken in the Indian context. Other important variables such as family/ household size (a proxy for labour supply), education of farmers, membership in farmer organisations were negative and insignificant; these findings deviate from several studies that postulate a positive relationship (Noltze et al., 2012; Teklewold et al., 2013; Moser and Barrett, 2003; Barrett et al. 2004; Pender and Gebremedhin 2008; Langyintuo and Mungoma, 2008; Barrett et al., 2004; Matuschke & Qaim, 2009; Khonje et al., 2015). The negative relationship with family size could be attributed to either a shift to non-farm activities, or a decrease in resources available for investment into farming. Similarly, the negative and statistically significant result witnessed in the case of education could be attributed to the gradual move away from farming, better opportunities available due to their education and the falling interest amongst educated farmers to adopt agronomic practices pertaining to black gram. In the case of membership in farmer organisations, our results showed that the membership in input supply co-operative had a positive impact only on the adoption of soil management, whereas a negative and statistically significant impact in the case of seed and soil management, seed and plant management, seed, soil and plant management was observed. This result could be attributed to better crop cultivation and marketing prospects already existent for farmers who are members of farmer organisations due to their ability to leverage on the opportunities and information available, due to which they do not have any additional incentive to further engage in yield-enhancement measures specific to black gram and are adopting only soil management practices that are not black gram specific.

The results for access to off-farm activities were quite mixed. The adoption of all practices-the 7^{th} combination bundle-increased with greater access to off-farm activities indicating that better access to resources is encouraging farmers in adopting yield enhancing agronomic practices.

Examining the impact of adoption of agronomic practices on yield pointed towards the sample selection bias especially if the yield equation is estimated without considering the adoption decision. The results from both the exogenous and endogenous adoption decisions showed that the adoption of various agronomic practices increased the yield. The impact was much more when we consider the yield impact as endogenous. Also, the results showed that the impact was greater under seed management, and the adoption of all the practices. In terms of policy implications, these results suggest that although full adoption would contribute to yield benefits, even the adoption of seed management alone can enhance the crop yield in the case of black gram. Thus, this empirical analysis strengthens the case for an emphasis on the adoption of recommended agronomic practices in the case of black gram in India.

CHAPTER 7

FARMERS' SOURCES FOR SEED AND THE MARKET PRICE RECEIVED

The present chapter analyses the impact of various sources for seed on the market price received by farmers using a multinominal endogenous treatment framework similar to chapter 6.

7.1. Green Gram

The major sources of seed for farmers were government, other farmers, private companies, and farmers' own stock from previous year. As far as green gram farmers are concerned, around 28 percent of farmers obtained their seed from government sources, 4 percent from other farmers, 21 percent from private companies, and 47 percent from own stock from previous year (see table 7.1).

Table 7.1: Source of Seeds for Green Gram

Source for Seeds	Number (%)
Government	112 (28.07)
Other Farmers	16 (4.01)
Private Companies	85 (21.30)
Own Stock from the last year	186 (46.62)
Total	**399 (100)**

Source: Survey data

We have employed a multinomial endogenous regression techniques to see the factors affecting farmers decision to choose the source of seed among various sources.

As discussed in the previous chapters, the multinomial endogenous treatment effects model has two stages. The factors affecting the decision to opt the seed source from the four sources mentioned above will be analysed in the first stage (Deb and Trivedi 2006a,b; Manda et al., 2015, Varma, 2019).

An instrument variable in the adoption equation will help us to get a robust estimate. The equations of treatment and outcome can be estimated with the same set of explanatory variables but including an instrument will provide us more robust estimate (Deb and Trivedi, 2006b). The selected instrument variable should not be correlated with the outcome variable-price received. We use information received from radio, mobile phone or TV as our instrument variable. The information is supposed to affect the source of seed but is hardly expected to affect the price received. We also ran a test to see the validity of instrument and the results are presented in Table A7.1 in the Appendix. The instrument variable that we selected information from TV, mobile phones or radio has an impact on the seed choice decision by farmers in most cases but does not have any impact on the outcome variable of the non-adopters.

The results from mixed multinomial logit regression for the factors affecting seed choice shows that farm size has a negative and significant impact in buying seed from government. Similarly, those who receive training from the government are seen to have a negative impact on the choice of seed from private companies. Having greater knowledge about production techniques is also reducing the likelihood of farmers using own seed. Similarly, information received from radio, TV or mobile phones also reduce the chances of farmers using own seed source. This shows that the farmers who are well aware of the production techniques do not use own seed. Similarly having greater information reduces the chances of using own seed (see table 7.2)

Table 7.2: Mixed Multinomial Logit Regression for Green Gram

Variables	Seed Source-Government	Seed Source-Private	Seed Source-Own Stock
Farm Size (Acres)	-.054 (.028) *	-.032 (.037)	-.033 (.026)
Number of Family Members	-.057 (.116)	-.100 (.118)	.101 (.104)
Education (No of Years)	. 021 (.089)	-.075 (.090)	-.024 (.088)
Received Training from Government-Frequency	-.048 (.377)	-.921 (.528)*	-.974 (.471)
Has the Rainfall been Satisfactory	. 430 (.598)	.375 (.626)	.210 (.588)
Distance from main market (km)	. 044 (.029)	.046 (.031)	.036 (.030)
Years of Experience in Farming	-.024 (.025)	-.034 (.025)	-.028 (.025)
Contact with Government Extension Agents	-.406 (.893)	-.365 (.887)	-.628 (.872)
Finance Source for Crop Activities	-1.510 (1.300)	-.223 (1.251)	-.878 (1.267)
Availed Loan under KCC	1.674 (1.304)	1.223 (1.244)	1.601 (1.265)
Knowledge about production technology in the last 5 years	-.353 (.450)	-.451 (.566)	-.978 (.521)*
Availing MSP for Green Gram	.364 (.743)	.203 (.784)	.130 (.747)
Radio/TV/Mobile as Source for Information	-.143 (.187)	-.325 (.204)	-.477 (.190)**
Constant	3.373 (1.596) **	5.283 (1.912)***	6.438 (1.762)***
Wald chi ^{2}(13)	13.48		
Prob > chi ^{2}	0.411		
Number of Observations	399		

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. standard errors are in parentheses.

The impact of seed source on prices received among green gram farmers are given in table 7.3. The results showed that price received has significant and negative relationship with seed source from government, seed source from private and own seed source when we treat price received as an exogenous variable. However, while treating the outcome variable-price received as an endogenous variable, the results showed that only the government source and private source has negative impact on the price received.

As far as other variables are concerned, farm size has a positive impact on the price received, number of family members and education have negative impact.

Table 7.3: Multinomial Endogenous Treatment Effects Model Estimates of Seed Sources Impacts on Crop Price Received

Price Received	Co-efficient
Exogenous	
Source for Seed-Government	-12.453 (6.622)*
Source for Seed-Private	-15.410 (6.956)**
Source for Seed-Own Stock	-12.266 (6.873)*
Farm Size (Acres)	1.328 (.466)***
Number of Family Members	-.964 (.355)***
Education (No of Years)	-.579 (.135)***
Received Training from Government-Frequency	-1.004 (1.308)
Has the Rainfall been Satisfactory	-5.005(2.096)**
Distance from main market (km)	-.106 (.059)*
Years of Experience in Farming	-.097 (.066)
Contact with Government Extension Agents	-5.447 (3.378)
Finance Source for Crop Activities	1.854 (1.989)
Availed Loan under KCC	-1.595 (2.181)
Knowledge about production technology in the last 5 years	-.492 (2.314)
Availing MSP for Green Gram	-11.762 (2.081)***
Constant	42.285 (11.163)***
Endogenous	
Source for Seed-Government	-15.498 (7.370)**
Source for Seed-Private	-16.271 (7.220)**
Source for Seed-Own Stock	-9.564 (7.094)
Farm Size (Acres)	1.312 (.460)***
Number of Family Members	-1.092 (.379)***
Education (No of Years)	-.554 (.137)***
Received Training from Government-Frequency	-.435 (1.272)
Has the Rainfall been Satisfactory	-4.872 (2.115)**
Distance from main market (km)	-.094 (.060)
Years of Experience in Farming	-.098 (.066)
Contact with Government Extension Agents	-5.257 (3.372)
Finance Source for Crop Activities	1.432 (2.038)
Availed Loan under KCC	-1.545 (2.228)
Knowledge about production technology in the last 5 years	-.226 (2.326)
Availing MSP for Green Gram	-11.718 (2.132)**
Constant	41.163 (11.143)

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. standard errors are in parentheses.

7.2. Black Gram

The major sources of seed for black gram farmers were government, other farmers, private companies, and own stock from previous year. Around 7 percent of farmers obtained their seed from government sources, 7 percent from other farmers, 37 percent from private companies, and 46 percent from own stock from previous year (see table 7.5).

Though the percentage of farmers who use own seed from previous years were the same as green gram and black gram farmers, the percentage of farmers who get their seed from government sources were lower among black gram farmers than green gram farmers. Similarly, the percentage of farmers who obtain their seed from private companies were slightly higher among black gram farmers than green gram farmers (see table 7.4).

Table 7.4: Source of Seeds for Black Gram

Source for Seeds	Number (%)
Government	27 (6.92)
Other Farmers	27 (6.92)
Private Stock	143 (36.67)
Own Stock from the last year	193 (46.49)
Total	390

Source: Survey data

The results from the first stage of regression showed that the distance from the main market reduced the chance for getting the seed from government. Similarly, the farm size had a negative impact on obtaining the seed from private companies. This result was counter-intuitive. Distance from market and years of experience reduced the chance for using the own seed stock (see Table 7.5).

Table 7.5: Mixed Multinomial Logit Regression for Black Gram

Variables	Seed Source-Government	Seed Source-Private	Seed Source-Own Stock
Farm Size (Acres)	-.005 (.030)	-.0537 (.028)*	-.019 (.028)
Number of Family Members	-.027 (.150)	-.081 (.109)	-.056 (.106)
Education (No of Years)	-.087 (.107)	-.001 (.078)	-.094 (.078)
Received Training from Government-Frequency	-.613 (.482)	-.158 (.379)	-.340 (.373)
Has the Rainfall been Satisfactory	-.153 (.709)	-.201 (.556)	.158 (.536)
Distance from main market (km)	-.130 (.047)***	-.107 (.035)	-.102 (.036)***
Years of Experience in Farming	-.046 (.033)	-.004 (.026)	-.046 (.026)*
Contact with Government Extension Agents	1.166 (1.134)	.227 (.760)	.169 (.753)
Finance Source for Crop Activities	-1.563 (.672)	.234 (.528)	-.932 (.510)*
Availed Loan under KCC	-.046 (.743)	.196 (.594)	.293 (.589)
Knowledge about production technology in the last 5 years	.022 (.762)	.363 (.610)	.383 (.590)
Availing MSP for Black Gram	-.693 (.952)	.553 (.654)	.275 (.652)
Radio/TV/Mobile as Source for Information	1.325 (1.455)	-1.887 (1.030)*	-1.468 (1.029)
Constant	3.485 (2.614)	5.232 (1.807)***	7.613 (1.841)***
Wald chi ^{2}(13)	28.54		
Prob > chi ^{2}	0.0076		
Number of Observations	390		

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. standard errors are in parentheses.

The outcome regression results showed that the price received had a positive and significant relationship with government seed. Similarly farm size, satisfactory rainfall and distance from market had a positive impact on the price received whereas education, and number of family members had a negative impact on the price received (see table 7.6).

Table 7.6: Multinomial Endogenous Treatment Effects Model Estimates of Seed Sources and Impacts on Crop Price Received

Price Received	Co-efficient
Exogenous	
Source for Seed-Government	1.210 (.624)*
Source for Seed-Private	.369 (.380)
Source for Seed-Own Stock	.509 (.374)
Farm Size (Acres)	.098 (.027)***
Number of Family Members	-.080 (.038)**
Education (No of Years)	-.103 (.024)***
Received Training from Government-Frequency	.063 (.145)
Has the Rainfall been Satisfactory	1.590 (.221)***
Distance from main market (km)	.044 (.017)**
Years of Experience in Farming	-.005 (.008)
Contact with Government Extension Agents	.165 (.309)
Finance Source for Crop Activities	-.204 (.203)
Availed Loan under KCC	.629 (.193)**
Knowledge about production technology in the last 5 years	-.331 (.279)
Availing MSP for Black Gram	-.764 (.154)***
Constant	2.707 (.662)***
Source for Seed-Government	1.383 (.688)**
Source for Seed-Private	-.561 (.529)
Source for Seed-Own Stock	.762 (.673)
Farm Size (Acres)	.090 (.026)***
Number of Family Members	-.083 (.040)**
Education (No of Years)	-.083 (.026)***
Received Training from Government-Frequency	.093 (.149)
Has the Rainfall been Satisfactory	1.525 (.228)***
Distance from main market (km)	.040 (.019)**
Years of Experience in Farming	.002 (.009)
Contact with Government Extension Agents	.152 (.315)
Finance Source for Crop Activities	.023 (.222)
Availed Loan under KCC	.647 (.202)
Knowledge about production technology in the last 5 years	-.324 (.290)***
Availing MSP for Black Gram	-.736 (.173)***
Constant	2.525 (.867)***

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. standard errors are in parentheses.

Table 7.7: Linear Regression – Black Gram

Total Yield	Co-efficient
Farm Size (Acres)	.042 (.024)*
Number of Family Members	.116 (.375)
Education (No of Years)	.017 (.109)
Received Training from Government-Frequency	-.035 (.391)
Has the Rainfall been Satisfactory	1.034 (.809)
Distance from main market (km)	.032 (.043)
Years of Experience in Farming	.007 (.033)
Contact with Government Extension Agents	.690 (1.021)
Finance Source for Crop Activities	.136 (1.257)
Availed Loan under KCC	.882 (.734)
Knowledge about production technology in the last 5 years	.538 (.858)
Availing MSP for Black Gram	1.234 (1.845)
Radio/TV/Mobile as Source for Information on MSP	-1.343 (2.995)
Constant	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. standard errors are in parentheses.

7.3 Conclusion

The results from the analysis employed in this chapter showed that the percentage of farmers who use government seed was more among the green gram farmers than black gram farmers. Similarly, a greater number of black gram farmers obtained the seed from private companies. Still, it was observed that a large chunk of both green gram and black gram farmers were still using own seed from previous year. Those who had better knowledge about the production techniques were not using their own seed. As far as the impact of seed sources on the prices received, the results were quite mixed. The black gram farmers who sourced their seed from government received higher prices for the crop while selling, whereas opposite was the case for green gram farmers.

CHAPTER 8

ROLE OF CROP INSURANCE IN AGRONOMIC PRACTICES ADOPTION

8.1 Introduction

The present chapter discusses the role of crop in insurance in influencing the adoption of various agronomic practices among the black gram farmers. Crop insurance is supposed to reduce the risk of farmers. Agriculture is a risky enterprise and theoretically farmers are risk averse in nature. Therefore, it would be of interest to see how the availing of crop insurance is affecting the risk perceived by the farmers and the impact on adoption of agronomic practices.

The chapter is structured as follows. Section 8.2 will briefly discuss the literature on risk and uncertainty and their role in technology adoption. Section 8.3 will present the empirical framework of the study. Results and discussion are given in section and section 4 concludes with policy implications.

8.2 Literature Review

Risk and uncertainty are inherent in agricultural production (Musser and Patrick, 2002) and small holder farmers especially from developing countries often operate within risky and uncertain situations (Ullah, et al., 2015). Supply shocks that take place due to climate abnormalities or catastrophic events such as floods or drought puts farmers under jeopardy (Li et al., 2022). Farmers from developing countries are more vulnerable to climate change impact on agriculture as agriculture is the main source of livelihood for majority of population and they lack effective risk management tools or resources to cope up with risk (Birthal et al., 2022). Theoretically, farmers are seen to be risk averse and their risk preferences play a role in agricultural production decisions (Liu and Huang, 2013). Farmers attitude towards risk also play crucial role in technology adoption (Hardaker et al., 2015). The empirical literature on the impact of farmers' risk attitude on technology adoption is mixed: with one set of studies showing technology adoption increases as risk aversion increases (Liu, 2013; Visser and Brick, 2015) while the other set of studies proving the opposite (Pannell and Burton, 2005; Begho, 2021). There are studies that also show an increase in technology adoption among farmers who are willing to take more risk (Tarun et al., 2020).

Farmers perceptions and their response to risk and uncertainty play a crucial role in their willingness to adopt sustainable agricultural practices. United Nations' goal of zero hunger by 2030 will require dramatic improvements in agricultural productivity as the world population grows at a faster rate (Pham et al., 2021). With respect to Sustainable agricultural practices (SAPs); while there is a constant discussion about what are these practices and vary from region to region[17], the literature highlights the positive impact of adopting SAPs on crop yield and household income (Manda et al., 2016, Varma, 2019) since SAPs focus on reducing input requirements as well as causing less harm to the environment (Varma, 2019). Therefore, food production takes place at a low environment cost by retaining the food accessibility and availability for the current as well as future generations (Muhie, 2022). Despite the benefits of adopting such practices, the adoption rate is generally low in developing countries (Pham et al., 2021) and this is especially true in India, where pulses production is experiencing a crisis due to the inadequate supply to meet the growing demand.

[17] Please refer to Pham et al., 2021, Muhie 2022,

Since risk and perception of risk plays a crucial role in farmers production decision making, the chapter explicitly analyse the role of crop insurance in influencing farmers adoption of agronomic practices. Though the nature and intensity of agronomic practices adoption may not be the same with the access to crop insurance, the adoption of agricultural technologies in general can be inter-linked with crop insurance (Salazar et al., 2019) especially since agricultural production is a risky venture. Therefore, it would be of interest to see how risk management tools such as insurance and availability of insurance are affecting farmers decision making. Though there are a few studies that explicitly draw the linkage between crop insurance and technology adoption (for e.g., Salazar et al., 2019) the literature analysing the linkage between crop insurance and agronomic practices is relatively scarce. This is especially true for India. The present study contributes to the empirical literature on technology adoption by explicitly analysing the impact of crop insurance on the adoption of agronomic practices.

8.3 Empirical Framework

Following the studies on agricultural technology adoption, the present study makes use of random utility framework to explain the adoption behaviour of farm households (Ojiako, et al., 2007; Shiferaw *et al.*, 2015; Varma, 2018). As per the random utility framework, the utility of adopting a new technology by a farm household can be characterised as a linear function of several household level characteristics such as number of family members, education of the family members, experience in farming and farm level characteristics such as the size of the farm, several institutional and risk related factors such as membership in farmer organisations, distance to market, access to credit and insurance along with a stochastic component (Marenya and Barrett, 2007). The farmer will adopt the new technology if the utility derived from the new technology is superior to the current technology.

Adoption probability of an alternative agricultural technology k depends on a set of households, farm, institutional, risk and all other factors that are hypothesised to influence the adoption is X. By denoting A_k=1 for adoption of k we can write:

$$P_i = P_r(A_k = 1) = P_r(U_{ik} > U_{im}) \quad (1)$$

$$1 - P_i = P_r(A_k = 0) = P_r(U_{ik} < U_{im}) \quad (2)$$

Where i refers to farmer, k refers to alternative technology and m refers to the current technology. The utility from the alternative technology is U_{ik} and the current technology is U_{im},

Based on the random utility in equation 1, the probability to adopt an alternative technology can be expressed as:

$$P_i = P_r(A_k = 1) = P_r[U_{ik} + e_{i1} > +U_{i0} + e_{i0}] \quad (1)$$

$$= P_r[\alpha_1 F_i(Q_i R_i) + e_{i1} > \alpha_0\, F_i(Q_i R_i) + e_{i0}] \quad (2)$$

$$= P_r[e_{i1} - e_{i0} > F_i(Q_i, R_i)(\beta_1 - \beta_0)] = P_r\{\delta_i > -F_i(Q_i R_i)\gamma\} \quad (3)$$

$$P_i = F_i(X_i\beta) \quad (4)$$

Where *X* refers to the set of independent variables that are hypothesised to influence the adoption decisions and β refers to the parameters that needs to be estimated, Pr (.) is the probability function, ϒ is the random error term, and F_i $(X_i\, \beta)$ is the cumulative distribution function for $\delta_{(i)}$ evaluated at $X_i\, \beta$.

The probability that a farmer i will adopt an alternative technology is a function of a set of explanatory variables, X and of the unknown parameters β and error term ϒ. Similarly, the probability that a farmer i has availed insurance is a function of a vector of explanatory variables Z, and of the unknown parameters μ and error term ε.

$$P_i = F_i(Z_i \mu) \quad (5)$$

The probit models can be computed from equations 4 and 5. The probit model gives maximum likelihood estimators by providing asymptotically consistent and efficient parameter estimates (Ojiako, et al., 2007). In our analysis, the adoption of technology is characterised by the interaction of two probit equations, one the probability to avail insurance and two the probability to adopt the new technology.

The Conditional (recursive) Mixed Process Estimator (CMP) developed by Roodman (2009,2011) is very useful and increasingly popular in the empirical literature in analysing inter-dependant equations that maybe correlated across a recursive system (Melesse eta l., 2021). The CMP can run employing binary, ordered or truncated dependant variables. The framework allows us to include the endogenous independent variable in one equation to act as dependant variable in the other equation through recursive arrangement. Therefore, CMP offers better estimates as compared to standard single equation techniques. The joint probability for adoption of agricultural technology in our analysis is therefore estimated using conditional (recursive) mixed process estimator (CMP). [1]

In our analysis we have seven agronomic practices- climate requirement, fertiliser and manure applications, plant protection, water management, harvesting, threshing and storage, seed rate and spacing and seed treatment. Adoption of each of these agronomic practices is analysed using probit equation which has been allowed to interact with the insurance access model. So, both the equations (access to insurance and adoption of each practice) are modelled using probit equations.

However, the adoption of a greater number of practices are definitely superior to adoption of a smaller number of practices. Farmers may choose a single practice or a combination of practices. Therefore, we can rank the adoption from 1 to 7 as we have 7 agronomic practices. The 8th model is run using probit equation (access to insurance) as the first part and an ordered probit equation (total number of agronomic practices) as the second part. The variables that affect the adoption of a single agronomic practice may differently affect the adoption of more than one practices (Teklewold et al, 2013). This is because the probability for adopting first practice can differ from the probability of adopting a second practice or a third practice and so on.

8.4 Results and Discussion

The results from bivariate probit models showed that availing of crop insurance increased the likelihood of adopting almost all the agronomic practices except water management practice. As far as the access to crop insurance model is concerned, farm size, satisfactory rainfall, membership with input supply co-operatives, knowledge of KCC, availing of loan under KCC, experience of crop failure and access to off farm activities increased the likelihood of availing insurance (see Tables 8.1 to 8.7). The results from ordered probit model also supported the hypothesis that the insurance is increasing the adoption of agronomic practices (see Table 8.8). Similar to bivariate probit models, farm size, satisfactory rainfall, membership with input supply co-operatives, knowledge of KCC, availing of loan under KCC, experience of crop failure and access to off farm activities increased the likelihood of availing insurance even in the ordered probit model.

Table 8.1: Climate Requirement – Probit Models

Variable	Climate Requirement	
	Co-efficient	Marginal Effects
Have Crop Insurance		
Years of Experience in Farming	-.011 (.010)	-.001 (.001)
Years of Education	-.010 (.032)	-.001 (.003)
Number of Family Members	.042 (.049)	.004 (.005)
Farm Size (Acres)	.146 (.063)**	.016 (.007)**
Access to Off-Farm Activities	.287 (.429)	.031 (.047)
Is the Rainfall Satisfactory	1.340 (.292)***	.149 (.032)***
Member of Input Supply Cooperatives	.837 (.285)***	.093 (.031)***
Experience of Crop Failures	.753 (.271)**	.083 (.029)**
Knowledge of KCC	1.202 (.378)***	.133 (.040)***
Availed Loan Under KCC	.640 (.322)**	.071 (.035)**
Contact with Government Extension Agents	.189 (.314)	.021 (.034)
Ln Distance	.194 (.283)	.021 (.031)
Availing MSP for Black Gram	.246 (.417)	.027 (.046)
Ln Farm Income	-.210 (.171)	-.023 (.019)
Constant	-.108 (2.048)	
Climate Requirement		
Years of Experience in Farming	.002 (.007)	.007 (.001)
Years of Education	.033 (.023)	.008 (.006)
Number of Family Members	-.074 (.035)**	-.018 (.009)**
Farm Size (Acres)	.043 (.022)**	.011 (.005)**
Access to Off-Farm Activities	1.296 (.238)***	.330 (.053) **
Is the Rainfall Satisfactory	-.440 (.201)**	-.112 (.051) ***
Member of Input Supply Cooperatives	-.890 (.243)***	-.221 (.049) **
Experience of Crop Failures	-.752 (.200)***	-.191 (.048) ***
Knowledge of KCC	-.620 (.320)**	-.158 (.082)**
Availed Loan Under KCC	-.871 (.204)***	-.221 (.049)***
Contact with Government Extension Agents	.479 (.223)**	.122 (.055)**
Ln Distance	.147 (.151)	.037 (.038)
Availing MSP for Black Gram	.326 (.239)	.083 (.060)
Have Crop Insurance	1.947 (.413)***	.495 (.104)***
Ln Farm Income	-.126 (.117)	-.032 (.029)
Constant	.682 (1.327)	
No of observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.2. Fertiliser and Manure Application – Probit Models

Variable	Fertiliser and Manure Application	
	Co-efficient	Marginal Effects
Have Crop Insurance		
Years of Experience in Farming	-.012 (.010)	-.001 (.001)
Years of Education	.003 (.032)	.000 (.003)
Number of Family Members	.045 (.049)	.005 (.005)
Farm Size (Acres)	.116 (.063)*	.012 (.007)*
Access to Off-Farm Activities	.163 (.431)	.018 (.047)
Is the Rainfall Satisfactory	1.372 (.301)***	.152 (.032)***
Member of Input Supply Cooperatives	.817 (.290)**	.090 (.031)**
Experience of Crop Failures	.623 (.280)**	.069 (.030)**
Knowledge of KCC	1.138 (.388)***	.126 (.041)***
Availed Loan Under KCC	.693 (.332)**	.076 (.036)**
Contact with Government Extension Agents	.204 (.312)	.022 (.034)
Ln Distance	.204 (.297)	.022 (.032)
Availing MSP for Black Gram	.378 (.406)	.041 (.044)
Ln Farm Income	-.142 (.175)	-.015 (.019)
Constant	-.858 (2.159)	
Fertiliser and Manure Application		
Years of Experience in Farming	-.002 (.007)	-.000 (.001)
Years of Education	.013 (.025)	.003 (.005)
Number of Family Members	-.061 (.037)*	-.014 (.008)*
Farm Size (Acres)	.015 (.016)	.003 (.003)
Access to Off-Farm Activities	1.392 (.243)***	.322 (.048)***
Is the Rainfall Satisfactory	-.741 (.228)***	-.171 (.052)***
Member of Input Supply Cooperatives	-1.716 (.283)***	-.398 (.057)***
Experience of Crop Failures	-.783 (.202)***	-.181 (.044)***
Knowledge of KCC	.870 (.518)*	.201 (.116)*
Availed Loan Under KCC	-1.044 (.230)***	-.242 (.050)***
Contact with Government Extension Agents	1.035 (.273)***	.240 (.059)***
Ln Distance	-.361 (.159)**	-.083 (.036)**
Availing MSP for Black Gram	.447 (.278)*	.103 (.063)*
Have Crop Insurance	1.185 (.670)*	.274 (.158)*
Ln Farm Income	.002 (.116)	.000 (.027)
Constant	.046 (1.328)	
No of observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.3: Plant Protection – Probit Models

Variable	Plant Protection	
	Co-efficient	**Marginal Effects**
Have Crop Insurance		
Years of Experience in Farming	-.009 (.010)	-.001 (.001)
Years of Education	-.001 (.032)	-.000 (.003)
Number of Family Members	.049 (.049)	.005 (.005)
Farm Size (Acres)	.131 (.060)**	.014 (.006)**
Access to Off-Farm Activities	.214 (.426)	.023 (.047)
Is the Rainfall Satisfactory	1.296 (.302)***	.144 (.032)***
Member of Input Supply Cooperatives	.706 (.294)**	.078 (.031)**
Experience of Crop Failures	.642 (.276)**	.071 (.030)**
Knowledge of KCC	1.223 (.378)***	.136 (.041)***
Availed Loan Under KCC	.723 (.325)**	.080 (.035)**
Contact with Government Extension Agents	.259 (.298)	.028 (.033)
Ln Distance	.282 (.296)	.031 (.032)
Availing MSP for Black Gram	.216 (.417)	.024 (.046)
Ln Farm Income	-.178 (.169)	-.019 (.018)
Constant	-.689 (2.040)	
Plant Protection		
Years of Experience in Farming	.002 (.007)	.000 (.001)
Years of Education	.038 (.025)	.008 (.005)
Number of Family Members	-.082 (.038)**	-.017 (.008)**
Farm Size (Acres)	.056 (.026)**	.011 (.005)**
Access to Off-Farm Activities	1.478 (.284)***	.314 (.052)***
Is the Rainfall Satisfactory	-.636 (.231)**	-.135 (.049)**
Member of Input Supply Cooperatives	-1.019 (.271)***	-.217 (.055)***
Experience of Crop Failures	-.783 (.222)***	-.166 (.045)***
Knowledge of KCC	-.089 (.373)	-.019 (.079)
Availed Loan Under KCC	-.771 (.228)***	-.164 (.046)***
Contact with Government Extension Agents	.929 (.235)***	.197 (.047)***
Ln Distance	.831 (.172)***	.177 (.032)***
Availing MSP for Black Gram	.534 (.259)**	.113 (.054)**
Have Crop Insurance	1.799 (.508)***	.383 (.112)***
Ln Farm Income	-.163 (.128)	-.034 (.027)
Constant	-1.111 (1.449)	
No of observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.4: Water Management – Probit Models

Variable	Water Management	
	Co-efficient	Marginal Effects
Have Crop Insurance		
Years of Experience in Farming	-.012 (.010)	-.001 (.001)
Years of Education	.004 (.034)	.000 (.003)
Number of Family Members	.050 (.061)	.005 (.006)
Farm Size (Acres)	.129 (.069)*	.014 (.008)*
Access to Off-Farm Activities	.139 (.477)	.015 (.053)
Is the Rainfall Satisfactory	1.345 (.305)***	.150 (.032)***
Member of Input Supply Cooperatives	.770 (.289)**	.085 (.031)**
Experience of Crop Failures	.671 (.287)**	.074 (.032)**
Knowledge of KCC	1.121 (.428)**	.125 (.044)**
Availed Loan Under KCC	.617 (.334)*	.068 (.037)*
Contact with Government Extension Agents	.166 (.370)	.018 (.041)
Ln Distance	.109 (.315)	.012 (.034)
Availing MSP for Black Gram	.374 (.397)	.041 (.044)
Ln Farm Income	-.174 (.176)	-.019 (.019)
Constant	-.221 (2.120)	
Water Management		
Years of Experience in Farming	-.010 (.009)	-.001 (.001)
Years of Education	-.052 (.035)	-.008 (.005)
Number of Family Members	-.129 (.061)**	-.019 (.009)**
Farm Size (Acres)	.006 (.024)	.000 (.003)
Access to Off-Farm Activities	-.275 (.394)	-.042 (.060)
Is the Rainfall Satisfactory	.113 (.737)	.017 (.112)
Member of Input Supply Cooperatives	-1.624 (.444)***	-.248 (.070)***
Experience of Crop Failures	-.030 (.405)	-.004 (.062)
Knowledge of KCC	.383 (1.289)	.058 (.194)
Availed Loan Under KCC	-.071 (.423)	-.010 (.064)
Contact with Government Extension Agents	.231 (.301)	.035 (.045)
Ln Distance	.934 (.207)***	.142 (.026)***
Availing MSP for Black Gram	-.297 (.401)	-.045 (.061)
Have Crop Insurance	-.192 (2.921)	-.029 (.445)
Ln Farm Income	-.075 (.147)	.011 (.022)
Constant	-2.331 (1.684)	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.5: Harvesting, Threshing and Storage – Probit Models

Variable	Harvesting, Threshing and Storage	
	Co-efficient	Marginal Effects
Have Crop Insurance		
Years of Experience in Farming	-.019 (.010)**	-.002 (.001)**
Years of Education	-.009 (.033)	-.001 (.003)
Number of Family Members	.065 (.049)	.007 (.005)
Farm Size (Acres)	.141 (.061)**	.015 (.006)**
Access to Off-Farm Activities	.457 (.442)	.050 (.048)
Is the Rainfall Satisfactory	1.391 (.304)***	.152 (.032)***
Member of Input Supply Cooperatives	.842 (.304)**	.092 (.032)***
Experience of Crop Failures	.767 (.268)***	.083 (.028)***
Knowledge of KCC	1.174 (.393)***	.128 (.040)***
Availed Loan Under KCC	.748 (.326)**	.081 (.035)**
Contact with Government Extension Agents	.037 (.309)	.004 (.033)
Ln Distance	.285 (.300)	.031 (.032)
Availing MSP for Black Gram	.144 (.434)	.015 (.047)
Ln Farm Income	-.222 (.175)	-.024 (.019)
Constant	-.014 (2.111)	
Harvesting, Threshing and Storage		
Years of Experience in Farming	.007 (.007)	.001 (.001)
Years of Education	-.036 (.027)	-.008 (.005)
Number of Family Members	-.048 (.036)	-.010 (.008)
Farm Size (Acres)	-.006 (.013)	-.001 (.003)
Access to Off-Farm Activities	1.614 (.257)***	.355 (.046)***
Is the Rainfall Satisfactory	-.692 (.209)***	-.152 (.046)***
Member of Input Supply Cooperatives	-1.393 (.296)***	-.306 (.059)***
Experience of Crop Failures	-1.155 (.196)***	-.254 (.037)***
Knowledge of KCC	-.454 (.360)***	-.100 (.080)
Availed Loan Under KCC	-.201 (.226)	-.044 (.049)
Contact with Government Extension Agents	.809 (.260)***	.178 (.054)***
Ln Distance	-.117 (.154)	-.025 (.034)
Availing MSP for Black Gram	.828 (.309)**	.182 (.064) **
Have Crop Insurance	1.856 (.378)***	.408 (.090)***
Ln Farm Income	-.002 (.116)	-.000 (.025)
Constant	-.387 (1.311)	
No of observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.6: Seed Rate, Spacing and Method – Probit Models

Variable	Seed Rate, Spacing and Method	
	Co-efficient	**Marginal Effects**
Have Crop Insurance		
Years of Experience in Farming	-.011 (.010)	-.001 (.001)
Years of Education	-.007 (.032)	-.000 (.003)
Number of Family Members	.059 (.048)	.006 (.005)
Farm Size (Acres)	.147 (.064)**	.016 (.007)**
Access to Off-Farm Activities	.144 (.430)	.015 (.047)
Is the Rainfall Satisfactory	1.350 (.306)***	.149 (.032)***
Member of Input Supply Cooperatives	.810 (.287)***	.089 (.030)***
Experience of Crop Failures	.656 (.270)**	.072 (.029)**
Knowledge of KCC	1.223 (.407)***	.134 (.042)***
Availed Loan Under KCC	.756 (.337)**	.083 (.036)**
Contact with Government Extension Agents	.282 (.303)	.031 (.033)
Ln Distance	.293 (.290)	.032 (.032)
Availing MSP for Black Gram	.305 (.407)	.033 (.044)
Ln Farm Income	-.224 (.180)	-.024 (.019)
Constant	-.338 (2.072)	
Seed Rate, Spacing and Method		
Years of Experience in Farming	.004 (.007)	.001 (.001)
Years of Education	.008 (.025)	.002 (.006)
Number of Family Members	-.050 (.036)	-.011 (.008)
Farm Size (Acres)	-.005 (.013)	-.001 (.003)
Access to Off-Farm Activities	1.202 (.247)***	.281 (.050)***
Is the Rainfall Satisfactory	-.573 (.210)**	-.134 (.050)**
Member of Input Supply Cooperatives	-1.903 (.328)***	-.446 (.062)***
Experience of Crop Failures	-.994 (.190)***	-.233 (.040)***
Knowledge of KCC	.517 (.421)	.121 (.094)***
Availed Loan Under KCC	-.798 (.214)***	-.187 (.048)
Contact with Government Extension Agents	.773 (.258)***	.181 (.056)***
Ln Distance	-.185 (.152)	-.043 (.035)***
Availing MSP for Black Gram	.912 (.330)**	.213 (.071)**
Have Crop Insurance	1.554 (.462)***	.364 (.117) ***
Ln Farm Income	-.038 (.115)	-.009 (.027)
Constant	.012 (1.290)	
No of Observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.7: Seed Treatment – Probit Models

Variable	Seed Rate, Spacing and Method	
	Co-efficient	Marginal Effects
Have Crop Insurance		
Years of Experience in Farming	-.016(.009)*	.002(.001)*
Years of Education	.010(.032)	.001(.004)
Number of Family Members	.062(.045)	.007(.005)
Farm Size (Acres)	.108(.058)*	.012(.007)*
Access to Off-Farm Activities	.369(.401)	.042(.047)
Is the Rainfall Satisfactory	1.499(.276)***	.170(.031)***
Member of Input Supply Cooperatives	.889(.269)***	.101(.030)***
Experience of Crop Failures	.553(.241)**	.063(.027)**
Knowledge of KCC	1.367(.356)***	.155(.038)***
Availed Loan Under KCC	.752(.322)**	.085(.037)**
Contact with Government Extension Agents	.126(.277)	.014(.031)
Ln Distance	.380(.217)*	.043(.026)*
Availing MSP for Black Gram	.168(.425)	.019(.048)
Ln Farm Income	-.101(.134)	-.011(.015)
Constant	-1.998(1.572)	
Years of Experience in Farming	.007(.007)	.002(.002)
Years of Education	-.000(.025)	-.000(.006)
Number of Family Members	-.067(.035)**	-.015(.008)**
Farm Size (Acres)	-.005(.014)	-.001(.003)
Access to Off-Farm Activities	1.281(.237)***	.296(.048)***
Is the Rainfall Satisfactory	-.673(.190)***	-.155(.044)***
Member of Input Supply Cooperatives	-2.017(.279)***	-.465(.053)***
Experience of Crop Failures	-1.141(.189)***	-.263(.038)***
Knowledge of KCC	.197(.290)	.045(.066)
Availed Loan Under KCC	-.777(.207)***	-.179(.046)***
Contact with Government Extension Agents	.449(.228)**	.104(.052)**
Ln Distance	.013(.149)	.003(.034)
Availing MSP for Black Gram	.660(.275)**	.152(.062)**
Have Crop Insurance	2.31(.229)***	.533(.048)***
Ln Farm Income	-.022(.103)	-.005(.024)
Constant	-.277(1.184)	
No of Observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.8: Probit and Ordered Probit Models

Variable	Total Black Gram	
	Co-efficient	**Marginal Effects**
Have Crop Insurance		
Years of Experience in Farming	-.016 (.010)	-.001 (.001)
Years of Education	-.003 (.033)	-.003 (.003)
Number of Family Members	.075 (.052)	.008 (.005)
Farm Size (Acres)	.129 (.061)**	.014 (.007)*
Access to Off-Farm Activities	.254 (.453)	.027 (.049)
Is the Rainfall Satisfactory	1.245 (.307)***	.134 (.030)***
Member of Input Supply Cooperatives	.898 (.281)***	.096 (.029)***
Experience of Crop Failures	.679 (.250)***	.073 (.027)***
Knowledge of KCC	1.343 (.371)***	.144 (.038)***
Availed Loan Under KCC	.772 (.325)**	.083 (.034)**
Contact with Government Extension Agents	.239 (.321)	.025 (.034)
Ln Distance	.269 (.290)	.029 (.031)
Availing MSP for Black Gram	.009 (.439)	.001 (.047)
Ln Farm Income	-.225 (.159)	-.024 (.017)
Constant	-.216 (.920)	
Total Black Gram		
Years of Experience in Farming	.015 (.008)*	.015 (.008)*
Years of Education	-.002 (.025)	-.002 (.025)
Number of Family Members	-.147 (.040)***	-.147 (.040)***
Farm Size (Acres)	.077 (.033)**	.077 (.033)**
Access to Off-Farm Activities	1.427 (.292)***	. 1.427 (.292)***
Is the Rainfall Satisfactory	-.601 (.221)**	-.601 (.221)**
Member of Input Supply Cooperatives	-1.298 (.257)***	-1.298 (.257)***
Experience of Crop Failures	-1.041 (.247)***	-1.041 (.247)***
Knowledge of KCC	-.640 (.363)*	-.640 (.363)*
Availed Loan Under KCC	-.445 (.241)*	-.445 (.241)*
Contact with Government Extension Agents	.823 (.266)***	.823 (.266)***
Ln Distance	.958 (.221)***	.958 (.221)***
Availing MSP for Black Gram	-.108 (.253)	-.108 (.253)
Have Crop Insurance	2.867 (.289)***	2.867 (.289)***
Ln Farm Income	-.188 (.119)*	-.188 (.119)*
Constant	-.219 (1.446)	
No of Observations	390	

Notes: ***, ** and * indicates statistical significance at 1%, 5% and 10% respectively. Standard errors are in parentheses.

Table 8.9: Descriptive Statistics

Variables	All Farmers	Non-Adopters
Years of Experience in Farming	26.598 (11.922)	25.326 (12.528)
Years of Education	7.574 (4.931)	8.038 (4.353)
Number of Family Members	5.346 (2.564)	6.538 (2.845)
Farm Size (Acres)	5.438 (7.263)	2.734 (2.859)
Access to Off-Farm Activities	.317 (.466)	.096 (.296)
Is the Rainfall Satisfactory	.435 (.496)	.403 (.493)
Member of Input Supply Cooperatives	.615 (.487)	.788 (.410)
Experience of Crop Failures	.558 (.497)	.836 (.371)
Knowledge of KCC	.892 (.310)	.923 (.267)
Availed Loan Under KCC	.589 (.492)	.711 (.455)
Contact with Government Extension Agents	.874 (.331)	.769 (.423)
Walking Distance from the Market	12.584 (8.401)	9.413 (5.841)
Availing MSP for Black Gram	.471 (.499)	.346 (.478)
Have Crop Insurance	.866 (.340)	.836 (.271)
Annual Family Income	217141 (327533.6)	270536.5 (293804.7)
Number of Observations	390	104

Table 8.10: Descriptive Statistics for Adopters of Agronomic Practices – Black Gram

Variables	Climate	Fertiliser & Manure	Plant Protection	Water Management	Harvesting, Threshing &Storage	Seed Rate, Spacing &Method
Years of Experience in Farming	26.7 (11.5)	26.4 (10.6)	26.2 (11.9)	30.0 (11.9)	28.3 (10.5)	27.2 (10.7)
Years of Education	8.3 (4.9)	7.9 (4.9)	8.5 (4.9)	8.6 (4.5)	7.3 (5.0)	7.7 (4.9)
Number of Family Members	5.2 (2.4)	5.2 (2.5)	5.1 (2.3)	5.7 (2.6)	5.2 (2.6)	5.2 (2.6)
Farm Size (Acres)	6.6 (9.1)	6.4 (9.3)	6.7 (8.7)	5.4 (7.9)	6.1 (6.6)	5.8 (6.5)
Access to Off-Farm Activities	.4 (.5)	.5 (.5)	.5 (.5)	.4 (.5)	.6 (.5)	.5 (.5)
Is the Rainfall Satisfactory	.4 (.5)	.4 (.5)	.4 (.5)	.3 (.5)	.4 (.5)	.4 (.5)
Member of Input Supply Cooperatives	.6 (.5)	.6 (.5)	.6 (.5)	.8 (.4)	.6 (.5)	.5 (.5)
Experience of Crop Failures	.4 (.5)	.4 (.5)	.5 (.5)	.6 (.5)	.3 (.4)	.3 (.5)
Knowledge of KCC	.9 (.3)	.9 (.3)	.9 (.3)	.9 (.3)	.9 (.3)	.9 (.3)
Availed Loan Under KCC	.5 (.5)	.5 (.5)	.5 (.5)	.6 (.5)	.5 (.5)	.5 (.5)
Contact with Government Extension Agents	.9 (.2)	.9 (.2)	.9 (.2)	.9 (.3)	.9 (.2)	.9 (.2)

Variables	Climate	Fertiliser & Manure	Plant Protection	Water Management	Harvesting, Threshing &Storage	Seed Rate, Spacing &Method
Walking Distance from the Market	12.9 (8.9)	10.8 (6.9)	14.2 (9.4)	11.6 (8.3)	10.0 (5.6)	10.9 (7.1)
Availing MSP for Black Gram	.6 (.5)	.6 (.5)	.6 (.5)	.6 (.5)	.6 (.5)	.6 (.5)
Have Crop Insurance	.9 (.3)	.9 (.3)	.9 (.3)	.9 (.3)	.9 (.3)	.9 (.3)
Annual Family Income						
Number of Observations	209	186	230	86	175	181

Note: Standard deviations are in parentheses.

Table 8.11: Farmers with Crop Insurance

Climate	Fertiliser & Manure	Plant Protection	Water Management	Harvesting, Threshing & Storage	Seed Treatment	Seed Rate, Spacing & Method
.88(.32)	.87 (.34)	.89 (.31)	.79 (.41)	.86 (.34)	.87 (.33)	.86 (.34)
209	186	230	86	175	196	181

Note: Standard deviations are in parentheses.

8.5 Conclusion

The results from the analysis in this chapter showed the crop insurance play a significant role in affecting farmers adoption of various agronomic practices. Similarly, variables such as farm size, membership in input supply co-operatives, crop failure, access to off-farm activities etc increased the likelihood of accessing the crop insurance. Apart from crop insurance the other factors that affected the likelihood of adopting various agronomic practices were farm size, access to government's extension services and availing of MSP.

CHAPTER 9

INDIA'S IMPORTS OF PULSES AND MYANMAR – KEY LESSONS AND OBSERVATIONS

9.1 Introduction

The present chapter will discuss India's import dependency on pulses imports with a special focus on Myanmar and the lessons that can be learned from Myanmar's successful experience.

9.2 The Import Scenario

The imports of green gram and black gram are currently not facing any import restrictions and are placed under the free category. Thus, India has continually depended on imports since 1981 and has emerged as the largest importer of pulses in the world at present. During the 1970s and 1980s, imports were restricted in order to protect the interest of domestic farmers. The government achieved this by imposing trade barriers such as quotas, tariffs and quantitative restrictions. It was in 1990-91 when India faced a balance of payment crisis that the possible growth benefits of trade liberalization were realized and import duties declined steadily. From 2007-12, imports of pulses were made duty free and in 2013 the custom's duty on imports was reduced to zero (Negi and Roy, 2015). The perpetual shortage in India's pulses production in the wake of rising demand and adoption of a more liberal approach to international trade led to a rise in the volume of imports in the past decade.

It is estimated that around 20 per cent of total pulses demand is met through imports (Jadhav, Swamy, and C.P., 2018). In the financial year 2021-22 (April-January), India's imports of pulses (HS 0713) amounted to USD 1956.19, and exports amounted to USD 293.47 million, with a trade gap of USD 1663.19 million. While exports have increased by 28 per cent in the last five years, and imports have shown a decrease by 33 per cent in the same period, the trade gap remains and has been rising since 2018-19. The fluctuation of exports in terms of both value and volume has been attributed to a stagnation in production in India in the last five decades as well as fluctuations in the foreign exchange rate (Indian Council of Food and Agriculture, 2016; Joshi and Saxena, 2002; Srivastava et al., 2010).

In the context of India, the top 5 export destination and import sources for pulses have been presented below.

Table 9.1: Major Export Destinations and Import Sources for Pulses

Pulses	Top 3 Export Destinations (% of total exports)	Top 3 Import Sources (% of total exports)
Pulses (0713)	US (17 %), China (11%), Nepal (9%)	Canada (31.8%), Myanmar (23%), Republic of Tanzania (12%)

The government has been seeking to address the trade gap by placing restrictions on imports and subsidising exports since 2017. For example, moong and urad witnessed an import duty of 10 per cent in March, 2017 and there was a 30 per cent tariff on imports of the desi variety of chickpeas and lentils in December, 2017 which was heightened to 40 per cent in February, 2018. In terms of export policy, the government of India made all varieties of pulses, including organic pulses free for exports without any quantitative ceilings in November, 2017, and in April, 2018 an export subsidy of 7 per cent was introduced for chickpeas under the Merchandise Exports from India Scheme for a period of 3 months. There has been an increasing policy emphasis on boosting domestic production and achieving self-sufficiency in pulses production. However, at the same time, in order to prevent a situation of scarcity, India has signed a MoU with countries such as Myanmar to import 250,000 tonnes of urd and 100,000 tonnes of tur for the subsequent 5 years from 2021-22.

9.3 Trade in Pulses – Global Trade in Pulses, with Emphasis on India

This section first examines the global trade in pulses (9.3.1), and then examines India's trade in pulses with a specific focus on green gram and black gram (section 9.4.1).

9.3.1 Global Trade in Pulses

The global trade in pulses (HS Code 0713) was valued at USD 2625.93 million in 2021, out of which exports were valued at USD 1296.75 million and imports were valued at USD 1329.2 million. The global trade in pulses increased by 2.35 percent between the period 2017-2021, with imports increasing by 2.18 percent and exports increasing by 7.5 percent in the same period. Table 9.2 presents the top 10 pulses importing countries in the world and their share in world imports, and table 9.3 presents the top 10 pulses exporting countries in the world, and their share in world exports. It can be seen that India is among the top ten pulse importing and exporting countries, constituting a share of 15.8 percent of global exports and 2.5 percent of global imports respectively.

Table 9.2: Top 10 Pulses Importing Countries (HS Code 0713), 2021 (USD million)

Rank	Country	Value (USD million)	Quantity (Million Tonnes)	Share
1	India	210.23	2.1	15.8
2	China	118.76	1.18	8.9
3	Pakistan	76.03	0.76	5.7
4	Turkey	67.03	0.67	5
5	Bangladesh	66.13	0.66	5
6	United States of America	54.86	0.54	4.1
7	United Arab Emirates	50.95	0.50	3.8
8	Egypt	37.21	0.37	2.8
9	Italy	36.02	0.36	2.7
10	Iraq	26.49	0.26	2

Source: ITC Trade Map

Table 9.3: Top 10 Pulses Exporting Countries (HS Code 0713), 2021

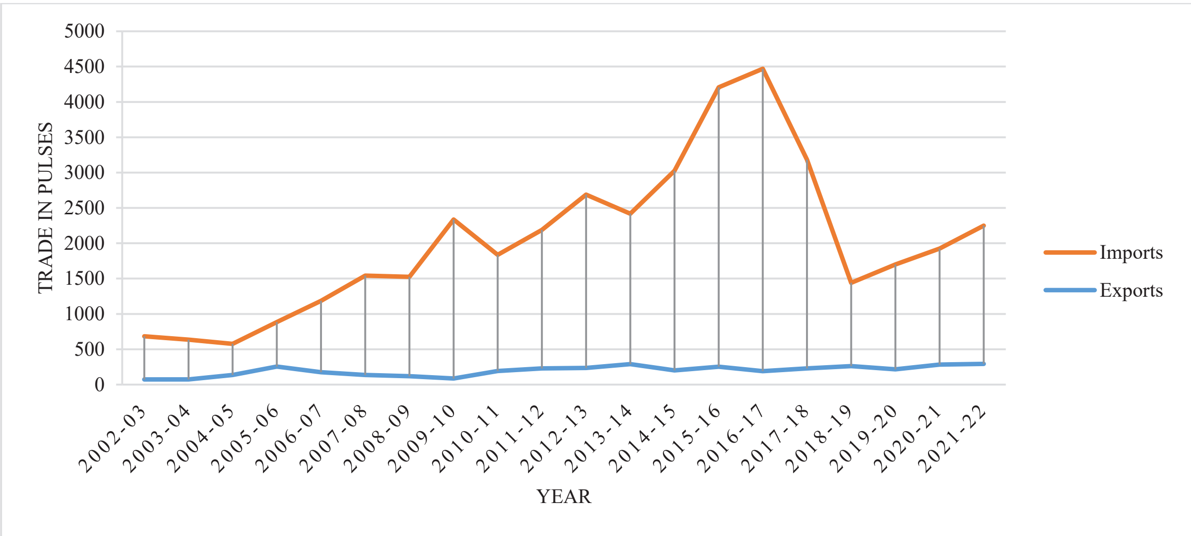
Rank	Country	Value (USD million)	Quantity (Million Tonnes)	Share
1	Canada	2.94	5.25	22.7
2	Australia	1.44	2.71	11.1
3	Myanmar	1.38	1.62	10.7
4	United States of America	0.87	1.12	6.7
5	Turkey	0.69	0.80	5.3
6	Russian Federation	0.63	1.52	4.9
7	Argentina	0.45	0.57	3.5
8	China	0.36	0.20	2.8
9	India	0.32	0.34	2.5
10	United Arab Emirates	0.29	0.28	2.2

Source: ITC Trade Map

9.4 Trade in Pulses: The Indian Scenario

For India, the most recent data is provided by the Directorate General of Foreign Trade (DGFT), Ministry of Commerce and Industry. In the financial year (FY) 2021-22, India imported pulses worth USD 2293.14 million from the world and exported pulses worth USD 380.29 million, marking a trade gap of USD 1912.85 million. The import-export gap in the last decade has been presented in Figure 9.1. For the months April-June of the financial year 2022-23, India's imports of pulses were valued at USD 295.39 million, and exports were valued at USD 256.85 million. While exports have increased by 28 per cent in the last five years, and imports have shown a decrease by 33 per cent in the same period, the trade gap remains and has been rising since 2018-19. The fluctuation of exports in terms of both value and volume has been attributed to a stagnation in production in India in the last five decades as well as fluctuations in the foreign exchange rate (Indian Council of Food and Agriculture, 2016; Joshi and Saxena, 2002; Srivastava et al., 2010). India has continually depended on imports since 1981 and has emerged as the largest importer of pulses in the world at present. During the 1970s and 1980s, imports were restricted in order to protect the interest of domestic farmers. The government achieved this by imposing trade barriers such as quotas, tariffs and quantitative restrictions. It was in 1990-91 when India faced a balance of payment crisis that the possible growth benefits of trade liberalization were realized and import duties declined steadily. From 2007-12, imports of pulses were made duty free and in 2013 the custom's duty on imports was reduced to zero (Negi and Roy, 2015). The perpetual shortage in India's pulses production in the wake of rising demand and adoption of a more liberal approach to international trade has led to a rise in the volume of imports in the past decade.

Figure 9.1: Trade Gap in Pulses in India in the Period 2002-03 to 2020-21



Source: Export-Import Data Bank, Directorate General of Foreign Trade, 2022

The top five countries from which India has imported pulses in the financial year 2021-22 include Myanmar, Canada, Mozambique, Tanzania Republic and Australia, constituting a share of 80.81 percent of total imports. Myanmar has been amongst the top three importing countries in the last five years, constituting a share of 33.15 percent of India's pulses imports in 2021-22. Table 9.4 presents the top ten countries whom India is importing pulses from, and their shares out of total global imports.

Table 9.4: Top 10 Pulses Importing Countries to India

Rank	Country	Values (USD Million)	Share (%)
1	Myanmar	760.24	33.15
2	Canada	411.24	17.93
3	Mozambique	294.68	12.85
4	Tanzania	263.29	11.48
5	Australia	123.74	5.40
6	Brazil	112.75	4.92
7	Sudan	70.18	3.06
8	Malawi	43.71	1.91
9	China	24.77	1.08
10	United Arab Emirates	24.13	1.05
	Total of Top 10	2128.73	92.83

Source: Export Import Data Bank, Ministry of Commerce and Industry, Government of India

In terms of exports, the top five export destinations for India's pulses include the United Arab Emirates, China, United States, Nepal, and Canada. constituting a total share of almost 80 percent of exports (see Table 9.5 for top 10 export destinations).

Table 9.5: Top 10 Countries for India's Export of Pulses

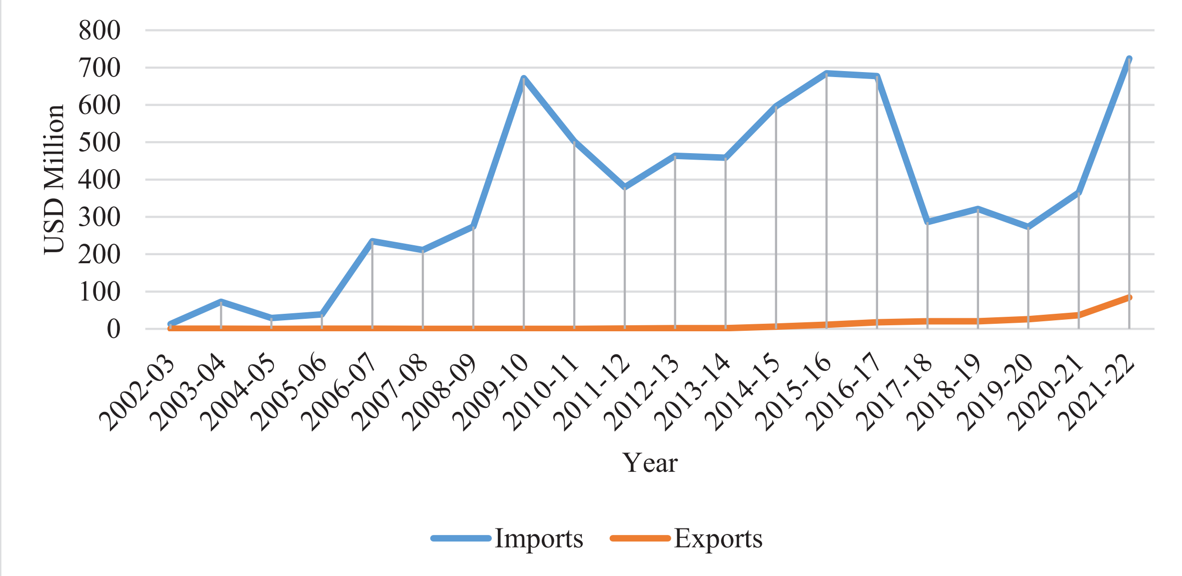
Rank	Country	Value (USD million)	Share (%)
1	United Arab Emirates	105.58	27.76
2	China	88.38	23.24
3	United States	44.12	11.60
4	Nepal	24.96	6.56
5	Canada	13	3.41
6	Iran	9.03	2.37
7	UK	8.99	2.36
8	Saudi Arabia	8.6	2.26
9	Sri Lanka	8.03	2.11
10	Bangladesh	7.81	2.05
	Total of Top 10		

Source: Export Import Data Bank, Ministry of Commerce and Industry, Government of India

9.4.1 India's Trade in Moong and Urad

In the financial year 2021-22, India imported moong bean and urad bean valued at USD 724.32 million (HS 071331) and exported moong bean and urad bean worth USD 84.22 million. Figure 9.2 presents India's imports and exports of moong and urad respectively and highlights the trade gap in each pulse category in the last decade. It can be seen that the exports of moong bean and urad bean have witnessed a gradual increase in the period 2014-15, when the Government of India removed an export curb on the exports of pulses in the wake of surplus production. Imports of moong bean and urad bean witnessed a sharp decline in the period 2017-18, and have been fluctuating until 2020-21.

Figure 9.2: India's Exports and Imports of Green Gram and Black Gram



Source: Export Import Data Bank, Ministry of Commerce and Industry, Government of India

The top 5 exporters for green gram and black gram in the financial year 2021-22, and top five importers for moong bean and urd bean, as well as the trade values have been provided in Table 9.6. Myanmar has emerged as the top importer of green gram and black gram, constituting 77.2 percent of India's total imports, while Mozambique, Tanzania, Afghanistan, and Singapore constitute 16.12 percent of India's total imports. In terms of exports of green gram and black gram, the United Arab Emirates is the top export destination, constituting 50.4 of total exports, while the United States, China, Nepal and Canada constitute 43 percent of India's total exports.

Table 9.6: Major Importers and Exporters of Green Gram and Black Gram

Rank	Import Source-Green Gram and Black Gram (USD million)	Export Destination-Green Gram and Black Gram (USD million)
1	Myanmar (559.41)	United Arab Emirates (22.5)
2	Mozambique (51.95)	United States (14.93)
3	Tanzania Republic	China (12.66)
4	Afghanistan (22.42)	Nepal (9.12)
5	Singapore (16.94)	Canada (6.38)

Source: Export Import Data Bank, Ministry of Commerce and Industry, Government of India

Myanmar has emerged as the top importing country for green gram and black gram. The next section examines Myanmar's production and trade in pulses to a greater extent.

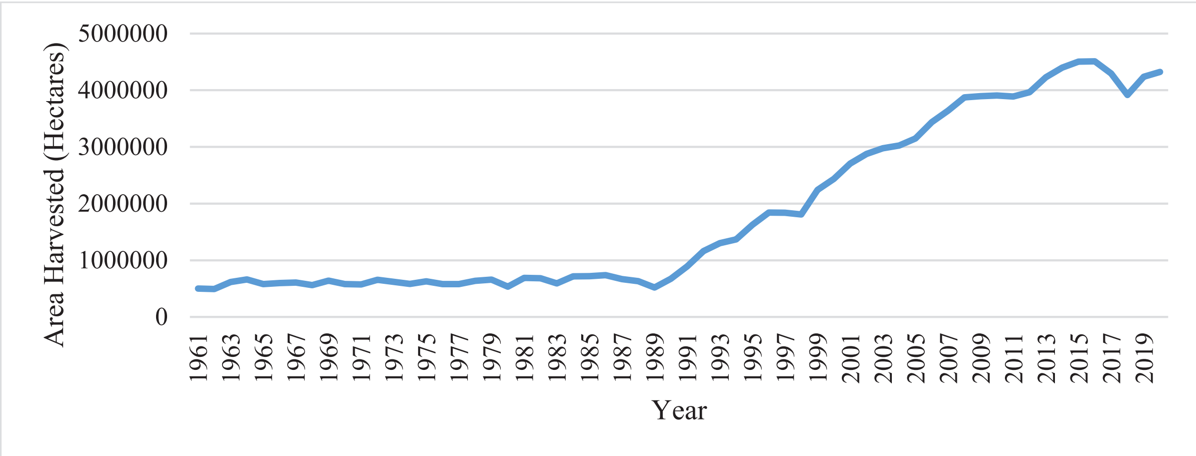
9.5 Pulses Production and Exports – Myanmar

The agricultural sector is the backbone of Myanmar's economy, representing around 38 per cent of GDP, and accounting for 50 per cent of the total employment (FAO, 2017; National Institute of Agricultural Extension Management, 2015). Within the agriculture sector, pulses have emerged as the second most import crop after rice with strong export potential. Myanmar is the leading producer of pulses in the ASEAN (Association of Southeast Asian Nations) region, one of the top five world producers for key pulse crops such as black gram, pigeonpea and chickpea, and the only country in Southeast Asia with surplus pulse production (Gumma et al, 2018; Raitzer et al., 2015).

9.5.1 Pulse Production and Yield in Myanmar

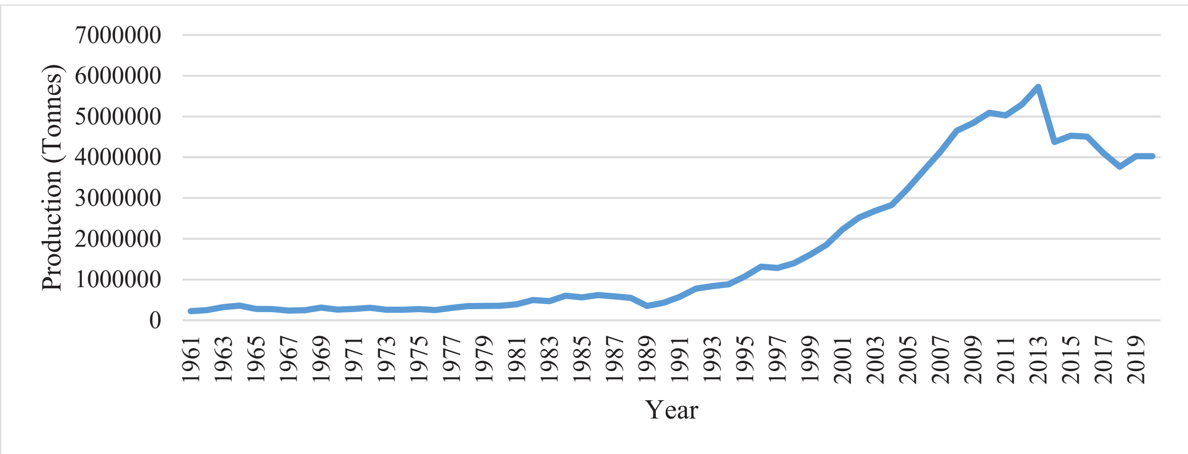
The pulses cultivation in Myanmar covers almost 6 percent of the overall land as of 2015-16 (4.4 million hectares). There are over 20 pulse varieties being grown in the country, with the major pulse varieties include green gram, black gram, chickpea, and pigeon pea, sown in 33 per cent of the arable land. Pulses have been cultivated in Myanmar since the 1960s, with production being facilitated by several factors including the wide range of agro-ecologies, diverse soils and new legume production systems. Between 1962-88, Myanmar's crop production and trade were governed by the government controlled agricultural marketing system, and 0.5-0.7 million hectares were under pulse cultivation. From 1988-2011, Myanmar's production and trade in pulses received major impetus with the launch of market-oriented economic reforms, wherein production quotas on pulses were lowered and domestic marketing was liberalised. This was complemented by the opening up of India's market to international suppliers of pulses after 1991, with India emerging as a key export destination for Myanmar's pulses. Figure 9.3, 9.4 and 9.5 presents the area harvested, production and yield of pulses in Myanmar between the period 1960-2020. Myanmar's trade scenario, as well as its export markets such as India are explored in greater detail in Section 9.6.

Figure 9.3: Area Harvested – Total Pulses in Myanmar, 1960-2020



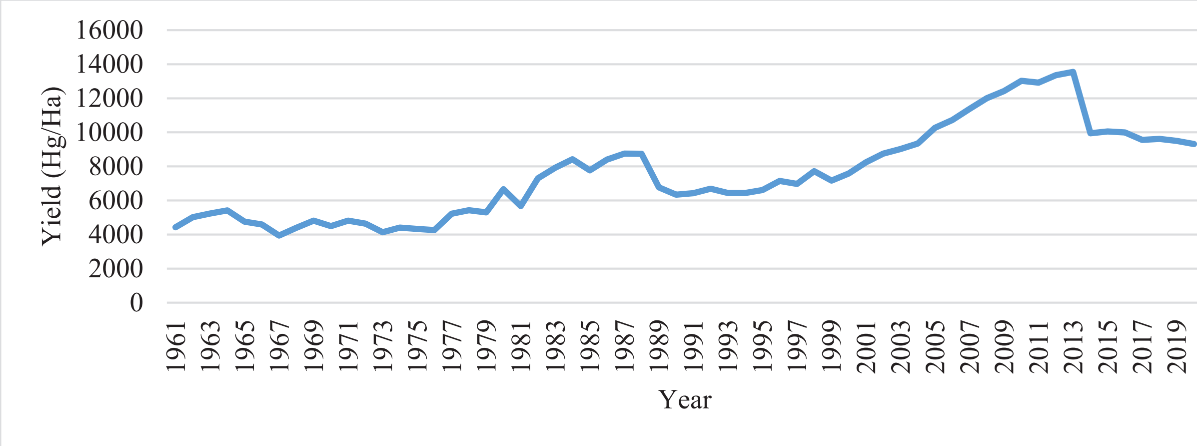
Source: FAOSTAT

Figure 9.4: Production of Pulses in Myanmar, 1960-2020



Source: FAOSTAT

Figure 9.5: Yield of Pulses in Myanmar, 1960-2020



Source: FAOSTAT

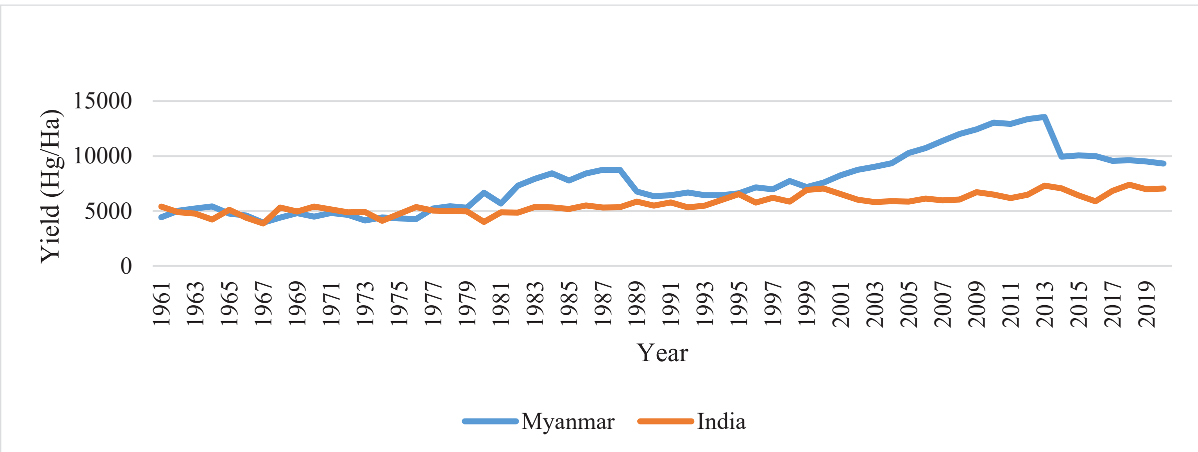
The area and production of pulses increased during the period 1961-2020 from 0.50 million hectares and 0.22 million tonnes in 1961 to 4.32 million hectares and 4.02 million tonnes in 2020 respectively. The yield grew from 4424 hectograms/ hectare to 9314 hectograms/ hectare in the same period. It is further observed that since 1977, the yield of pulses has been consistently higher than the yields witnessed in India, despite India having a large area and production throughout that period. Table 9.7 compares the area and production in Myanmar and India while Figure 9.6 presents the difference in yields over the years. Studies have attributed the lower yield in India to factors such as a decline in productivity as a result of drought in the mid and late 1990s, amongst others, and the yield difference between India and Myanmar to the favorable climatic conditions in Myanmar, as well as the lower area harvested in Myanmar as compared to India (Rimal, 2014).

Table 9.7: Area and Production of Pulses in Myanmar and India, 1961-2020

Indicator	Country	1961-62	1970-71	1980-81	1990-91	2000-01	2010-11	2020-21
Area (Hectares)	Myanmar	502504	579924	533533	673748	2435796	3907881	4322968
	India	23810206	22357900	22909500	23415000	19471600	26529800	33182633
Production (Tonnes)	Myanmar	222330	260633	355491	427410	1848459	5090700	4026467
	India	12859873	12085700	9167100	12856900	13712800	17236300	23368478

Source: FAOSTAT

Figure 9.6: Yield of Pulses in Myanmar and India, 1961-2020



Source: FAOSTAT

Table 9.8 presents the area harvested under major pulse varieties in the period 2017-18 to 2019-20. It is estimated that Myanmar's production of black gram in 2019-20 amounted to 1.3 million metric tonnes, while its production of green gram and pigeonpea amounted to 1.5 million metric tonnes and 0.50 million metric tonnes respectively, in the same period.

Table 9.8: Area Harvested under Major Pulse Varieties, 2017-18 to 2019-20 (hectares)

Pulse Type	2017-18	2018-19	2019-20
Black Gram	976349	946441	942181
Green Gram	1237975	1165321	1155166
Pigeonpea	658125	444459	441786
Cowpea	141195	124452	119418

Source: United States Department of Agriculture, 2020

9.6 Government Thrust to Pulse Production in Myanmar

The prioritisation of pulses is outlined in the Government of Myanmar's objectives of the agriculture sector, one of which is to 'step up the production and export of pulses and industrial crops'. The liberalisation of the Myanmar economy in 1981 and increased participation of the private sector, for instance, the formation of the Myanmar Pulses, Beans and Sesame Seeds Merchants Association in 1992, spurred the rapid growth of the pulses sector in Myanmar. In recent years, the Government of Myanmar has taken several steps to develop comprehensive strategies to increase productivity, enhance exports and contribute to the socio-economic development the entire supply chain in a sustainable manner. The key existing policies and strategies in the context of pulses are outlined below:

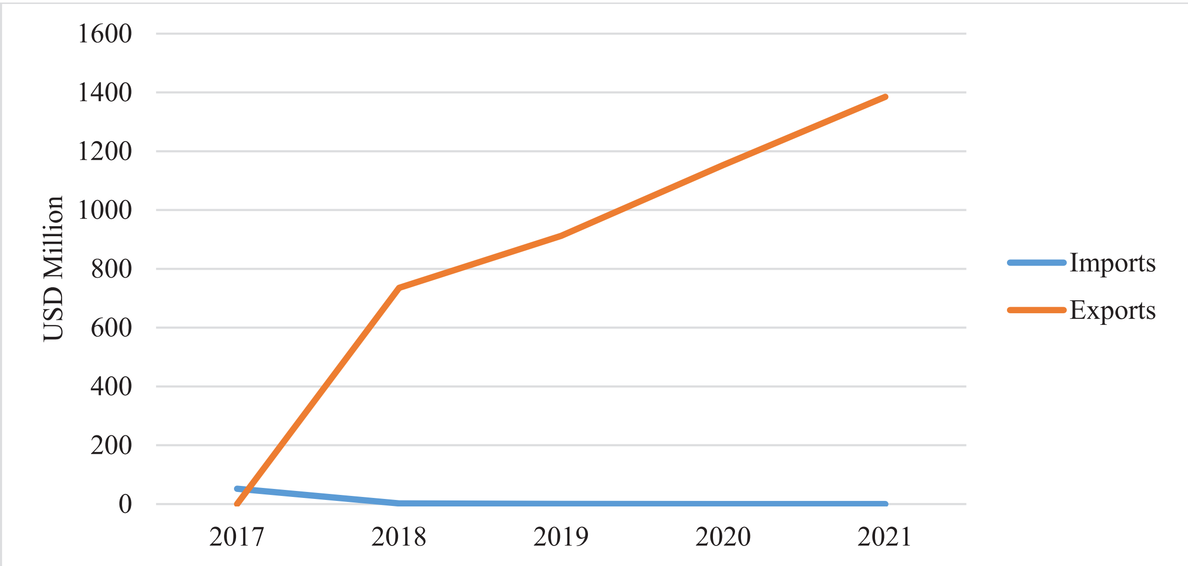
- **National Export Strategy for Beans, Pulses and Oilseeds, 2015-19:** The strategy envisions ' contributing to the socio-economic development of Myanmar by being a global provider of environmentally sustainable and value added products based on modern farming and trading techniques', through five strategic objectives: (a) increase production and productivity of the pulses, beans and oilseeds sector through enhanced farming techniques, upgradation of farmers; capabilities, improved infrastructure, (b) enable compliance of the sector's products to international standard, (c) strengthening cooperation and efficiency by enhancing inter-institutional collaboration and private-public partnerships, (d) enhancing business management capabilities and modernizing processing facilities and techniques, and (e) ensure continuous growth and global reach of the sector through reliable market information, more efficient export procedures, etc.
- **Ministry of Agriculture, Livestock and Irrigation Second Short-Term Five-Year Agriculture Policies and Strategic Thrusts, 2016:** This is a national sectoral policy that aims to develop an inclusive and internationally competitive agricultural production system with a focus on production.
- **Pulses Development Strategy, 2017:** This aims to create an 'inclusive, regionally and globally competitive, sustainable and adaptable pulses sector contributing to the socio-economic well-being of all members of the pulses supply chain' The implementation plan has a three-fold strategy namely(a) fostering a demand driven pulses sector by improving export market intelligence, developing a Myanmar pulses brand etc., (b) increasing productivity in the production and processing of pulses in Myanmar by strengthening governance, increasing research and development fundings, and increasing extension for good agricultural practices and (c) increasing the value and reducing the risk of production and processing in Myanmar.

9.6.1 Exports of Pulses

Myanmar has emerged as a major pulse exporting nation in the last three decades following the liberalisation of its agricultural sector, with its pulse export industry valued at over USD 1 billion. 'Dried leguminous vegetables (DLV)' which include black and green gram, chickpea and pigeonpea constitute Myanmar's second largest agricultural exports (19 percent of total exports) after rice (Roy, Ajmani, Boss, Pradhan and Laitha, 2022). According to government sources, black gram, black gram and pigeon pea (whole) account for around 75 per cent of total pulse exports. India has emerged as an important market for exports; around 80-90 per cent of Myanmar's pigeonpea production and 70-80 per cent of Myanmar's black gram production is exported to India. The export destinations for green gram are more extended and include countries such as Bangladesh, Malaysia, Indonesia. India and the European Union. The domestic price for pulses is also related to the demand experienced from key importing countries such as India (in the case of pigeonpea and black gram) and China (in the case of green gram) (United States Department of Agriculture, 2020).

As per the latest data available, Myanmar's pulse exports (HS 0713) were 1.6 billion tonnes, valued at USD 1385.17 million, while pulse imports were valued at USD 0.04 million in 2021. Pulse exports have witnessed a 33.7 percent increase from 2017 to 2021, while imports have witnessed a decline of almost 99 percent in the same period. These figures refer to only formal documented trade; studies indicate that around 26 percent of Myanmar's trade is undocumented, including trade to countries along its borders such as India, China, Thailand and Bangladesh. Figure 9.7 presents Myanmar's pulse imports and exports in the period 2017-21.[18]

Figure 9.7: Myanmar's Imports and Exports of Pulses (HS 0713) to the World between 2017-21



Source: UN Comtrade

9.6.2 Myanmar's Top Exporting Partners[19]

The pulses that are being grown extensively have gradually changed in accordance to market demand, with India and China emerging as the major export destinations. As per the latest data available from UN Comtrade, India and China account for almost 70 percent of total pulse

[18] The trade data for Myanmar's pulse imports and exports to the world is only available for the period 2017-21

[19] We have not examined Myanmar's imports given that UN Comtrade data for 2021 has only import data pertaining to few countries in the context of Myanmar.

exports, while the top five exporting partners (see table 9.9) constituting almost 87 per cent of total pulse exports.

Table 9.9: Myanmar's Top 5 Export Partners, 2021

Rank	Country	Values in USD Million (Share of Myanmar's Export to Total Export)
1	India	524.19 (37.8)
2	China	439.68 (31.7)
3	Singapore	110.35 (7.9)
4	Indonesia	69.133(4.9)
5	Pakistan	59.08 (4.2)
	Total of Top 5	1202.44 (86.8)

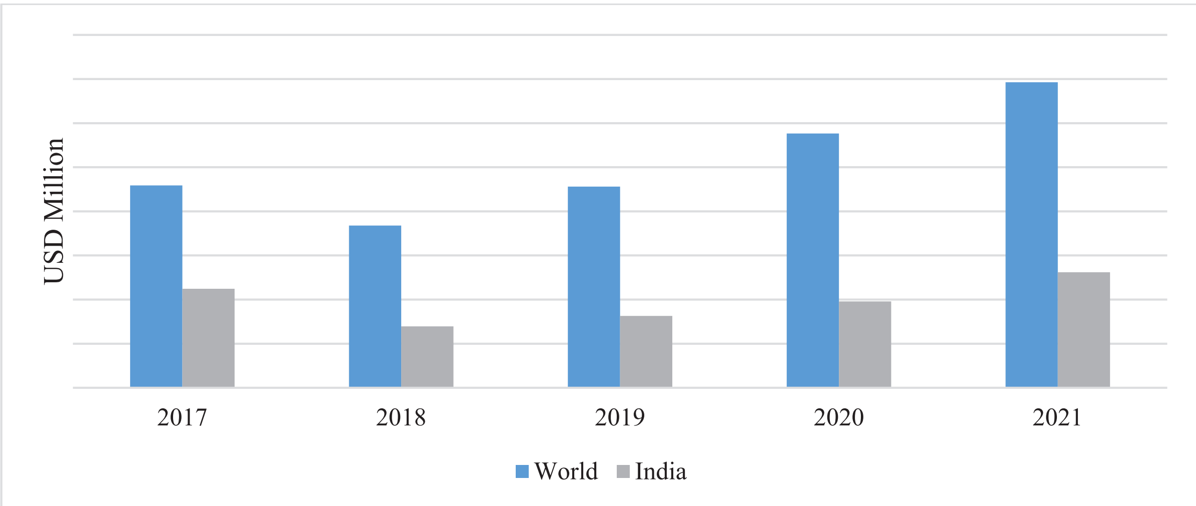
Source: UN Comtrade

India is the largest export destination for black gram and green gram, constituting almost 39 per cent of Myanmar's total exports, followed by China (18.4%) and Singapore (9.56%) in 2021. More than 97 per cent of Myanmar's pigeonpea exports are to India, followed by Nepal (2.65%) and Pakistan (0.25%). Given that India is a key trade partner with respect to pulses, and that India's import policies have impacted Myanmar's production over the years, the next section focuses on trade in pulses between Myanmar and India.

9.6.3 Myanmar and India: Trade in Pulses

Myanmar is the largest import partner for India in pulses. Figure 9.8 looks at the Myanmar's exports to the world in the last five years in comparison to Myanmar's export of pulses specifically to India. India's share in Myanmar's world exports has fallen from almost 49 per cent in 2017 to almost 38 per cent in 2021.

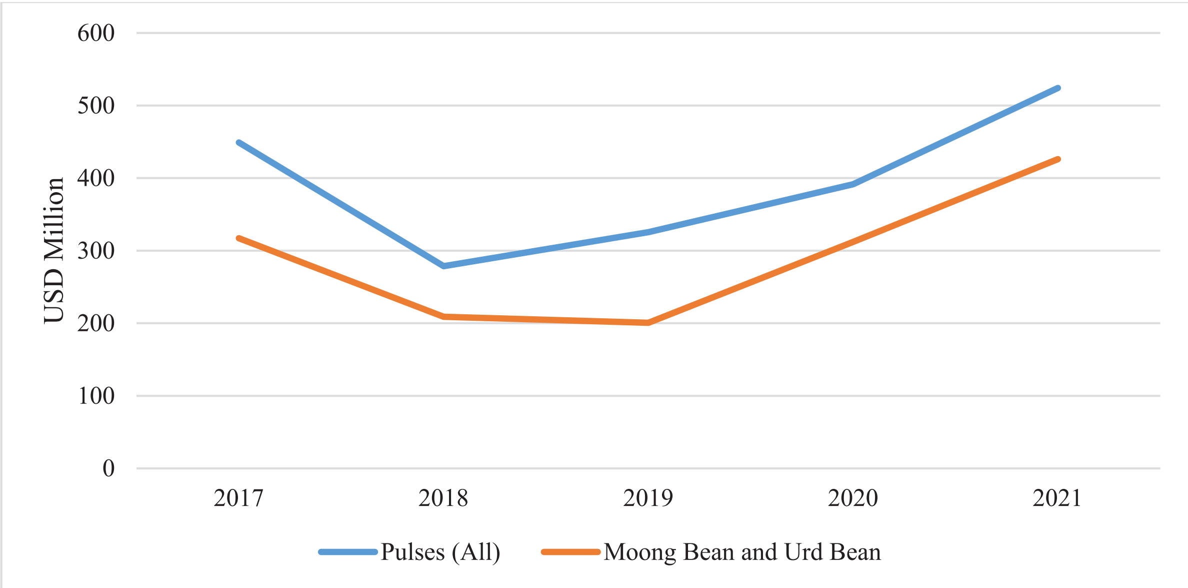
Figure 9.8: Myanmar's Exports



Source: UN Comtrade

Figure 9.9 further looks at Myanmar's pulse exports to India in the last five years, as well as the exports of green gram and black gram specifically. The exports of pulses (overall) as well as black gram and green gram have been fluctuating due to India's import restrictions and changing policies on imports of pulses, and increased production in India, which has detrimentally impacted Myanmar's production as well (see Box 9.11 for India's changing import policies over the years). Myanmar's exports of black gram and green gram have been particularly impacted with the expansion of countries exporting these pulses to India, such as Australia, Mozambique, Russia and Tanzania (Ajmani et al., 2018).

Figure 9.9: Myanmar's Pulses Exports to India in last 5 years



Source: UN Comtrade

9.11 Changes in India's Foreign Trade Policy from 1970s-present

1970s-1980s: Pulses were in India's special list, and were permitted only under licensed imports

1988-95/96: An import duty of 10 per cent was imposed, which was increased to 35 per cent in 1989/90. It was reduced to 5 per cent in 1996/97 and eliminated in 1998.

March, 2001: A duty of 5 per cent was imposed, subsequently removed, reinstated in February, 2002 and increased to 10 per cent later in the year.

2006-2017: The duty on pulse imports was completely removed.

August 5, 2017: Pulse imports were restricted to an annual fiscal quota of 2 lakh MT as per the procedure, and the import policy of pigeon peas was revised from 'free' to "restricted'.

August 21, 2017: The import of black/green gram (HS 07133100) was revised from 'free' to 'restricted', with imports being restricted to an annual fiscal quota of 3 lakh MT.

November 22, 2017: All varieties of pulses including organic pulses were made free for export without any quantitative ceilings.

December, 2017: Import duties increased to 30 per cent for chickpea and lentils

February, 2018: Import duties increased to 40 per cent for chickpea

28 September, 2018: The import of peas (including yellow peas, green peas, dun peas and kaspa peas) was revised from 'free' to 'restricted.

2018-19: Quantitative restrictions were placed on black/green gram (3 lakh MT) and pigeonpea (4 lakh MT)

March 29, 2022: The imports of black gram (HS 07133110) and Pigeon pea/tur (HS 07136000) was declared free until 31.03.2023.

Source: Circulars and notifications issued by the Ministry of Commerce and Industry, Government of India

India had extended its import policy of free imports of three pulse varieties from Myanmar, which was originally set to expire on January 31, 2022 to March 31, 2022. More recently, the Government of India has signed a MoU with the Government of Myanmar for the import of black gram and pigeonpea/tur from Myanmar in order to have a more stable and predictable import policy, wherein India has agreed to provide an annual quota of 2.5 lakh of black gram and 1 lakh MT of tur/pigeonpea of Myanmar origin to be imported, through private trade, over five financial years, i.e. 2021-22 to 2025-26. These imports are subject to the following conditions; (a) the imports will only be allowed through five ports, namely Mumbai, Tuticorin, Chennai, Kolkata and Hazira, and (b) the imports shall be subject to the production of "certificate of origin" certified by the authorised signatories of the Department of Trade, Ministry of Commerce. Given that India has been the largest market for the Myanmar pulse export industry in the last four decades, pulse producers in Myanmar seek a greater enhancement of the annual import quota, for instance 5 lakh tonnes for urd and 2 lakh tonnes for tur in the wake of high production anticipated, and to prevent a shift in production to other cash crops. There have also been talks to pursue the G2G advance agreement proposal, which was initially proposed in 2016, wherein India would buy an agreed upon quantity of pulses at pre-fixed prices from Myanmar; this has not come through until now since the two countries could not decide upon either the price or import volume in past discussions.

9.7 Conclusion

Through a descriptive analysis of the trends in area, production and exports of gram and urad from Myanmar with a comparison to India and the world showed that India is the largest export destination for black gram and green gram, constituting almost 39 per cent of Myanmar's total exports. The success of Myanmar in the export market is due to the relatively higher yield that they have achieved since 1960s. Whereas in India, the pulses production, including black gram and green gram were stagnant since 1960s and the yield was also poor. The differences in the food security policies in the two countries are also a reason for the differences in the emphasis on the crops. In India, the Green Revolution shifted focus more towards cereals production and enhancing the cereal production to meet the food security was a necessary in the 1960s and 1970s.

CHAPTER 10

CONCLUSION

Pulses play a significant role in a country like India and play a critical role in meeting the protein requirement of the Indian population. Pulses serve as a good substitute for the rural population, as other superior alternatives such as livestock and meat consumption is relatively low among them. The protein content in pulses is double the protein content of wheat and three times more than that of rice. While India is the largest producer of pulses in the world, the production of pulses is not sufficient to meet the growing domestic demand. Though the production has improved in recent years due to the government's efforts through an array of interventions such as the NFSM, the available quantity is still lower than the demand. The excess demand has resulted in high and volatile prices. The persistent deficit and the soaring pulses domestic prices make it inevitable for the country to import pulses. In spite of being the largest producer of pulses, the dependency on imported pulses continues to grow in the country.

Against this background, the present study makes an attempt to analyse the factors affecting the production and productivity of two major pulses varieties produced and consumed in India-black gram and green gram. The study analyses major agronomic practices recommended by the government for improving the productivity of these pulses, examines how the adoption of these practices takes place and measures impact of the adoption of these agronomic practices on crop yield. This analysis enables us to undertake a detailed examination of the impact of government interventions in the form of minimum support price policy and crop insurance, NFSM etc. in encouraging the adoption of yield enhancing agronomic practices. The study also makes an attempt to draw lessons from the successful experience of Myanmar as Myanmar is the largest importer of green gram and black gram to India. Around 80 percent of their domestic pulses production is being exported, and India is their major market. An analysis on Myanmar's domestic production and export will shed light into how they managed to become successful in the production of green gram and black gram.

Therefore, the specific objectives of the study are:

- To analyse the factors affecting the adoption of various yield enhancing agronomic practices among the black gram and green gram farmers.
- To understand the impact of adoption of various agronomic practices on crop yield.
- To study the impact of government interventions such as Minimum Support Price (MSP) in encouraging the adoption of various agronomic practices.
- To analyse the role of crop insurance in encouraging the farmers' adoption of various agronomic practices.
- To study the factors affecting the access to seed by taking into consideration various seed sources.
- To study the impact of seed sources on the market price received by farmers.
- To analyse the factors influencing the consumption demand and import dependency on pulses imported from Myanmar.

The study makes use of a comprehensive primary survey undertaken in four major pulses producing States-Madhya Pradesh, Andhra Pradesh, Maharashtra and Rajasthan. Using a multi stage random sampling technique, farmers are interviewed from districts which held one of the top ranks in terms of area under cultivation but were characterised by one of lowest yields for green gram and black gram in the respective state. The total number of cultivator households interviewed was 789. The total number of green gram cultivators was 390 whereas the total number of black gram cultivators were 399. An analysis of Myanmar's export and production performance are undertaken using the secondary data on trade and production.

This report has been divided into 10 chapters including introduction and conclusion. Chapter 1 gives the introduction, objectives, methodology and chapter scheme of the report. Chapter 2 provides an overview of the Indian pulses economy with a special emphasis on black gram and green gram. Chapter 3 provides a brief over-view of the socio-economic profile of the black gram and green gram sample households. Chapter 4 discusses major yield enhancing agronomic practices recommended by the government for black gram and green gram to improve the production and productivity of these crops. The chapter also makes a detailed analysis of the factors influencing the adoption of these agronomic practices by black gram and green gram farmers by employing multivariate and ordered probit models. Chapter 5 analyses the impact of minimum support price in influencing farmers' adoption of various agronomic practices among both green gram and black gram farmers. Chapter 6 makes an attempt to analyse the impact of the adoption of agronomic practices on crop yield employing a multinomial endogenous treatment effects regression framework. Chapter 7 analyses the various seed sources and factors affecting the access to these seed sources and its impact on market price received by farmers. Chapter 8 makes an attempt to analyse the role of crop insurance availed by farmers in influencing farmers risk aversion behaviour, thereby measuring its impact on the adoption of agronomic practices. Chapter 9 provides a detailed discussion about Myanmar's domestic production of pulses and their exports in order to draw lessons from their success story.

After discussing the background, objectives, data and methodology in the first chapter, the second chapter provided an overview of pulses economy with a special emphasis on the trends in area, production and yield of green gram and black gram in comparison with world. The 3rd chapter provides the data discussion, sample region and socio-economic profile of the sample households. The 4th chapter discusses various agronomic practices such as soil management, water management, plant management etc. recommended by the government specifically for both the crops-green gram and black gram. In addition to this, the chapter also makes an attempt to analyse the adoption of these agronomic practices using a multi variate probit and ordered probit models. These models help us to jointly analyse the adoption of multiple practices and the number of agronomic practices adopted while recognising the interrelationship among them. Our approach extends the existing empirical studies by allowing for correlations across different agronomic practices. The results from the analysis showed that the contact with government extension agents, access to off-farm activities, availing of MSP, price at which the crop is sold and own stock of seed increased the likelihood of adopting several practices for both black gram and green gram. While these results were not counter-intuitive, the results for membership in input supply co-operatives and distance to main market was counter-intuitive. As per the literature one would expect a positive relationship between the membership in input supply co-operatives and the adoption of agronomic practices. Similarly, one would expect a negative relationship between the distance and the adoption. However, the findings are just the opposite.

The negative relationship between membership in input supply co-operatives and adoption could be due to the fact the membership in input supply co-operatives means better farming situation of farmers and they cultivate more market oriented and less risky crops. This could be the reason for a positive relationship between the distance and adoption. It indicates that the agronomic practices are mainly adopted by farmers who are less market oriented but resource poor farmers as a livelihood maximisation strategy.

The results from size of the farm and education are also mixed. These results also point out that the adoption of agronomic practices is undertaken by resource poor farmers. Also, the availing of MSP had a significant and positive impact in influencing the adoption of most practices.

The 5th chapter makes an attempt to analyse the impact of MSP in encouraging the adoption of various agronomic practices among black gram and green gram farmers. By explicitly incorporating the MSP in the adoption decision models and using multi equations (cmp command developed by Roodman), the results showed that the availing of MSP is an important factor in positively affecting the adoption of almost all agronomic practices among the black gram and green gram farmers. Availing of MSP model showed that information about MSP received from radio was more important than newspaper and this was especially true in the case of black gram farmers. Similarly, crop failure and crop insurance resulted in the lowering of availing of MSP. This could be due to the insurance coverage that the farmers receive during crop loss, or the lack of enough crops to be sold when there is a crop loss. As expected, membership in input supply co-operatives, education, knowledge of KCC and access to off-farm activities generally increased the likelihood of availing MSP. Household income lowered the probability in the case of black gram farmers and shows the importance of MSP as a risk mitigating strategy for resource poor farm households, especially when they experience crop failure.

The 6th chapter analysed the impact of adoption of various agronomic practices on the yield for black gram. [20] The impact of adoption is analysed using a joint framework of adoption and the impact where the first stage will analyse the factors affecting the adoption and second stage will analyse the impact on crop yield. Such a joint framework is useful when there are possibilities for endogeneity in model. For example, the factors affecting the adoption such as entrepreneurial nature of the farmers may be correlated with the outcome variable-yield. Therefore, the study employs a multinomial endogenous treatment effects regression.

The examination of the factors impacting adoption of agronomic practices indicated several results consistent with the available literature, as well as some interesting deviations. For instance, our results regarding the positive impact of farm size, training from government or NGOs, selling price on agronomic practice adoption were in line with studies undertaken in the Indian context. Other important variables such as family/ household size (a proxy for labour supply), education of farmers, membership in farmer organisations were negative and insignificant; these findings deviate from several studies that postulate a positive relationship (Noltze et al., 2012; Teklewold et al., 2013; Moser and Barrett, 2003; Barrett et al. 2004; Pender and Gebremedhin 2008; Langyintuo and Mungoma, 2008; Barrett et al., 2004; Matuschke & Qaim, 2009; Khonje et al., 2015). The negative relationship with family size could be attributed to either a shift to non-farm activities, or a decrease in resources available for investment into farming. Similarly, the negative and statistically significant result witnessed in the case of education could be attributed to the gradual move away from farming, better opportunities available due to their education and the falling interest amongst educated farmers to adopt agronomic practices pertaining to black gram. In the case of membership in farmer organisations, our results showed that the membership in input supply co-operative had a positive impact only on the adoption of soil management, whereas a negative and statistically significant impact in the case of seed and soil management, seed and plant management, seed, soil and plant management was observed. This result could be attributed to better crop cultivation and marketing prospects already existent for farmers who are members of farmer organisations due to their ability to leverage on the opportunities and information available, due to which they do not have any additional incentive to further engage in yield-enhancement measures specific to black gram

[20] We could not analyse the yield impact of adoption of agronomic practices on green gram as the collected data had numerous errors. So our analysis on the impact of adoption focuses only on black gram.

and are adopting only soil management practices that are not black gram specific.

Examining the impact of adoption of agronomic practices on yield pointed towards the sample selection bias, especially if the yield equation is estimated without considering the adoption decision. The results from both the exogenous and endogenous adoption decisions showed that the adoption of various agronomic practices increased the yield. The impact was much more when we consider the yield impact as endogenous. Also, the results showed that the impact was greater under seed management, and the adoption of all the practices. In terms of policy implications, these results suggest that although full adoption would contribute to yield benefits, even the adoption of seed management alone can enhance the crop yield in the case of black gram. Thus, this empirical analysis strengthens the case for an emphasis on the adoption of recommended agronomic practices in the case of black gram in India.

The 7th chapter analyses the impact of various seed sources (government, private, own stock from previous years and other farmers on the prices received by the farmers. The results showed that the percentage of farmers who use government seed was more among the green gram farmers than black gram farmers. Similarly, a greater number of black gram farmers obtained the seed from private companies. Still, it was observed that a large chunk of both green gram and black gram farmers were still using own seed from previous year. Those who had better knowledge about the production techniques were not using their own seed. As far as the impact of seed sources on the prices received, the results were quite mixed. The black gram farmers who sourced their seed from government received higher prices for the crop while selling, whereas opposite was the case for green gram farmers.

The 8th chapter makes an attempt to analyse the role of crop in insurance in influencing the adoption of various agronomic practices among the black gram farmers. Since around 80 percent of the sample farmers have availed crop insurance, our results may be upward biased. However, the results indicate that the availing of crop insurance has a positive impact on the adoption of almost all agronomic practices among black gram farmers. Similarly, variables such as farm size, membership in input supply co-operatives, crop failure, access to off-farm activities etc. increased the likelihood of accessing the crop insurance. Apart from crop insurance the other factors that affected the likelihood of adopting various agronomic practices were farm size, access to government's extension services and availing of MSP.

The 9th chapter focused on the descriptive analysis of the production and export performance of Myanmar and the lessons that can be learned from Myanmar's successful experience. The analysis showed that India is the largest export destination of Myanmar for black gram and green gram, constituting almost 39 per cent of total exports. The success of Myanmar in the export market is due to the relatively higher yield that they have achieved since 1960s. Whereas in India, the pulses production, including black gram and green gram were stagnant since the 1960s and the yield was also poor. The differences in the food security policies in the two countries are also a reason for the differences in the emphasis on the crops. In India, the Green Revolution shifted the focus more towards cereals production in order to meet the food security objectives in the 1960s and 1970s.

To sum it up, the study provided unique policy insights for the promotion of cultivation of pulses in general, green gram and black gram in particular. The study showed the importance of various agronomic practices which are environment friendly. The agronomic practices are yield enhancing without harming the environment. However, in order to remove the barriers that farmers face from adoption of these practices, the government needs to take effective measures to reduce the risk and uncertainty. Price risk and yield risk are the two main sources of uncertainty. The study showed that the MSP can reduce the risk and uncertainty faced by farmers and thereby encourage the adoption of yield enhancing agronomic practices. The price-stabilisation policies would encourage farmers to adopt yield enhancing technologies. Thus, appropriate actions need to be taken to increase the awareness of MSP among farmers, scale up the procurement operations, ensure that farmers can avail MSP (especially in states such as Andhra Pradesh) and make the procurement more effective in order to encourage the uptake of recommended yield-enhancing agronomic practices for black gram and green gram. Similarly, crop insurance plays a crucial role in encouraging farmers in adopting agronomic practices. Furthermore, in order to enhance the adoption of yield enhancing agronomic practices, the government can bolster training efforts in terms of input requirements, crop management and post-harvest management across the study states, especially in Andhra Pradesh and Maharashtra.

The better pulses production and export performance of Myanmar was mainly due to the high levels of yield that they have achieved since 1960s. During the same period India's production of pulses declined and yield remained low. Currently also, the yield remains the lowest due to the lack of adequate public investment and the higher risk and uncertainty perceived by the farmers. Along with this, the cereal oriented food security policies followed by India until recently also resulted in the crowing out of the pulses from the farm. Correcting such biases and a more balanced approach in terms of incentives such as MSP will help the pulses sector to become self-sufficient.

APPENDICES

Table A4.1(a): Descriptive Statistics for Black Gram

Variables	All	Non-Adopters	Soil	Seed	Plant	Water
			Adopters			
Years of experience in farming	26.6 (11.9)	25.3 (12.5)	25.0 (11.5)	26.0 (11.6)	26.2 (11.9)	25.3 (11.9)
Number of Years of Education	7.6 (4.9)	8.0 (4.3)	6.0 (5.4)	4.5 (4.9)	8.5 (4.9)	3.8 (4.4)
Number of Family Members	5.3 (2.6)	6.5 (2.8)	4.4 (2.1)	4.3 (2.2)	5.1 (2.3)	3.9 (1.6)
Farm Size (Acres)	5.4 (7.3)	2.7 (2.8)	6.7 (9.1)	5.6 (5.0)	6.7 (8.7)	5.6 (4.4)
Walking Distance to Main Market (Km)	12.6 (8.4)	9.4 (5.8)	15.6 (9.1)	14.0 (7.7)	14.2 (9.4)	16.0 (7.9)
Price at which Black Gram is sold (Per Quintal)	5460.2 (838.3)	5599.0 (510.9)	5636.5 (894.1)	5607.1 (763.6)	5375.6 (1010.4)	5663.4 (838.2)
Availing MSP for Black Gram	.47 (.50)	.35 (.48)	.28 (.45)	.19 (.39)	.63 (.48)	.08 (.27)
Contact with Government Extension Agents	.87 (.33)	.77 (.42)	.88 (.33)	.88 (.32)	.94 (.24)	.87 (33)
Access to Off Farm Activities	.32 (.47)	.10 (.30)	.16 (.37)	.12 (.32)	.49 (.50)	.03 (.18)
Crop Insurance	.87 (.34)	.84 (.37)	.86 (.34)	.79 (.41)	.89 (.31)	.79 (.41)
Seed Source Own Stock	.49 (.50)	.06 (.23)	.61 (.49)	.75 (.44)	.66 (.47)	.70 (.46)
Seed Source -Government	.07 (.25)	.04 (.19)	.11 (.32)	.14 (.35)	.05 (.22)	.17 (.38)
Seed Source Private Stock	.37 (.48)	.84 (.37)	.18 (.39)	.07 (.26)	.22 (.41)	.07 (.26)
Member of Input Supply Cooperatives	.61 (.49)	.79 (.41)	.36 (.48)	.18 (.39)	.64 (.48)	.08 (.27)
Knowledge of Kisan Credit Card (KCC)	.89 (.31)	.92 (.27)	.84 (.36)	.82 (.38)	.91 (.28)	.82 (.38)
Procurement Centre as APMC	.65 (.48)	.96 (.19)	.33 (.47)	.24 (.43)	.60 (.49)	.15 (.36)
Procurement by Miller and Traders	.35 (.48)	.04 (.19)	.67 (.47)	.76 (.43)	.39 (.49)	.85 (.36)
Experience of Crop Failure	.56 (.50)	.84 (.37)	.52 (.50)	.36 (.48)	.47 (.50)	.41 (.49)
No. of observations	390	104	148	126	230	86

Note: Standard deviation is given in parentheses.

Table A 4.1(b): Descriptive Statistics for Green Gram

Variables	All	Soil	Seed	Plant	Cropping System & Rotation	Water
		Adopters				
Years of experience in farming	24.233 (12.047)	25.417 (12.000)	24.878 (11.639)	24.238 (11.504)	24.853 (11.956)	24.164 (11.949)
Number of Years of Education	6.283 (5.401)	4.502 (4.128)	5.035 (4.161)	5.630 (4.849)	5.322 (4.846)	6.534 (5.562)
Number of Family Members	5.117 (2.339)	5.413 (2.632)	6.185 (2.824)	5.513 (2.557)	5.249 (2.468)	5.124 (2.352)
Farm Size (Acres)	6.716 (7.701)	5.948 (5.995)	5.523 (5.752)	6.504 (7.571)	6.544 (6.714)	6.401 (6.635)
Walking Distance to Main Market (Km)	14.208 (13.829)	11.915 (14.262)	16.1 (15.269)	14.788 (14.749)	12.201 (13.774)	14.431 (13.839)
Price at which Black Gram is sold (Per Quintal)	6291.04 (804.774)	6137.394 (602.935)	6092. 357 (658.401)	6192.59 (721.909)	6207.033 (790.061)	6320.792 (738.758)
Availing MSP for Black Gram	.541 (.498)	.591 (.492)	.814 (.390)	.666 (.472)	.549 (.498)	.531 (.499)
Contact with Government Extension Agents	.814 (.389)	.826 (.379)	.964 (.186)	.882 (.322)	.805 (.396)	.822 (.382)
Access to Off Farm Activities	.418 (.493)	.530 (.500)	.7 (.459)	.558 (.497)	.457 (.499)	.397 (.490)
Crop Insurance	.731 (.443)	.680 (.467)	.671 (.471)	.698 (.460)	.710 (.454)	.739 (.439)
Seed Source Own Stock	.466 (.499)	.633 (.482)	.721 (.449)	.581 (.494)	.553 (.498)	.416 (.493)
Seed Source -Government	.280 (.449)	.084 (.278)	.114 (.319)	.121 (.327)	.179 (.384)	.332 (.471)
Seed Source Private Stock	.213 (.409)	.258 (.438)	.15 (.358)	.274 (.447)	.227 (.419)	.211 (.408)
Seed Source Others	.040 (.196)	.023 (.151)	.014 2(.119)	.022 (.148)	.040 (.197)	.040 (.197)
Member of Input Supply Cooperatives	.501 (.500)	.488 (.501)	.657 (.471)	.567 (.496)	.483(.500)	.515 (.500)
Knowledge of Kisan Credit Card (KCC)	.716 (.451)	.680 (.467)	.692 (.462)	.702 (.458)	.714 (.452)	.717 (.450)
Procurement Centre as APMC	.413 (.493)	.474 (.500)	.678 (.468)	.536 (.499)	.410 (.492)	.413 (.493)
Procurement by Miller and Traders	.127 (.334)	.159 (.367)	.142 (.351)	.126 (.332)	.146 (.354)	.121 (.326)
Procurement by Others (FPOs, etc)	.185 (.389)	.079 (.271)	.071 (.258)	.126 (.322)	.135 (.342)	.201 (.402)
Experience of Crop Failure	1.458 (.616)	1.375 (.513)	1.285 (.453)	1.396 (.551)	1.435 (.559)	1.465 (.631)
No. of observations	399	213	140	22	273	322

APPENDIX A5

Table A5.1: Descriptive Statistics for Variables used in the Model for Black Gram

Variables	All	Climate	Fertiliser and Manure Application	Seed	Plant	Water	Harvesting Threshing & Storage
		Adopters	Adopters	Adopters	Adopters	Adopters	Adopters
Years of Experience in Farming	26.6 (11.9)	26.7 (11.5)	26.4 (10.6)	27.2 (10.7)	26.2 (11.9)	25.3 (11.9)	28.3 (10.5)
Years of Education	7.6 (4.9)	8.3 (4.9)	7.9 (4.9)	7.7 (4.9)	8.5 (4.9)	3.8 (4.4)	7.3 (5.0)
Household Size	5.3 (2.6)	5.2 (2.4)	5.1 (2.5)	5.2 (2.6)	5.1 (2.3)	3.9 (1.6)	5.2 (2.6)
Farm Total Area (Acres)	5.4 (7.3)	6.6 (9.11)	6.4 (9.3)	5.8 (6.5)	6.7 (8.7)	5.6 (4.41)	6.1 (6.6)
Access to Off Farm Activities	.32 (.47)	.53 (.51)	.61 (.55)	.54 (.49)	.5 (.50)	.08 (.35)	.59 (.51)
Member of Input Supply Cooperatives	.62 (.49)	.62 (.48)	.56 (.49)	.54 (.49)	.64 (.48)	.08 (.27)	.56 (.49)
Experience of Crop Failure	.56 (.50)	.43 (.49)	.38 (.48)	.34 (.47)	.47 (.50)	.40 (.49)	.29 (.45)
Knowledge of Kisan Credit Card(KCC	.89 (.31)	.88 (.31)	.92 (.26)	.92 (.26)	.91 (.28)	.82 (.38)	.89 (.30)
Availed Loan under KCC	.59 (.49)	.47 (.50)	.51 (.50)	.51 (.50)	.49 (.50)	.62 (.48)	.55 (.49)
Have Crop Insurance	.87 (.34)	.88 (.31)	.87 (.33)	.86 (.34)	.89 (.31)	.79 (.40)	.86 (.34)
Walking Distance from Market (Km)	12.6 (8.4)	12.9 (8.9)	10.8 (6.9)	10.9 (7.1)	14.2 (9.2)	16.0 (7.9)	10.0 (5.6)
MSP from Newspaper	.43 (.49)	.58 (.49)	.63 (.48)	.66 (.47)	.56 (.49)	.22 (.41)	.64 (.47)
MSP from Radio	.29 (.45)	.48 (.50)	.54 (.49)	.55 (.49)	.43 (.49)	0 (0)	.57 (.49)
Household Income	2.2 (3.3)	2.2 (3.8)	2.1 (3.9)	1.7 (1.8)	2.1 (3.7)	1.6 (1.6)	1.7 (1.9)
Seed Source Own Stock from last Year	.49 (.50)	.67 (.46)	.75 (.43)	.80 (.40)	.65 (.47)	.69 (.46)	.78 (.40)
Seed Source Private Stock	.37 (.48)	.18 (.38)	.14 (.35)	.11 (.31)	.21 (.41)	.06 (.25)	.12 (.33)
Seed Source Government or Others	.06 (.25)	.07 (.25)	.08 (.27)	.06 (.23)	.05 (.22)	.17 (.38)	.07 (.26)
Contact with Government Extension Agents	.87 (.83)	.92 (.25)	.96 (.19)	.95 (.21)	.93 (.23)	.87 (.33)	.95 (.20)
Number of observations	390	209	186	181	230	86	175

Note: Standard deviation is given in parentheses

Source: Survey data

Table A5.2: Adopters who Avail MSP – The Case of Black Gram Farmers

Variables	All	Climate	Fertiliser and Manure Application	Seed	Plant	Water	Harvesting Threshing & Storage
Availing MSP	.47 (.49)	.62 (.48)	.60 (.49)	.61 (.48)	.63 (.48)	.08 (.27)	.62 (.48)
Number of Observations	390	209	186	181	230	86	175

Note: Standard deviation is given in parentheses

Source: Survey data

Table A5.3: Adoption of Agronomic Practices among Black Gram Farmers

Variables	Adopters (%)
Climate	53
Fertiliser and Manure Application	47
Seed	46
Plant	58
Water	21
Harvesting, threshing and storage	44

Source: Survey data

Table A5.4: State-Wise Adoption of Agronomic Practices among Black Gram Farmers

Variables	Climate	Fertiliser and Manure Application	Seed	Plant	Water	Harvesting Threshing & Storage
Andhra Pradesh	.53 (.50)	.53 (.50)	.55 (.5)	.55 (.5)	.63 (.48)	.63 (.48)
Madhya Pradesh	1 (0)	1 (0)	1 (0)	1 (0)	0 (0)	1 (0)
Maharashtra	.58 (.49)	.28 (.45)	.27 (.45)	.82 (.38)	.23 (.42)	.1 (.30)
Rajasthan	.03 (.17)	.07 (.25)	.01 (.1)	.01 (.1)	.02 (.14)	.03 (.17)
Number of Observations	390	390	390	390	390	390

Note: Standard deviation is given in parentheses

Source: Survey data

Table A5.5: Descriptive Statistics for Variables used in the Model for Green Gram

Variables	All	Climate	Fertiliser and Manure Application	Seed	Plant	Water	Harvesting Threshing & Storage
		Adopters	Adopters	Adopters	Adopters	Adopters	Adopters
Years of Experience in Farming	24.2 (12.0)	24.37 (11.84)	25.41 (12.0)	24.87 (11.63)	24.23 (11.50)	24.55 (11.58)	24.60 (12.15)
Years of Education	6.3 (5.4)	6.79 (5.65)	4.50 (4.12)	5.03 (4.16)	5.63 (4.84)	5.22 (4.72)	6.62 (5.56)
Household Size	5.1 (2.3)	5.02 (2.39)	5.41 (2.63)	6.18 (2.82)	5.51 (2.55)	5.31 (2.52)	5.07 (2.25)
Farm Size	6.7 (7.7)	6.72 (7.64)	5.94 (5.99)	5.52 (5.75)	6.50 (7.57)	6.93 (8.19)	6.78 (8.04)
Access to Off Farm Activities	.42 (.49)	.37 (.48)	.53 (.50)	.7 (.45)	.55 (.49)	.51 (.50)	.41 (.49)
Member of Input Supply Cooperatives	.50 (.50)	.49 (.50)	.48 (.50)	.65 (.47)	.56 (.49)	.51 (.50)	.51 (.50)
Experience of Crop Failure	.93 (.25)	.92 (.26)	.98 (.12)	1 (0)	.97 (.17)	.97 (.16)	.92 (.26)
Knowledge of Kisan Credit Card(KCC)	.72 (.45)	.72 (.44)	.68 (.46)	.69 (.46)	.70 (.45)	.69 (.46)	.73 (.44)
Availed Loan under KCC	.53 (.50)	.51 (.50)	.58 (.49)	.57 (.49)	.56 (.49)	.57 (.49)	.52 (.50)
Have Crop Insurance	.73 (.44)	.74 (.43)	.68 (.46)	.67 (.47)	.69 (.46)	.69 (.46)	.76 (.42)
Walking Distance From Market	14.2 (13.8)	14.7 (13.6)	12.0 (14.2)	16.1 (15.3)	14.8 (14.8)		14.4 (13.7)
MSP info from Newspaper	.73 (.44)	.52 (.49)	.76 (.42)	.82 (.37)	.68 (.46)	.69 (.46)	.54 (.49)
MSP info from Radio	.57 (.50)	.69 (.45)	.84 (.35)	.92 (.27)	.80 (.39)	.81 (.39)	.71 (.45)
Household Income (in lakhs)	2.19 (2.75)	2.2 (2.8)	1.8 (2.0)	1.5 (1.9)	1.9 (2.1)	2.1 (2.4)	2.3 (2.9)
Seed Source Own Stock from last Year	.46 (.49)	.40 (.49)	.63 (.48)	.72 (.44)	.58 (.49)	.57 (.49)	.43 (.49)
Seed Source Private Stock	.21 (.41)	.20 (.40)	.25 (.43)	.15 (.35)	.27 (.44)	.25 (.43)	.19 (.39)
Seed Source Government or Others	.28 (.45)	.33 (.47)	.08 (.27)	.11 (.31)	.12 (.32)	.14 (.34)	.32 (.46)
Contact with Government Extension Agents	.81 (.39)	.81 (.38)	.82 (.37)	.96 (.18)	.88 (.32)	.83 (.37)	.81 (.39)
Number of observations	399	308	213	140	222	248	318

Note: Standard deviation is given in parentheses

Source: Survey data

Table A5.6: Adopters who Avail MSP – The case of Green Gram

Variables	All	Climate	Soil	Seed	Plant	Water	Harvesting Threshing & Storage
Availing MSP	.54 (.50)	.50 (.50)	.59 (.49)	.81 (.39)	.66 (.47)	.59 (.49)	.53 (.49)
Number of Observations	399	308	213	140	222	248	318

Note: Standard deviation is given in parentheses

Source: Survey data

Table A5.7: Adoption of Agronomic Practices among Green Farmers

Variables	Adopters (%)
Climate	77
Soil	53
Seed	35
Plant	55
Water	62
Harvesting, threshing and storage	79

Source: Survey data

Table A5.8: State-Wise Adoption of Agronomic Practices among Green Gram Farmers

Variables	Climate	Soil	Seed	Plant	Water	Harvesting Threshing & Storage
Andhra Pradesh	.79 (.40)	.56 (.49)	0 (0)	.34 (.47)	.63 (.48)	.8 (.40)
Madhya Pradesh	.66 (.47)	.78 (.41)	.67 (.47)	.8 (.40)	. 8 (.40)	.75 (.43)
Maharashtra	.92 (.25)	.10 (.30)	.05 (.22)	.32 (.47)	.32 (.47)	.90 (.28)
Rajasthan	.71 (.45)	.69 (.46)	.68 (.46)	.76 (.42)	.73 (.44)	.73 (.44)
Number of Observations	399	399	399	399	399	399

Note: Standard deviation is given in parentheses

APPENDIX A6

Table A6.1: Parameter Estimates – Test on Validity of Selection Instruments

Variables	Crop Yield
Farm Size	.004 (.009)
No. of family members	-.030* (.017)
Education	-.005 (.013)
Selling Price	.089 (.513)
Access to off farm activities	-.008** (.117)
Distance to market	-.006 (.017)
Years of experience in farming	-.011** (.004)
Government of NGO training frequency per year	.111 (.122)
Membership in input supply cooperatives	-.055 (.131)
Constant	2.08 (4.37)
N	188

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are given in parentheses.

APPENDIX A7

Table A7.4: Instrument Validity Test – Green Gram

Total Yield	Co-efficient
Farm Size (Acres)	5.532 (.923)***
Number of Family Members	12.789 (8.179)
Education (No of Years)	-.052 (2.819)
Received Training from Government-Frequency	-51.483 (20.346)
Has the Rainfall been Satisfactory	-23.328 (19.425)
Distance from main market (km)	.947 (1.296)
Years of Experience in Farming	.226 (.636)
Contact with Government Extension Agents	16.289 (20.555)
Finance Source for Crop Activities	-2.977 (14.777)
Availed Loan under KCC	26.283 (13.347)**
Knowledge about production technology in the last 5 years	28.913 (24.322)
Availing MSP for Green Gram	31.931 (29.322)
Radio/TV/Mobile as Source for Information	-2.053 (6.030)
Constant	64.026 (6.030)

REFERENCES

Adesina, A.A., and M. M. Zinnah (1993). Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural* Economics, 9(4), 297–311. DOI:10.1016/0169-5150(93)90019-9.

Ali, M., & Gupta, S. (2012). Carrying capacity of Indian agriculture: pulse crops. *Current Science*, 874-881.

Bandiera, O & Rasul, I. (2006). Social networks and technology adoption in Northern Mozambique. *The Economic Journal, 514 (116),* https://doi.org/10.1111/j.1468-0297.2006.01115.x.

Barham, B. L., Chavas, J. P., Fitz, D., Salas, V. R., & Schechter, L. (2014). The roles of risk and ambiguity in technology adoption. *Journal of Economic Behavior & Organization*, *97*, 204-218.

Bantilan, M. C. S., & Parthasarathy, D. (1998). Adoption assessment of short-duration pigeonpea ICPL 87. In *Assessing joint research impacts: proceedings of an International Workshop on Joint Impact Assessment of NARS/ICRISAT Technologies for the Semi-Arid Tropics, 2-4 Dec 1996, ICRISAT, Patancheru, India* (Vol. 502, p. 136).

Banerjee, S., B, Martin, S., Roberts, R., Larkin, S., Larson, J., Paxton, K. W., English, B., Marra, M, Reeves, J. M. (2008). A binary logit estimation of factors affecting adoption of GPS guidance systems by cotton producers. *Journal of Agricultural and Applied Economics, 40* (1).

Barrett, C.B., C.M. Moser, O.V. McHugh and J. Barison (2004). Better technology, better plots or better farmers? Identifying changes in productivity and risk among Malagasy rice farmers. *American Journal of Agricultural Economics*, 86(4), 869–889.

Begho, T. (2021). Using farmers' risk tolerance to explain variations in adoption of improved rice varieties in Nepal. *Journal of South Asian Development*, *16*(2), 171-193.

Bekele, W & Drake, L. (2003). Soil and water conservation decision behaviour of subsistence farmers in the Eastern Highlands of Ethiopia: a case study of the Hunde-Lafto area. *Ecological Economics, 46* (3*)*, 437-451.

Beshir, H. (2014). Factors affecting the adoption and intensity of use of improved forages in North East Highlands of Ethiopia. *American Journal of Experimental Agriculture*, *4*(1), 12.

Bonabana-Wabbi, J. (2002). Assessing factors affecting adoption of agricultural technologies: the case of integrated pest management (IPM) in Kumi district, Eastern Uganda. Available at https://vtechworks.lib.vt.edu/handle/10919/36266.

Brick, K., & Visser, M. (2015). Risk preferences, technology adoption and insurance uptake: A framed experiment. *Journal of Economic Behavior & Organization*, *118*, 383-396.

Caviglia-Harris, J. L. (2003). Sustainable agricultural practices in Rondonia, Brazil: do local farmer organisations affect adoption rates? Available at https://facultyfp.salisbury.edu/jlcaviglia-harris/nsf/Papers/Caviglia-Harris-EDCC%202003.pdf.

Conley, T. G. & Udry, C. R. (2010). Learning about a new technology: pineapple in Ghana. *American Economic Review, 100 (1*), 35-69.

Deb, P., and P.K. Trivedi (2006a). Specification and simulated likelihood estimation of a non normal treatment outcome model with selection: Application to health care utilization. *The Econometrics Journal*, 9(2), 307–331.

Deb, P., and P.K. Trivedi (2006b). Maximum simulated likelihood estimation of a negative binomial regression model with multinomial endogenous treatment. *Stata Journal*, 6(2), 246–255.

Devi, K., and T. Ponnarasi (2009). An Economic Analysis of Modern Rice Production Technology and Its Adoption Behaviour in Tamil Nadu. *Agricultural Economics Research Review, 22*, 341–47.

Directorate of Pulses Development (2016). Pulses in India: retrospect and prospects. Available at https://www.nfsm.gov.in/StatusPaper/Pulses2016.pdf.

Feder, G., R.E. Just and D. Zilberman (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic development and cultural change*, 255–298.

Ghadim, A. K. A., Pannell, D. J., & Burton, M. P. (2005). Risk, uncertainty, and learning in adoption of a crop innovation. *Agricultural economics*, *33*(1), 1-9.

Ghimire, R., Wen-chi, H., Shrestha, R.B. (2015). Factors affecting adoption of improved rice varieties among rural farm households in central Nepal. *Rice Science*, *22* (1), 35-43. https://doi.org/10.1016/j.rsci.2015.05.006.

Gudadhe, N., Raut, A., Thanki, J. D., & Imade, P. B. S. (2018). Agronomic technologies for enhancing pulse production ahead of climate change. *Astral International Pvt. Ltd., New Delhi*, 27-52.

Gull, R., Bhat, T. A., Sheikh, T. A., Wani, O. A., Fayaz, S., Nazir, A., ... & Nazir, I. (2020). Climate change impact on pulse in India-A review. *Journal of Pharmacognosy and Phytochemistry*, *9*(4), 3159-3166.

Gupta, A., Ponticelli, J., & Tesei, A. (2019). Technology adoption and access to credit via mobile phones.

Haldar, S., Honnaiah and G. Govindaraj (2012). System of Rice Intensification (SRI) method of rice cultivation in West Bengal (India): An Economic analysis. Selected Poster prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August 2012, Available at http://ageconsearch.umn.edu/bitstream/126234/2/IAAE%20conference%20paper%20on%20SRI-uploading.pdf, Accessed on 16 November 2015.

Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. (2015). *Coping with risk in agriculture: Applied decision analysis*. Cabi.

Hu, Y., Li, B., Zhang, Z., Wang, J. (2022). Farm size and agricultural technology progress: Evidence from China. *Journal of Rural Studies*, *93*, 417-429.

Johnson, B., and K. Vijayaragavan (2011). Diffusion of System of Rice Intensification (SRI) Across Tamil Nadu and Andhra Pradesh in India. *Indian Research Journal of Extension Education*, *11*(3), 72–79.

Kaan, D. (1998). Defining risk and a framework for moving towards resilience in agriculture. *Risk and Resilience Agriculture Series*, *1*(3), 1-4.

Kaliba, A. R., Verkuiji, H., Mwangi, W. (2000). Factors affecting adoption of improved maize varieties and use of inorganic fertiliser for maize production in the intermediate and lowland zones of Tanzania, Journal of Agricultural and Applied Economics, 32 (1), 35-57. 10.1017/S1074070800027802.

Kassie, M., M. Jaleta, B. Shiferaw, F. Mmbando, and M. Mekuria (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change*, 80(3), 525–540. http://dx.doi.org/10.1016/j.agsy.2009.01.001.

Kassie, M., H. Teklewold, M. Jaleta, P. Marenya, and O. Erenstein (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa. *Land Use Policy*, *42*, 400–411. http://dx.doi.org/10.1016/j.landusepol.2014.08.016.

Kemeze, F. H., Miranda, M. J., Kuwornu, J. K., & Anim-Somuah, H. (2020). Smallholder farmer risk preferences in northern Ghana: Evidence from a controlled field experiment. *The Journal of Development Studies*, *56*(10), 1894-1908.

Khanna, M. (2001). Sequential adoption of site-specific technologies and its implications for nitrogen productivity: A double selectivity model. *American Journal of Agricultural Economics*, *83* (1), 35-51.

Kim, T. K., Hayes, D. J., & Hallam, A. (1992). Technology adoption under-price uncertainty. *Journal of Development Economics*, *38*(1), 245-253.

Khonje, M. G., Manda, J., Mkandawire, P., Tufa, A. H., & Alene, A. D. (2018). Adoption and welfare impacts of multiple agricultural technologies: evidence from eastern Zambia. *Agricultural Economics*, *49*(5), 599-609.

Khonje, M., Manda, J., Alene, A. D., & Kassie, M. (2015). Analysis of adoption and impacts of improved maize varieties in eastern Zambia. *World development*, *66*, 695-706.

Krishi Vigyan Kendra (2016). Production technology of pulses. Available at https://kvk.icar.gov.in/API/Content/PPupload/k0217_5.pdf.

Issahaku, G & Abdulai, A. (2020). Adoption of climate-smart practices and its impact on farm performance and risk exposure among smallholder farmers in Ghana. Australian Journal of Agricultural and Resource Economics, 64 (2), 396-420. https://doi.org/10.1111/1467-8489.12357.

Lakshmi, S. B. R., Patra, P., Gummagolmath, K.C. (2020). Impact of doubling farmers' income on area, production and productivity of pulses in India. *Current Journal of Applied Science and Technology, 39 (28)*, 73086. 10.9734/CJAST/2020/v39i2830939.

Langyintuo, A. S., and C. Mungoma (2008). The effect of household wealth on the adoption of improved maize varieties in Zambia. *Food policy*, 33(6), 550–559. http://dx.doi.org/10.1016/j.foodpol.2008.04.002.

Lee, D. R. (2005). Agricultural sustainability and technology adoption: Issues and policies for developing countries. *American journal of agricultural economics*, *87*(5), 1325-1334.

Liu, E. M. (2013). Time to change what to sow: risk preferences and technology adoption decisions of cotton farmers in China. *Review of Economics and Statistics 95* (4): 1386–1403. https://doi.org/10.1162/REST_a_00295.

Manda, J., A.D. Alene, C. Gardebroek, M. Kassie and G. Tembo (2015). Adoption and Impacts of Sustainable Agricultural Practices on Maize Yields and Incomes: Evidence from Rural Zambia. *Journal of Agricultural Economics*. DOI: 10.1111/1477-9552.12127.

Mansur, E.T., R. Mendelsohn and W. Morrison (2008). Climate change adaptation: A study of fuel choice and consumption in the US energy sector. *Journal of Environmental Economics and Management*, 55, 175–193.

Marenya, P. P., & Barrett, C. B. (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food policy*, *32*(4), 515-536.

Matsumoto, T., Yamano, T., Sserunkuuma, D. (2010). Technology adoption in agriculture: evidence from experimental intervention in maize production in Uganda. Available at https://www.theigc.org/wp-content/uploads/2014/08/matsumoto.pdf.

Matuschke, I., and M. Qaim (2009). The impact of social networks on hybrid seed adoption in India. *Agricultural Economics*, 40(5), 493–505.

Mazvimavi, K., & Twomlow, S. (2009). Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. *Agricultural systems*, *101*(1-2), 20-29.

Mekonnen, D. A., Gerber, N., Matz, J. A. (2018). Gendered social networks, agricultural innovations, and farm productivity in Ethiopia. *World Development, 105*, 321-335. https://doi.org/10.1016/j.worlddev.2017.04.020.

Meshram, V., N. Chobitkar, V. Paigwar, and S.R. Dhuware (2012). Factors Affecting on SRI System of Paddy Cultivation in Balaghat Ddistrict of Madhya Pradesh. *Indian Research Journal of Extension Education*, Special Issue (Volume I), 202–204.

Ministry of Agriculture and Farmers Welfare, Government of India (2021). First Advance Estimates of Production of Foodgrains for 2021-22. Retrieved from https://agricoop.nic.in.

Ministry of Agriculture and Farmers Welfare, Government of India (2020). Agricultural Statistics at a Glance 2020. Retreived from https://eands.dacnet.nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202020%20(English%20version).pdf.

Mitschke, V. (2017). Inducing the adoption of good agricultural practices by educating Tanzanian smallholder farmers-what works best and at what costs? Available at https://n2africa.org/sites/default/files/MSc%20Thesis_Verena%20Mitschke.pdf.

Mohamed, K. S., & Temu, A. E. (2008). Access to Credit and Its Effect on the Adoption of Agricultural Technologies: The Case of Zanzibar. *African Review of Money Finance and Banking*, 45–89. http://www.jstor.org/stable/41410533.

Moser, C.M., and C.B. Barrett (2003). The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. *Agricultural Systems*, 76(3), 1085–1100. http://dx.doi.org/10.1016/S0308-521X(02)00041-0.

Mutyasira, V., Hoag, D., & Pendell, D. (2018). The adoption of sustainable agricultural practices by smallholder farmers in Ethiopian highlands: An integrative approach. *Cogent Food & Agriculture*, *4*(1), 1552439.

Moser, C.M., and C.B. Barrett (2003). The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. *Agricultural Systems*, *76*(3), 1085–1100. http://dx.doi.org/10.1016/S0308-521X(02)00041-0.

NITI Aayog (2018). Demand and supply projections towards 2033: Crops, livestock, fisheries and agricultural inputs. Retrieved from https://www.niti.gov.in/sites/default/files/2021-08/Working-Group-Report-Demand-Supply-30-07-21.pdf.

Nkomoki, W., Bavorová, M., & Banout, J. (2018). Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. *Land use policy*, *78*, 532-538.

Ogada, M. J., G. Mwabu, and D. Muchai (2014). Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. *Agricultural and Food Economics*, *2*(1), 1–18. DOI: 10.1186/s40100-014-0012-3.

Organisation for Economic Co-operation and Development & Food and Agriculture Organization (2021). *OECD-FAO. Agricultural Outlook 2021-2030*. Paris: Rome/OECD Publishing.

Oyetunde-Usman, Z., Olagunju, K. O., Ogunpaimo, O. R. (2021). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil and Water Conservation Research, 9* (2), 241-248. https://doi.org/10.1016/j.iswcr.2020.10.007.

Patra, A. K. & Nayak, B. C. (2000). Response of horsegram (Macrotylama uniflorum) to agronomic management practices. *Indian Journal of Agronomy, 45 (2)*, 357-360.

Pender, J., and B. Gebremedhin (2008). Determinants of agricultural and land management practices and impacts on crop production and household income in the highlands of Tigray, Ethiopia. *Journal of African Economies*, *17*(3), 395–450. DOI: 10.1093/jae/ejm028.

Quinion, A., Chirwa, P. W., Akinnifesi, F. K., & Ajayi, O. C. (2010). Do agroforestry technologies improve the livelihoods of the resource poor farmers? Evidence from Kasungu and Machinga districts of Malawi. *Agroforestry systems*, *80*(3), 457-465.

Rahm, M. R., and W. E. Huffman (1984). The adoption of reduced tillage: the role of human capital and other variables. *American Journal of Agricultural Economics*, 66(4), 405–413. DOI: 10.2307/1240918.

Rao, C., Srinivasarao, M., Karlapudi, S., Patibanda, A. K. (2011). Adoption, impact and discontinuance of integrated pest management technologies for pigeonpea in south india. *Outlook on Agriculture, 40 (3),* 245-250. 10.5367/oa.2011.0055.

Reddy, A. A. A (2010). Pulses production technology: status and way forward. *Economic and Political Weekly, 44 (52)*, 73-80. http://dx.doi.org/10.2139/ssrn.1537540.

Reddy, A Amarender A., Policy Implications of Minimum Support Price for Agriculture in India (July 3, 2021). Academia Letters, Article 2406, 2021. https://doi.org/10.20935/AL2406, Available at SSRN: https://ssrn.com/abstract=3898357.

Roodman, D. (2009). Estimating fully observed recursive mixed-process models with cmp, Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1392466.

Roodman, D(2011). Fitting fully observed recursive mixed-process models with cmp. *The Stata Journal*, *11(*2), 159–206.

Sagemüller, F., & Mußhoff, O. (2020). Effects of household shocks on risk preferences and loss aversion: evidence from upland smallholders of South East Asia. *The Journal of Development Studies*, *56*(11), 2061-2078.

Sánchez-Toledano, B. I., Kallas, Z., Palmeros Rojas, O., & Gil, J. M. (2018). Determinant factors of the adoption of improved maize seeds in Southern Mexico: A survival analysis approach. *Sustainability*, *10*(10), 3543.

Sekhar, C. S. C., & Bhatt, Y. (2012). Possibilities and constraints in pulses production in india and impact of national food security mission. Final Report) Institute of Economic Growth University of Delhi Enclave Delhi–110007, 7, 150.

Shiferaw, B., T. Kebede, M. Kassie, and M. Fisher (2015). Market imperfections, access to information and technology adoption in Uganda: challenges of overcoming multiple constraints. *Agricultural Economics*, *46*(4), 475–488. DOI**:** 10.1111/agec.12175.

Simtowe, F., & Zeller, M. (2006). The Impact of Access to Credit on the Adoption of hybrid maize in Malawi: An Empirical test of an Agricultural Household Model under credit market failure.

Smale, M., P.W. Heisey and H.D. Leathers (1995). Maize of the ancestors and modern varieties: The microeconomics of high-yielding variety adoption in Malawi. *Economic Development and Cultural Change*, Vol. 43, Issue 2, 351–368.

Simtowe, F. (2011). Determinants of agricultural technology adoption: the case of improved pigeonpea varieties in Tanzania. MPRA Working Paper, 1-22.

Subramanian, A. (2016). Incentivising pulses production through minimum support price (MSP) and related policies. *Report by Chief Economic Adviser, Ministry of Finance, Government of India*.

Teklewold, H., M. Kassie and B. Shiferaw (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of agricultural economics*, 64(3), 597–623.

Thomas, L., Sundaramoorthy, C., & Jha, G. K. (2013). The impact of National Food Security Mission on pulse production scenario In India: An empirical analysis. *International Journal of. Agricultural and Statistical Science, 9(1)*, 213-223.

Tran, N. L. D., Rañola, R. F., Sander, B. O., Reiner, W., Nguyen, D. T., & Nong, N. K. N. (2020). Determinants of adoption of climate-smart agriculture technologies in rice production in Vietnam. *International journal of climate change strategies and management*, *12*(2), 238-256.

Tripathi, A. K. (2019). Feeling the Pulse: Towards Production Expansion of Pulses in India. *Journal of Asian and African Studies*, *54*(6), 894-912.

Tufa, A. H., Alene, A.D., Manda, J., Ainwale, M. G., Chikoye, D., Feleke, S., Wossen, T., Manyong, V. (2019). The productivity and income effects of adoption of improved soybean varieties and agronomic practices in Malawi. *World Development, 124.* 10.1016/j.worlddev.2019.104631.

Uaiene, R. (2011). Determinants of agricultural technology adoption in Mozambique. In *African Crop Science Conference Proceedings*, Vol. 10, 375–380.

Uematsu, H. & Mishra, A., K. (2010). Net effect of education on technology adoption by US farmers. Southern Agricultural Economics Association: Florida.

Ullah, R., Shivakoti, G. P., Kamran, A., & Zulfiqar, F. (2016). Farmers versus nature: managing disaster risks at farm level. *Natural Hazards*, *82*(3), 1931-1945.

Uphoff, N. (2002). Opportunities for raising yields by changing management practices: the system of rice intensification in Madagascar, in N. Uphoff (ed.) *Agroecological Innovations: Increasing Food Production with Participatory Development*, London: Earthscan, 145–161.

Uzonna, U. & Qijie, G. (2013). Effect of extension programs on adoption of improved farm practices by farmers in Adana, Southern Turkey. *Journal of Biology, Agriculture and Healthcare, 3 (15).*

Varma, P. (2018). Adoption of system of rice intensification under information constraints: an analysis for India. *The Journal of Development Studies*, *54*(10), 1838-1857.

Wang, W. J., Liu, W. J., Li, Y. L., Wang, S. W., Yin, L. N., Deng, X. P. (2021). Increasing rainfed wheat yield by optimising agronomic practices to consume more subsoil water in the Loess plateau. *Crop Journal, 9 (6),* 1418-1427. 10.1016/j.cj.2021.01.006.

Witcombe, J. R., Khadka, K., Puri, R. R., Khanal, N. P., Sapkota, A., & Joshi, K. D. (2017). Adoption of rice varieties–I. Age of varieties and patterns of variability. *Experimental Agriculture*, *53*(4), 512-527.

Wossen, T., Abdoulaye, T., Alene, A., Haile, M. G., Feleke, S., Olanrewaju, A., Manyoung, V. (2017). Impact of extension access and cooperative membership on technology adoption and household welfare. *Journal of Rural Studies, 54*, 223-233. https://doi.org/10.1016/j.jrurstud.2017.06.022.

Wu, J.J., and B.A. Babcock (1998). The choice of tillage, rotation, and soil testing practices: Economic and environmental implications. *American Journal of Agricultural Economics*, Vol. 80, 494–511.

Zakaria, A., Alhassan. S. I., Kuwornu, J., Azumah, S. B. (2020). Factors influencing the adoption of climate-smart agricultural technologies among rice farmers in Northern Ghana. *Earth Systems and Environment, 4 (1).* 10.1007/s41748-020-00146-w.

विद्याविनियोगाद्विकासः
INDIAN INSTITUTE of MANAGEMENT AHMEDABAD
Vastrapur, Ahmedabad, Gujarat 380015
CENTRE FOR MANAGEMENT IN AGRICULTURE (CMA)
email: cma@iima.ac.in | Phone: +91-79-71524650, 71524651, 71524652
Web: www.iima.ac.in