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CGIAR RESEARCH PROGRAM ON Maize

Bihar Study Report

Seed Sector functioning and the adoption of improved maize varieties

Photo: KIT – Geneviève Audet-Bélanger © Maize in Bihar

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Acronyms

ATMA	Agriculture Technical Management Agency
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CSISA	Cereal Systems Initiative for South Asia
DAP	Diammonium phosphate
DARS	Department of Agricultural Research Services
EGS	Early generation seed
FGD	Focus group discussion
GRC	Genetic resources conservation
ICAR	Indian Council for Agriculture Research
IIMR / DMR	Indian Institute of Maize Research, old Directorate for Maize Research
IOPV / OPV	(Improved) open pollinated variety
KVK	Krishi Vigyan Kendra
MOP	Muriate of potash
Nxxx	Number of units (producers, harvests, etc.) surveyed contributing to data
NBPGR	National Bureau of Plant Genetic Resources
PGRC	Plant Genetic Resources Centre
QPM	Quality Protein Maize
RAU	Rajendra Agricultural University
Rs	Indian rupees
SADC	Southern African Development Community
SSA	Seed Sector Analysis
SVCA	Seed Value Chain Analysis
TLS	Truthfully labelled seed

Exchange rate at the time of the study 66.26 Indian Rupees per US$1

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Executive summary

This document describes the adoption and impact of improved maize germplasm at small scale farmer level in the state of Bihar, India. The objective is to understand whether smallholder farmers have access to seed of improved maize varieties, and if so, how the seed sector supports this.

In the state of Bihar, a stakeholder workshop was held in August 2016 at the Rajendra Agricultural University (RAU) in Pusa, Samastipur district. Key informant interviews, focus group discussions (FGDs) with farmers and a household survey were also conducted in two districts of the state. The first survey area was located around Pusa, Samastipur, the second district was Muzaffarpur. Both locations were selected because of their high suitability to *rabi* (winter season) maize production, as well as their potential for spring production (particularly Muzaffarpur). This study is part of a larger research project commissioned by MAIZE, with similar studies conducted in Malawi, Chiapas in Mexico, and Zambia.

Although maize is not a new crop to Bihar, it does not constitute a major food product in the basic daily diet. However, in the past decade or so, maize production in the state has surged because of increasing demand by the poultry industry; the favorable climatic conditions for maize cultivation; and because higher yields of staple food crops like wheat and rice, have allowed for farmers to also consider commercial production of maize. Producers have shifted from traditional *kharif* (summer) production, to growing maize in the dryer, *rabi* season. Survey data shows that this adjustment started more than 10 years ago, but that in the spring season, maize is not widely produced yet. Maize is an important cash crop and producers tend to sell the majority of their harvest (66%). However, producers also grow other cash crops and areas under maize production are generally small.

Market orientation has led many producers to use improved open pollinated (IOPVs) and hybrid varieties, which offer high yields and short maturity cycles. Very few producers are using so-called 'local' varieties. Research institutes like RAU and the Indian Institute of Maize Research and International Maize and Wheat Improvement Center (CIMMYT) have long been involved in developing improved varieties. Private international seed companies like Pioneer and Monsanto/Dekalb are holding an important share of the maize seed market and are offering improved yellow maize hybrid varieties to producers through agro-dealers and seed traders. National companies are also active on the seed market, offering both IOPVs and hybrids to farmers. While the large international companies are carrying out both their own variety development and seed production, CIMMYT and the national research institutions license their varieties out to private seed companies for seed production and seed sales. Some seed production remains within the universities, but this represents a very small proportion of the maize seed used in the state. Most of the seed used is in fact produced within India, but outside of Bihar and is imported as truthfully labelled seed. The household survey data showed that many producers still grow an IOPV developed by RAU 30 years ago called *Lakshmi*, although its acreage has begun to decline. Local companies are licensed to multiply and commercialize the variety.

The certification system seems to cope with the amount of seed produced in the state of Bihar. However, the survey showed that farmers pay little attention to certification; branding by seed companies is a much stronger indicator of quality to farmers. Financial services for agricultural activities have limited reach in Bihar. Agricultural extension services are accessible through different channels, but lack coordination in their approach. The seed sector analysis concluded that Bihar's maize seed sector is highly influenced by the market demand for grain maize intended for the poultry industry, which is leading to an increasing number of players and dynamism in the sector. This in turn has resulted in the availability of a large number of varieties to farmers, developed by international companies.

The producer household survey provided valuable insights on the use of different variety types, appreciated varieties, agricultural practices, producers' preferences and productivity. Complemented by key informant interviews and FGDs, the survey provided information on the

functioning of both the formal and informal seed systems at farm level. Most producers source their seed from the rural market or agro-dealers and producers reported not to purchase seed through subsidies. Producers tend not to recycle their hybrid seed to produce maize grain, but some appear to sow recycled hybrids in the *kharif* season, using the plants as green fodder.

In Samastipur, fields were planted with 66% hybrid, 30% IOPVs and 4% local varieties, with hybrid varieties of Pioneer and Monsanto/Dekalb the most popular among producers surveyed. In Muzaffarpur, 78% of main maize plots are sown with hybrids, 21% improved OPVs and only 1% with local varieties. The determining factors for variety selection by farmers are high yields, availability and trust in the supplier. There is limited quality control within seed marketing services and therefore, trust in the supplier is an important criteria when purchasing seed.

Producers reported higher yields in Muzaffarpur (6.1 t/ha) than in Samastipur (4.9 t/ha). On average, hybrid varieties of maize give the highest yields and differences in average yield between locations and variety types were statistically significant. Virtually all producers are making use of urea as a fertilizer. Other fertilizers used include muriate of potash, zinc sulfate and NPK. A combination of the above was found to positively influence yield.

In summary, the strong market pull by the poultry industry is providing an incentive for producers to invest in yellow maize production. High yield is the main criteria for variety selection. *Lakshmi*, the white maize IOPV developed over 30 years ago, remains popular among producers and is thought to be popular for human consumption as opposed to poultry feed, where yellow maize is preferred. No other variety from the public sector is used as widely as *Lakshmi*. Finally, the adoption of improved maize varieties, notably hybrids for production during the *rabi* season, has been strongly supported by the market. Efforts to develop maize for the short spring season have not yet resulted in significant production in the districts surveyed. Further strengthening of the maize seed sector could be achieved by improving the reliability of the seed supply network such as seed traders, agro-dealers and local markets.

1 Introduction

Rural poverty remains an acute problem in Asia, even if important progress has been made since the year 2000. The small plots on which households farm, the lack of education, large families and limited access to technologies and finance often contribute to a vicious cycle of income poverty. However, it is also said that agriculture contributes to the GDP and to poverty reduction. Reducing risks for smallholders, environmental conservation and raising productivity are key components of the development agenda. Much focus has been put on the development and the adoption of improved varieties to boost production, productivity and income (IFAD, 2011b)

Through breeding, improved varieties of crops can be developed. The quality of seeds, both genetically and physiologically, determines to a large extent crop yield and produce quality, hence the crop's market value and/or its potential contribution to food security. Seed characteristics determine how the crop will cope with adverse conditions and risks (Louwaars and de Boef, 2012). IFAD (2011a) shows that in the 1980s and 1990s, the use of seed of improved crop varieties accounted for half of the yield growth in China for example. In Latin America, the adoption of improved varieties for cereals has drastically increased; the proportion of land sown with such varieties has doubled in 20 years (1982-2002) (IFAD, 2011b).

The Consultative Group on International Agricultural Research (CGIAR) Research Program 'MAIZE', takes a holistic approach to increasing the contribution of maize to food security and poverty reduction (http://maize.org/). The MAIZE flagship project 5, aims at reducing constraints to seed production and increasing the number of MAIZE derived varieties available to farmers. The project intends to do this by improving access to germplasm through working with the National Agricultural Research System and with small-scale, as well as larger seed companies. It is expected that improved access to germplasm and the release of improved varieties should positively impact on productivity and food security, and reduce demands on land and irrigation. For this, the maize seed sector in many countries needs to become more vibrant, plural, competitive and responsive to users' needs, in particular those of smallholder farmers.

The aim of this project is to document the adoption and impact of improved maize germplasm at poor, maize-dependent farmers' level, in combination with understanding how access to affordable quality maize seed can be achieved through seed sector development. The assumption is that understanding the challenges, opportunities and implications of change in the maize seed value chain, will improve research results and support higher adoption and impact of research-derived maize germplasm. For this project, four countries (Mexico/Chiapas, India/Bihar, Malawi and Zambia) were studied independently. Subsequently, an overarching analysis process will take place. This report describes the outcomes of the fieldwork in Bihar, India.

2 Methodology

The same methodology was applied for the four study sites of the research (Mexico, India/Bihar, Malawi and Zambia). India is the last country in which fieldwork took place.

A mixed-method approach to data collection on maize seed use by smallholder farmers was used. A quantitative survey was developed to collect data from farmer households, taking into consideration important elements such as maize grown in different seasons, subsidy schemes, production and sales figures, variety type and variety used, input use and changes in practices over time. The survey provided quantitative information about farmers' practices and access to and use of quality seed. A state level seed sector analysis workshop, key informant interviews, and focus group discussions (FGD) with farmers form the qualitative part of the study.

These tools were designed to provide insight into relevant factors, enablers and constraints of the maize seed sector. Key interventions influencing the functioning of the seed value chain, perceived changes and views of key actors on what will be needed to further optimize the seed value chain in the study areas, were also explored through these qualitative tools. By combining these different types of data, it is possible to obtain insights into seed sector functioning and the adoption of improved varieties of maize.

The state level seed sector analysis workshop took place at Pusa campus in Samatispur, Bihar, India. The quantitative surveys were carried out in Samastipur and Muzaffarpur districts.

Figure 1 Map Bihar Districts. Source: http://gov.bih.nic.in/Profile/Districts.htm

2.1 Data collection tools

The seed sector workshop and interviews make use of two qualitative data collection tools:

1) Seed Sector Analysis (Subedi *et al.,* 2013), a tool specially developed to understand the composition and variations within a seed sector.

2) Seed Value Chain Analysis (Audet-Bélanger *et al.,* 2013), which results in understanding of the functioning of the seed value chain, flows of seeds, services, financial resources and knowledge.

The Seed Sector Analysis (SSA) is a multi-stakeholder process tool used to understand the composition, distinctness and variations within a seed sector. SSA takes a systemic perspective in analyzing the role of seed systems and their complexity. It helps to identify specific seed systems by their domain of operation (farmers, public, private, NGO, others), crops and varieties, technologies, farmers targeted, seed quality assurance mechanisms, seed dissemination mechanisms, seed supply sources, service provision and associated strengths and weaknesses. This tool enables the establishment of key factors which have been instrumental in the development process, as well as the preconditions for this development to take place within a specific environment. It also explores the qualitative cause-effect relationship between maize seed sector development and the adoption of new germplasm.

A Seed Value Chain Analysis (SVCA) refers to the appraisal of the functioning of the chain; flows of the product, services, financial resources and knowledge are analyzed, to explore whether linkages between stakeholders are effective and efficient in terms of the performance of the entire value chain. It enables an understanding of the role played by various private and public actors in the development of the seed sector, and how the seed sector influences the impact of the introduction of improved germplasm. Both tools (SSA and SVCA) were most useful in analyzing the formal systems functioning.

For the key informant interviews, a snowballing process was used to identify key informants to interview. Criteria for interview included relevance, diversity of stakeholders and role in the maize seed value chain. While it was not possible to meet with all the stakeholders identified as important due to time and availability constraints, in total, 14 interviews were conducted with national and international seed companies, extension agents, agro-dealers, the seed trader association, policy-makers, NGO staff and researchers. The interviews provided valuable in-sights on seed sector functioning.

To gather quantitative information, the household survey was developed and rolled out in two locations. The locations were selected based on their different context for maize production. In Bihar, there are three crop seasons, rabi (November to April), spring (May to July) and kharif (August to October). The rabi season is the coolest and longest, the kharif season is the hottest and wettest. Several years ago, maize grown in Bihar would be mainly grown in the kharif season. However, now Samastipur and Muzaffarpur are known for their high production during the rabi season, and are thought to have significant potential for production in the spring season in addition to the rabi and kharif seasons (Singh et al., 2012).

Two days were allocated to training the enumerators and testing the data collection tool with producers around Pusa in Samastipur. Based on the training and testing, the tool was further adapted and tailored to the local context. Data collection lasted for 6 days, 3 days in each district. Villages were selected based on a transect pathway. Each day, a block was selected in a different direction from a central location, in which 4 to 5 villages were designated for the study with the support of the local CIMMYT advisors. These villages were based on a transect pathway from the center of the district. It was ensured that villages selected were typical to the district when it comes to maize production and agricultural practices. On average, in each village 8 to 10 interviews were conducted. The selection of households was done randomly based on a transect walk. Enumerators dispersed themselves geographically in the village first, then interviewed one or 2 households in the area. The first household was picked at random. For the second, or sometimes third household to be interviewed, enumerators were asked to perform a transect walk to the right of the household and select the 3rd house they encountered for the following interview. This ensured that producers interviewed were not selected because of their social and political relations, but rather systematically through the methodology developed.

Samastipur district	Muzaffarpur district
Pusa	Bandra

Tajpur	Bochaha
Patori	Sakra

Table 1 Selected blocks per district for household survey

Each producer was asked to provide quantitative figures on seed use and maize production for the past two completed seasons. Further, they were asked to answer, in a more qualitatively manner, questions regarding maize seed use and production 10 years ago - since it is generally more difficult to remember accurately such information over a long period of time. Each survey interview lasted on average for 40 minutes.

Additional to the household survey, FGDs with producers were held in the two locations of the survey. The villages where the FGDs took place were selected with the support of the CIMMYT staff. Selection criteria included the general representativeness of the village and the survey area as well as the ability to – on short notice - organize an FGD with producers. In total, 17 maize farmers were engaged in the FGDs. An additional shorter discussion was held with 6 farmers (mostly from the same extended family) in Muzaffarpur during a field visit to check on enumerators.

2.2 Limitations

Through efficient planning, working with the CIMMYT staff and highly organized local consultants, who had experience in the Bihari context and the use of interactive survey tools pre-loaded on tablets, a wealth of data was collected and analyzed. However, because of the limited time and resources available for the fieldwork and the long travel time for relatively short distances in Bihar, careful planning of the fieldwork activities was required. Constraints were amplified by the complexity of doing data collection and in-depth interviews in the Bihari seed sector environment. The limited availability of consultants in Bihar able to undertake the work required for the study, led the team to opt for New-Delhi based consultants which had previous experience in Bihar and working with CIMMYT. This enabled the team to quickly organize data collection and contributed to the success of the fieldwork, but the lack of familiarity with the Bihari seed sector proved challenging for the interpretation of some of the discussions during the workshop, for some of the interviews and during data collection.

Therefore it was not always possible to realize all ambitions regarding numbers and depth of data collection, as well as opportunities to engage with key informants for workshops and interviews. One important misinterpretation concerned the type of seed used. A popular maize variety in Bihar is *Lakshmi*. In the survey all *Lakshmi* users were classified as using hybrid varieties. However, *Lakshmi* is an IOPV, and hence reclassification of survey data was needed. Subtleties like the practice of recycling hybrids for use during the *kharif* season were noted during the FGDs, but no data was captured because it wasn't perceived as 'maize production'. Another flaw is the lack of female respondents to the survey. While an interview clearly revealed that women do engage in maize production, none were interviewed. Finally, after careful review of the data, a number of interviews were not used for the analysis because of mistakes made during the interviews that couldn't be resolved through triangulation.

The survey data provides useful information in capturing, in quantitative terms, farmers' practices. However, a number of choices with regard to questions to include had to be made in order to keep the survey to an acceptable length. Hence, only a few questions were asked on the general maize production and most questions were focused on a producers' main plot of maize for specific seasons. The assumption behind this choice is that producers are likely to apply different practices (sowing, varieties, and inputs) on different plots of the same crop. The second assumption is that producers using improved maize varieties would do so on their main plot. What is difficult to capture in the survey, is the mix of strategies that farmers are using when it comes to maize production. For example, it is difficult to assess the coverage and the volume of different varieties or crops on a specific farm.

Limited information was gathered on financial services available to seed multipliers and seed users, and on extension services, due to limited knowledge of stakeholders met. The fact that the majority of representatives at the workshop were from the public sector was at odds with the fact that most of the maize seed sector in Bihar, is actually in the hands of the private sector.

An important constraint observed throughout fieldwork and across data sources, was the recall period of 10 years to identify major changes and their triggers in maize seed sector functioning. Major changes seemed to have occurred earlier, with market liberalization in the 1990s and the emergence, of hybrid varieties. For example, it had been suggested that maize production in Bihar has changed from mainly *kharif* to the *rabi* season, but it was not possible to find evidence of this major shift by using the 10 year period for recall. Therefore, the information gathered mainly focuses on the current functioning of the maize seed sector in Bihar.

Overall, the stakeholder workshop provided good insights into the formal seed sector functioning, complemented with key-stakeholders interviews. The findings of this study, in particular those of the survey, are indicative but cannot be generalized to state level because of the limited size, the focus on the main maize plot of the farmer and the specific locations used for the household survey. Nevertheless, the team is confident that the sampling methodology provided a sufficient level of randomness when it comes to village and household selection, the results provide good insights in the general seed sector functioning because of the diversity of stakeholders interviewed and the mixed-methodology applied to collect information.

3 Seed Sector Functioning

Maize is an important crop grown in India, after rice and wheat (Shirsath 2016). Cultivation of maize has been documented from the Maratha empire, while some argue that evidence of maize in India dates from pre-European contact in the 12th and 13th century (Johannessen and Parker, 1989). Traditionally, Northern states such as Uttar Pradesh, Bihar, Rajasthan, Punjab, and Madhya Pradesh produced most of the maize in the country. Maize can be consumed in porridge or chapatti, but is increasingly used by the animal feed and poultry industry. The past 10 years have seen an unprecedented growth in maize production. Until 2006 or so, about 40 to 50 rail rakes of 2.6 t each would be loaded on trains annually in Bihar, 6 to 7 years later, this has risen to 500 to 550 rakes from 16 railway sidings[1] (Damodaran and Singh, 2015). This indicates that there is a market for grain maize and Bihar offers the appropriate agro-ecological and infrastructural conditions to produce the crop. White maize has been traditionally grown and consumed in Bihar, mostly during the *kharif* season. However, with the developing poultry industry in the country and the international market demanding (yellow) maize, production has shifted from the low yielding *kharif* season to the higher yielding *rabi* season, with some producers also expanding to additionally growing maize in the spring season (Singh *et al.,* 2012).

Hybrid varieties available to maize farmers adapted to the *rabi* season, and high yielding yellow varieties, have contributed to the growth of the commercial sector. However, maize continues to be grown in small quantities by producers for consumption/ livestock feeding at their own farms. While new varieties and a developing private sector are contributing to the rise of maize in Bihar, it is also advancement in other crops and climatic factors which allow the maize sector to grow at this pace. Maize used to be needed for subsistence by farmers in greater volumes in the past, because of the lower productivity of wheat. However, wheat productivity has significantly improved and it is now possible to grow sufficient quantities of wheat on smaller areas to meet livelihood needs. Maize consumption has reduced, while rice has become the preferred crop during *kharif* due to its better ability to cope with heavy waterlogging in the fields, as is typical for *kharif*. Maize hybrid varieties which are well adapted to the *rabi* season also allow for intercropping with potatoes, and are widely available.

3.1 The Maize Seed Value Chain

To understand the seed sector functioning, it is helpful to analyze the operations in the seed value chain. Actors making-up the seed value chains are inherent components of the seed sector. By looking more closely to their roles, functions and appreciation by the sector over the years, it is possible to draw conclusions for the maize sector as a whole. The information gathered during the workshop is focused on the formal seed system functioning. Participants were asked to score operations and services in the chain on a scale of one to five, one being low level functioning and five being excellent performance. Figure 2 shows that the workshop participants were of the opinion that the seed sector in Bihar had much improved in the past 20 years although there is still room for further improvements.

[1] Rakes: A formation of coupled coaches or cars that makes up a train (minus the loco) is called a rake; the same as a 'consist' or 'cut' of cars in US terminology. Sidings: Any track which is not a running line. (Source: http://www.irfca.org/faq/faq-jargon2.html)

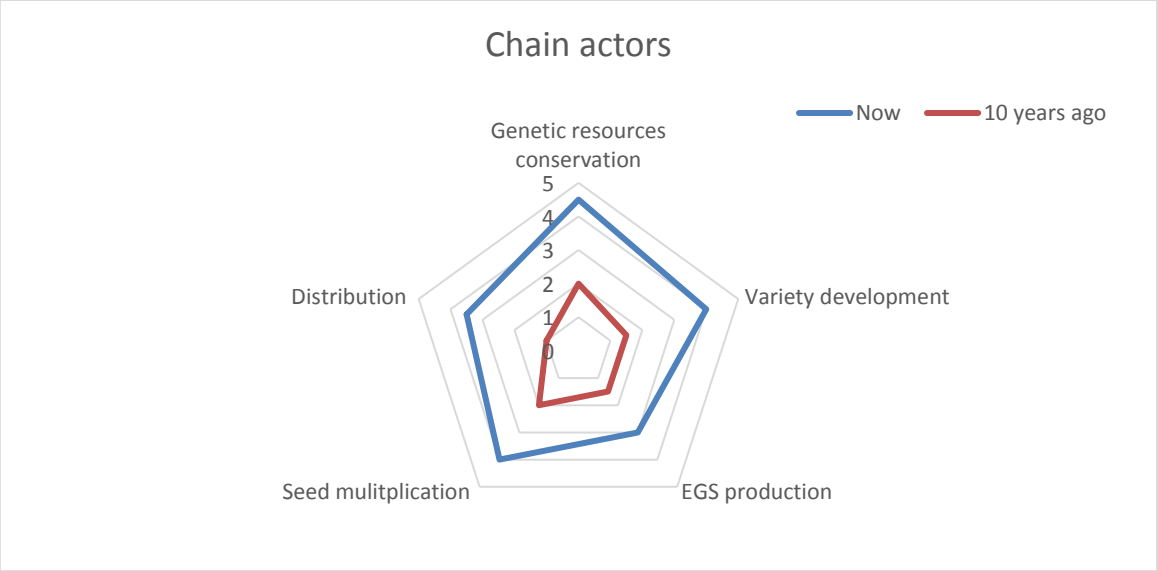

Figure 2 Seed value chain functioning, ranking by the participants of the state level workshop

Genetic resources conservation (GRC)
GRC is the responsibility of the National Bureau of Plant Genetic Resources (NBPGR) based in New Delhi under the Indian Council of Agricultural Research (ICAR). The main responsibility of the NBPGR is to organize the conservation of genetic resources of indigenous and exotic plants. The bureau is also in charge of introduction, exchange and quarantine of plant genetic resources, as well as characterization, evaluation and documentation of accessions. Collection of germplasm, evaluation, maintenance and enhancement is also part of the mandate of the Indian Institute of Maize Research (IIMR) (which used to be the Directorate for Maize Research /DMR), which is located in New Delhi but also has an office in Begusarai in Bihar. At the moment, they are only maintaining four parental lines in Bihar. In Bihar, the Dholi Agriculture College, part of RAU in Pusa, also maintains parental lines used for variety development and works in close collaboration with IIMR and ICAR. Private companies do their own conservation of genetic resources. The maintenance of genetic material is limited to the lines used for the production of early generation seed (EGS), in the case of maize, mainly parental inbred lines.

The system per se has not changed dramatically over the years. It was around 1995 that indigenous accessions started to be characterized and registered in the wake of development around intellectual property rights. Since 1996, maize germplasm has been registered and documented by NBPGR.

Variety development
With producers largely preferring hybrid varieties of maize, the largest share of variety development is presently done by private companies, which is seen as a clear change compared with 10 years ago. The big players are Monsanto, Pioneer and a handful of local companies. International companies only focus on hybrid varieties while the local companies also produce some IOPVs. Single-crosses make up the largest share of the hybrids developed.

While the market share of the varieties developed by the public sector are less important, there are a number of players around. RAU and ICAR are involved in developing maize varieties. For example, the Dholi Agriculture College (DAC) has germplasm of indigenous varieties and parental and in-bred lines used for variety development. Some germplasm also comes from the IIMR and CIMMYT and is used in these public breeding programs. Currently, DAC is carrying out four types of trials to select four new varieties, all single cross hybrids. The first breeding program is focused on producing varieties of yellow Quality Protein Maize (QPM), whilst the second program focuses on 'regular' maize (yellow and white). The third aims to produce early maturing yellow maize for the spring season, and the fourth set of variety trials revolve around selecting hybrids with tolerance to water logging and drought conditions. Pusa (RAU) is also currently involved in testing new varieties. IIMR is engaged in development of new varieties for maize in a program called

Development of Hybrid Maize for Eastern India, which is using germplasm from IIMR and NBPGR, New Delhi.

EGS production
International private companies produce their own parental lines. Neither EGS nor normal seed production are done in Bihar by the large companies, but in other Indian states where conditions are more favorable for seed production. Local companies multiply their own parental lines to ensure quality. However, the public sector trains and employs maize producers to produce EGS and parental lines on their farms. Bihar Rajya Beej Nigam is the state seed company which is in charge of producing and supplying foundation seed to multipliers. However, the company's capacity is limited and it has only four varieties in its catalogue.

It is felt that the public sector has limited capacity in producing EGS and subsequent multiplication steps of maize seed. The selling price of public sector breeder seed is fixed by the ICAR. Some EGS is also produced by IIMR however, according to the institute, much of the seed produced ends up getting sold outside the state (e.g. West Bengal, Odisha). While the quality is perceived to have improved over the past 10 years, the volumes and the diversity of the EGS produced has diminished.

Seed production
Seed production is carried out by seed multipliers who sell their seed to the companies. Some have formal agreements, others operate more informally. Multipliers are usually trained by the company or research organization in the production of seed. A major constraint for multipliers engaged in the production of hybrids is to respect isolation distances between seed production fields. Local companies work closely with the producers to ensure that quality seed is produced, providing them with EGS and extension services. However, public sector multipliers, which constitute the bulk of the seed producers in Bihar, are only provided with the planting material from the research and no other services. Overall, (public) seed production has decreased in the district in the past 10 years, being replaced on the market by seed imported from other states (e.g. Andhra Pradesh, West Bengal, Odisha) from the private sector.

Distribution
The distribution of seed is done mostly by private agro-dealers. Companies either have their own representatives (agents) or sell through agro-dealers, who stock a range of varieties and brands. One of the reasons why private companies have a larger share of the market, is because they are better and more aggressive in their marketing in comparison to the public sector. They also make sure that seed reaches selling points and farmers at the right moment – something which is said to be a problem with the seed produced in the public system. There are very few actors that are in charge of promoting varieties from the public sector. The Krishi Vigyan Kendra (KVK) usually organize some demonstrations, but it is not sufficient to successfully attract farmers to use public sector varieties.

3.2 Services

Certification
The certification of seed is ensured by Bihar Beij Pramanak Kendra. Only the seed produced within the state gets certified by the agency. Anyone who produces seeds in Bihar, public or private, needs to get certification from the agency. The agency certifies seeds for agricultural universities as well. The agency does certification for foundation seed and certified seed, but not breeders' seed. Most of the maize seed certification in Bihar is done for IOPVs, since very few hybrid varieties are produced in Bihar, and it is only a small volume of seed which is certified in the state. Since all the seed marketed by international companies is produced outside the state, it is sold as truthfully labelled seed (TLS).

For the certification of maize seed, the agency has a fixed procedure – a form is filled in and submitted by (groups of) farmers (who may form an association); institutional growers like universities can too submit the form for certification of their seed. There are 40 institutional

growers registered for all crops, including maize. Altogether for maize, there are only five to six companies using the services and 10 farmer groups which are registered as seed growers. The groups are served by 19 field inspectors. The agency charges Rs.300/ha as certification charges for inspection and verification. An additional Rs.30/farmer is charged (for farmers groups). The agency inspectors do not face important constraints in their work since the area of maize seed production is very small. The agency also performs seed certification for other crop seed, primarily for the National Seed Corporation (which does not produce maize seed). In 2014, the agency carried out certification for approx. 10,000 t of seeds for all crops, of which the maize proportion was negligible (0.5 to 1 t).

The system has not changed much in the past decade, except that the amount of certified maize seed has dropped because of the increasing imports of seed from international companies. As shown in Figure 3, seed certification is perceived as weak.

Quality in Marketing and Sales
Quality control of the seed marketed is limited. It seems that there is no control of the products sold by agro-dealers. Interviews revealed there are no documents needed or other requirements to become an agro-dealer. Informants said that their stock is not getting checked or controlled for quality. Agro-dealers interviewed revealed that most of the product information they get is from pamphlets and information provided by the seed companies.

Seed Extension
There are two main channels of government extension: the district agricultural officer which is from the state and the KVK by the Central Government. The first channel uses *Kissan Mitra* (farmers' friends) in the villages to provide information to producers. The second conducts various demonstrations for farmers to learn about new practices and technologies. Both also offer capacity building and training of producers. Additional to these two channels, there is the Agricultural Technical Management Agency (ATMA) which provides services related to pesticides, fertilizers, mechanization, etc. Private seed companies also engage in demonstrations and training of producers to support the marketing and sales of their products. Furthermore, projects and groups such as Vaishali Agriculture Small Farmers Association, provide a range of services to their members. These include access to fertilizer and quality seed, and support for collective marketing of products.

The Bihar Mahila Samakhya Society provides extension services specifically for women. The society joins forces with other organizations such as ATMA, and with projects like CIMMYT's Cereal Systems Initiative for South Asia (CSISA), to make sure that women also get trained in maize production and are able to earn a living from their production. Activities go beyond only technical capacity building of women by stimulating empowerment, improving women's position within the household and in society. Participatory approaches over top-down approaches are used, with the aim to tailor the content of the training to the needs of the women participating.

ICTs are making an appearance as part of extension services as well. For example, farmers that subscribe to the 'Green Sim Card' have the possibility to call the Kisan Call Center for information on agricultural practices, an initiative of the Ministry of Agriculture of India.

In general, seed extension services are rated quite high by stakeholders (Figure 3), but when discussed in the FGDs, producers reported a lack of coordination between the different streams of agricultural extension.

Financial Services
Financial services were not ranked during the workshop because of the lack of knowledge from participants on this subject. In-depth interviews with key informants indicated that it is possible for seed multipliers and maize producers to access credit through various means. For example, it is possible to get a loan from the bank at 7% interest per annum up to Rs 300,000, and 12% for above Rs 300,000 per annum from any nationalized bank. Microcredit is also available to producers. Yet, while credit is generally available, it is thought doubtful that this adequately

addresses producers' needs as these 'financial products' are not specifically designed to fit the purpose of farmers and the agricultural sector.

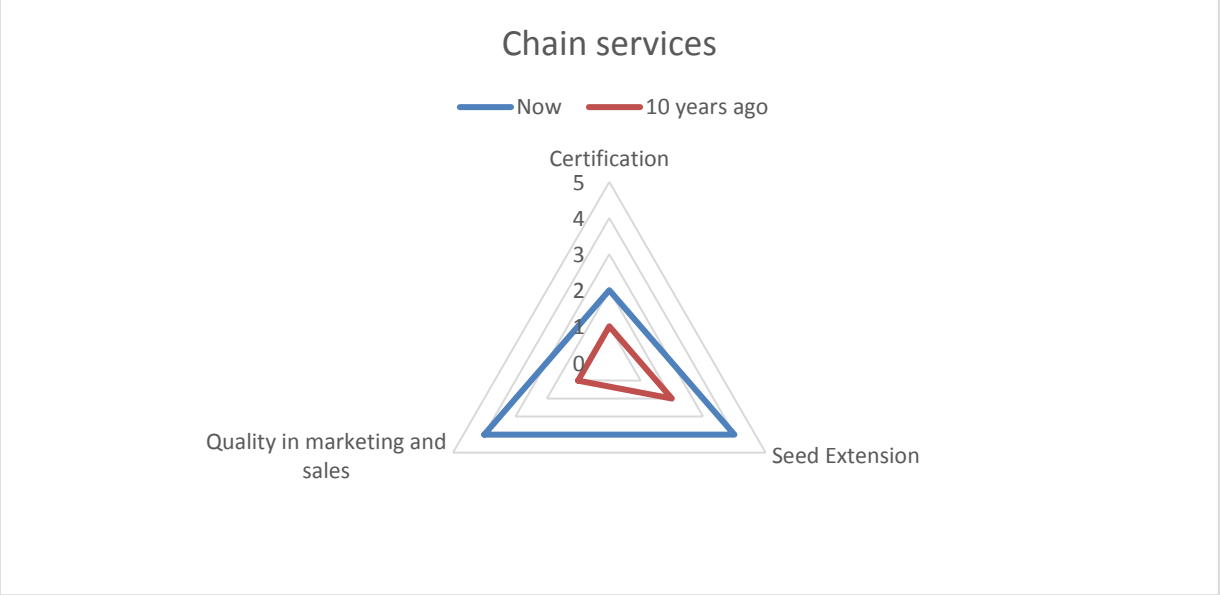

Figure 3 Seed value chain service functioning, ranking by state level workshop participants

3.3 The role of the public sector and the private sector in sector functioning

The private sector is undoubtedly the driving force behind Bihar's developing maize seed and grain sector. In fact, foreign companies (outside Bihar) are the most active on both markets. Some key informants pointed out that in terms of yield, the varieties developed by the public sector are probably similar in quality to the varieties developed by the private sector. However, the white varieties produced by the public sector tend to be less in demand because yellow varieties produced by companies are more appreciated by the market (poultry industry), and because private seed companies put much effort into marketing and into ensuring the timely delivery of the seed to producers. The number of public varieties remains low, and the available capacity to multiply these varieties and make them available to producers is also low, which contributes to the limited use of the public sector varieties. However, *Lakshmi*, an improved OPV of white maize released by the public sector in Bihar in 1983, appears still to be one of the varieties most appreciated by Bihari farmers. Shaktiman I is a hybrid developed by the public sector which also remains relatively widely used.

About 80% of the seed market is dominated by international companies with Monsanto, Pioneer, Limagrain and Syngenta leading the market. The buyers of maize grain are also international companies, such as Cargill, Louis Dreyfus, Glencore, Noble Grain and Bunge. Most of the grain is exported outside of the state and the country due to the fact that while there are some poultry industries in Muzaffarpur, their capacity and infrastructures and hence their need for maize, is limited.

4 Evidence of use of improved varieties at farmers' level

4.1 Maize and livelihood strategies

Using the Out of Poverty Index[2] an easy to access and country specific tool, it is estimated that 90% of producers interviewed are likely to live on less than US$2.50 per day (81% probability). Therefore, it can be assumed that producers interviewed for the study are relatively poor (Table 2).

Likelihood percentage of households living under poverty line	N of producers	%	Cumulative %
100	2	1	1
100	19	7	7
99.8	34	12	20
99.1	36	13	32
98.1	26	9	42
96.3	35	12	54
91.7	41	15	69
86.3	38	14	82
80.7	**23**	**8**	**90**
73.6	11	4	94
64.2	8	3	97
55.2	1	0	98
47.2	5	2	99
40.2	1	0	100
23	1	0	100

Table 2 Likelihood of household (N281) to be under US$2.50/day 2005 PPP

Agriculture is an important economic activity for producers, with 90% of the producers interviewed reporting that agriculture provides them with a least 50% of their income. Thirty two percent relied entirely upon agriculture for their income; this used to be at 45% in the past. Over 90% of the producers reported that maize only contributes 50% or less to their agricultural income, which means that producers have other crops that are at least as important as maize as cash crops. Surprisingly, this percentage has hardly changed in the past 10 years. (Table 3). For example, tobacco is grown as a cash crop in Samastipur.

Share of income	Total agricultural activities now	Total agricultural activities 10 years ago	Share of maize in agricultural income now	Share of maize in agricultural income 10 years ago
Little (10% or less)	2	2	7	13
A quarter (25%)	7	8	46	35
Half (50%)	30	21	42	47
Three quarters (75%)	12	10	4	5
Nearly all (90%)	17	15	1	0
Full (100%)	32	45	0	0

Table 3 Importance of agricultural activities and maize for income amongst producers surveyed (%)

When they sold their maize, producers got on average 10.3 Rs per kg (US$0.16 per kg[3]) (N of sales surveyed over two seasons 411; confidence intervals: 10.2 – 10.4). Farmers don't make an enormous amount of money but this is because their farms and hence, the areas under maize cultivation, are small. Twenty seven percent of producers either used their maize for their own

[2] The PPI is statistically-sound, yet simple tool to use: the answers to 10 questions about a household's characteristics and asset ownership are scored to compute the likelihood that the household is living below the poverty line – or above by only a narrow margin. http://www.progressoutofpoverty.org/

[3] At the time of writing of this report

use including feeding their animals, without gaining any income out of it, or they did earn an income but could not quantify either the volumes sold or the selling price. Close to half of the sales recorded over the two seasons yielded a gross income of between Rs 5,000 to 50,000 (Table 4).

	Freq.	%	Cum.
No income / Don't know	153	27	27
1 to 5,000	107	19	46
5,001-10,000	117	21	67
10,001-50,000	157	28	94
50,001-100,000	16	3	97
More than 100,000	16	3	100

Table 4 Gross revenues from maize sales in Rs (N of sales in two harvests 566)

4.2 Site comparison

Main plot dedicated to maize

The main maize plot (largest in area) of the producers interviewed was relatively small. On average the plot of the producers surveyed over the last two seasons dedicated to maize production, was a quarter of a ha. In Samastipur, the average area was 0.2 ha (C.I. 95% 0.2-0.3) and in Muzaffarpur 0.3 ha (C.I. 95% 0.3-0.4). In both cases this area accounted for about a quarter of the total land cultivated over the year (Table 5).

Samastipur	Mean	95% Conf. interval - low	95% Conf. interval - high	N plots
Rabi	0.2	0.2	0.3	233
Kharif	0.2	0.2	0.3	37
Spring	0.2	0.1	0.3	16
Mean	*0.2*	*0.2*	*0.3*	*286*
Mean total land	0.8	0.7	1.0	143
Muzaffarpur	Mean	95% Conf. interval - low	95% Conf. interval – high	N plots
Rabi	0.4	0.3	0.4	253
Kharif	0.4	0.2	0.5	12
Spring	0.2	0.2	0.3	12
Mean	*0.3*	*0.3*	*0.4*	*277*
Mean total land	1.3	1.0	1.5	139

Table 5 Maize plot size in ha per location and season (N plots over last 2 seasons 563)

From the survey data it becomes clear that the *rabi* season is the predominant season in both locations, with only a handful of producers producing in more than one season a year (Table 6). It is also clear that producers have abandoned *kharif* production for the higher potential *rabi* season. Hardly any producers had engaged in spring production which requires shorter term varieties, although this had been indicated as a significant option for producers of Muzaffarpur during the workshop and expert interviews. It also emerged from the discussions with enumerators carrying out the household survey, that producers recycle their hybrid varieties grown in the *rabi* season, i.e. harvest seed for sowing in the *kharif* season to produce green fodder for their own animals. Producers do not consider this as maize production and no hard data was collected on this practice.

	Samastipur		Muzaffarpur		Total	
	Freq	%	Freq	%	Freq	%
Kharif only	4	3	0	0	4	1
Kharif and rabi	12	8	9	6	21	7
Rabi only	121	85	124	89	245	87
Rabi and spring	3	2	3	2	6	2
Spring only	3	2	4	3	7	2
Total	143	100	140	100	283	100

Table 6 Seasons in which the interviewed producers usually grow maize (N producers 283)

Producers were also asked how many seasons a year they produced maize 10 years ago. Ninety eight percent of producers reported only growing maize once a year in Samastipur and 93% in Muzaffarpur. Of the producers interviewed, 74% in Samastipur and 90% in Muzaffarpur were producing maize in the *rabi* season 10 years ago. This indicates that the transition from the *kharif* season towards growing maize in *rabi* was already well under way 10 years ago in the two districts surveyed.

Data analysis revealed differences in yield between the two locations (Table 7). Table 8 shows that in Samastipur, yields per ha were higher for the last season at 5.3 t/ha, when compared to the second to last season, at 4.5 t/ha. Yields per ha were more consistent in Muzaffarpur, at around 6.1 t/ha – 6.3 t/ha. Overall, yields were consistently higher in Muzaffarpur than in Samastipur.

Average yields per location	Mean	95% Conf. interval - low	95% Conf. interval - high	N Fields	N Farmers
Samastipur	4870	4609	5131	277	139
Muzaffarpur	6160	5879	6441	272	136

Table 7 Average yields (kg/ha) according to survey location (N plots 549, N farmers)

Most recent season	Mean	95% Conf. interval - low	95% Conf. interval - high	N yields	N Farmers
Samastipur	5289	4811	5494	137	69
Muzaffarpur	6057	5661	6453	133	67
Second to last	Mean	95% Conf. interval - low	95% Conf. interval - high	N yields	N Farmers
Samastipur	4461	4103	4819	140	70
Muzaffarpur	6260	5858	6661	139	69

Table 8 Average yields (kg/ha) according to survey location per season (N plots 549, N farmers)

The yields of farmers in both seasons were correlated only to a limited extent, at r=0.38 for Samastipur and r=0.32 for Muzaffarpur. This suggests that the differences in skill, farm quality and resources between farmers explain less than 15% of the variation in maize yields recorded.

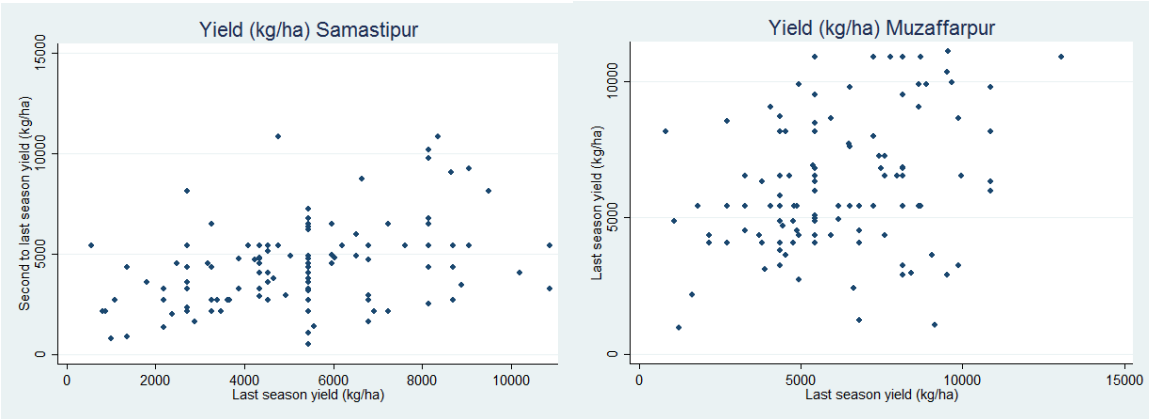

Figure 4 Scatter graphs of yields (kg/ha) in recent seasons for Samastipur and Muzaffarpur

Few farmers are using what is called a local traditional variety of maize. In the last two seasons in Samastipur, an improved OPV was used on 30% of the fields and hybrid varieties as a main variety on 66% of the main maize plots. The large majority of cases (78%) in Muzaffarpur used a hybrid variety on the main maize plot.

Type of seed sown	Samastipur		Muzaffarpur		Total
	N plots	%	N plots	%	Total N
Local variety	12	5	3	1	15
Improved OPV	85	30	58	21	143
Hybrid seed	188	66	219	78	407
	285	100	280	100	565

Table 9 Different types of seed used by farmers at two survey locations for two seasons (N plots 565)

4.3 Farming system

Quite a large share of producers reported not using any of the maize they had produced over their latest two seasons. Sixteen percent of producers kept less than 50% of their production. Use encompasses both household consumption and feeding farm animals. Only, ten percent of producers produce exclusively for their household needs (Table 10). A larger share of producers in Muzaffarpur (71%) sell their entire production as compared to Samastipur (61%). Producers in Samastipur also tend to keep in larger proportion their entire maize harvest (14% in Samastipur, 6% in Muzaffarpur).

Ratio use to sale	Samastipur		Muzaffarpur		Total	
	Freq.	%	Freq.	%	% Total	Cum.
100% sales	175	61	197	71	66	100
1-25% used	11	4	39	14	8	34
26-50% used	33	12	23	8	10	26
51-75% used	8	3	1	0	2	16
76-90% used	4	1	1	0	1	14
91-99% used	14	5	1	1	3	13
100% used	41	14	17	6	10	10

Table 10 Ratio consumption to production (N harvests over two seasons 566)

Subsidies related to maize production are not part of the production system in Bihar. Ninety eight percent of producers reported not having received any subsidized inputs for their maize production (Table 11).

	Freq.	%
No subsidy	556	98
Seed	8	2
Fertilizer	2	0
Total	566	100

Table 11 Percentage of producers having received input subsidy in the past two seasons of maize

4.4 Maize varieties, variety selection and seed renewal

Varieties

Three quarters of the main plots under maize cultivation in recent seasons were under only one variety of maize (Table 12); figures were similar for both survey locations. For the farmers mixing varieties, the reason most often cited for such a strategy was that different varieties fulfil different purposes. For example, one variety will be dedicated to human consumption, while the other will be dedicated to feed for animals. Risk mitigation (having a successful variety when the other would fail) is also an important reason for which producers engage in sowing multiple varieties on a single plot. Seed unavailability of the preferred variety is not an important reason for having more than one variety on the main plot (Table 13).

Number of varieties grown	N plots	%
1	416	74

2	137	24
3 and more	12	2
Total	565	100

Table 12 Number of varieties grown by producers on the main maize plot for the last two seasons (N plots 565)

Reason for using more than one variety	N plots	%
Different varieties for different uses	44	56
Risk mitigation strategy	30	39
Unable to access enough seed of one	3	4
Other	1	1

Table 13 Reason for growing more than one variety on the main plot of maize in the last season (N plots 78)

Variety Selection

In both districts, the IOPV *Lakshmi* was frequently sown by producers on their main plot (25% total, 29% in Samastipur and 20% in Muzaffarpur). It was also the variety most frequently sown overall. Pioneer varieties are generally appreciated, although Pioneer 3522 is the second most frequently sown variety in the two districts. In Muzaffarpur, the variety most commonly used was Pioneer 3522 (on 23% of fields). Monsanto varieties (DKC) are also appreciated, a popular one is DKC 9081 (Table 14). *Lakshmi* is the only IOPV and the only variety from the public domain (RAU Dholi) which is widely used. Interviews revealed that *Devki*, another IOPV released by the public sector some years ago, was bred to replace *Lakshmi*. Yet, producers interviewed seemed not to have adopted *Devki* and rather stuck to *Lakshmi* as a variety. Interviews showed that most of the appreciated varieties with the exception of *Lakshmi,* have been developed by the private sector. Most of the yellow varieties come from the private sector, while the white maize varieties for human consumption have been developed by the public sector.

	Samastipur		Muzaffarpur		Total	
	N plot	%	N plot	%	N plot	%
Lakshmi	81	29	55	20	136	25
Pioneer 3522	68	25	64	23	132	24
DKC 9081	25	9	59	21	84	15
DKC 900M Gold	27	10	41	15	68	12
Numbered, no brand	11	4	12	4	23	4
Local varieties	10	4	3	1	13	2
DKC 9120	5	2	6	2	11	2
Pioneer 30R77	7	3	3	1	10	2
DKC 7074	6	2	3	1	9	2
Shankar	6	2	3	1	9	2
NK 6240	3	1	4	1	7	1
Jogia	6	2	1	0	7	1
Pioneer other varieties	1	0	5	2	6	1
900M Super	0	0	5	2	5	1
PP 808	3	1	0	0	3	1
DKC 9144	2	1	1	0	3	1
DKC 9108	0	0	2	1	2	0
Shaktiman 1	1	0	0	0	1	0
Devki	1	0	0	0	1	0
NK 6240	0	0	1	0	1	0
Other	14	5	8	3	22	4
Total	277	100	276	100	553	100

Table 14 Main maize variety used by producers on the main maize plot in recent seasons, per location (the category 'Other' refers unnamed varieties)

Generally, at least 50% of the producers who had sown a certain variety of maize, sowed the same variety the following season. This indicates that farmers tend to stick with a variety when they like it. Table 15 also indicates that the (older) IOPV *Lakshmi* may be going down in popularity in the districts surveyed, with Pioneer 3522 gaining popularity.

	Last season							
Second to last season	Lakshmi	Pioneer 3522	DKC 9081	DKC 900M Gold	DKC 9120	DKC 7074	…	Total all varieties
Lakshmi	**40**	6	1	7	1	1		69
Pioneer 3522	1	**44**	4	2	1	0		58
DKC 9081	1	7	**24**	4	1	0		40
DKC 900M Gold	7	4	5	**16**	1	1		38
DKC 9120	1	0	2	0	**2**	0		5
DKC 7074	2	0	0	1	0	**1**		4
…								
Total all varieties	59	74	42	30	6	5		271

Table 15 Variety sown from season to season by producers

Producers were requested to outline the two most important reasons for maize variety selection. Table 16 represents the answers most often given as a percentage of total answers. Reasons for selecting the variety sown varied among producers interviewed and survey location. However, higher yields was consistently reported as the most important factor followed by availability. Key informant interviews revealed that yields are also the main breeding goal when the private sector develops new varieties. Among producers taking part in the FGD, white maize is generally more appreciated for human consumption than yellow maize, which is not appreciated for its taste and gets fed to animals; some interviewees reported the same for QPM. Trusting the origin of the seed is also an important component of farmers' decisions as well as trust in the brand of seed. Ten years ago, most producers also selected their varieties based on availability and yields, and in particular Muzaffarpur already showed a strong bias towards yields (27%) (Table 16).

	Samastipur		Muzaffarpur		10 years ago Samastipur		10 years ago Muzaffarpur	
Reason	N answers	% of answers	N answers	% of answers	N answers	% of answers	N answers	% of answers
I get better yields	93	29	108	33	19	19	50	27
It is the variety that was available at the time	67	21	72	22	29	28	46	25
I trust the origin of the seed	47	15	63	19	14	14	25	14
Possibility to recycle the variety	24	8	20	6	9	9	16	9
I like the taste and / or texture for food	22	7	14	4	7	7	19	10
I can easily sell this maize	16	5	5	2	1	1	3	2
I can process this maize into food	14	4	16	5	16	16	7	4
Maturity cycle	10	3	9	3	0	0	5	3
Easy to store	9	3	10	3	2	2	0	0
Got these seed free	6	2	1	0	2	2	3	2
Drought tolerant	5	2	10	3	2	2	6	3
These seeds were subsidized	2	1	0	0	0	0	0	0
This variety is required by my contract	1	0	0	0	0	0	0	0
Other	2	1	0	0	0	0	3	2
Total	318	100	328	100	101	100	183	100

Table 16 Two main reasons for variety selection. N.B some producers indicated one reason only

Producers also select the varieties they plant according to the final use of the maize. Again, the two main reasons were collected from households. Interviewed producers clearly have a market orientation, with an average of 33% of answers focused on price paid by buyers (Table 17).

	Samastipur		Muzaffarpur		Total	
	N answers	% of answers	N answers	% of answers	N answers	% of answers
Price paid by buyers	67	29	88	36	155	33
Storability	52	23	64	26	116	25
Colour of grains	53	23	47	19	100	21
Taste	25	11	21	9	46	10
Processing into flour	20	9	16	7	36	8
Dry mass	11	5	7	3	18	4
Total	0	100	0	100	0	100

Table 17 Selection of variety according to final use of the maize

Type of seed

Hybrids were the predominant type of seed used by producers, with 78% of plots in recent seasons sown with hybrids in Muzaffarpur and 66% in Samastipur. OPVs (mostly *Lakshmi*) were sown on 30% of plots in recent seasons in Samastipur and 21% of plots in Muzaffarpur. Local varieties were only marginally used (Table 18).

	Samastipur		Muzaffarpur	
Type of seed used	N plots	% of plots	N plots	% of plots
Hybrid	188	66	219	78
Improved OPV	85	30	58	21
Local variety	12	4	3	1
Total	285	100	280	100

Table 18 Variety type used on the main maize plot in Samastipur and Muzaffarpur in recent seasons

It is difficult to draw robust conclusions about the type of seed used per season because of the low number of observations for *kharif* and spring seasons. In *rabi* however, it is clear that producers prefer hybrid varieties over other types of seed, which suggests that hybrids are well adapted to the *rabi* growing conditions. Producers have used hybrids during *kharif,* although they are believed to be less adapted to the heavy water conditions.

Samastipur	Rabi		Kharif		Spring	
	N	%	N	%	N	%
Local OPV	3	1	9	25	0	0
Improved OPV	73	31	7	20	5	31
Hybrid	157	68	20	55	11	69
Total	233	100	36	100	16	100
Muzaffarpur	Rabi		Kharif		Spring	
Local OPV	2	1	1	8	0	0
Improved OPV	57	22	1	8	0	0
Hybrid	197	77	10	84	12	100
Total	256	100	12	100	12	100

Table 19 Type of seed used per season in the two survey locations

Source of the seed

There is only a limited difference in the source of seed between the two survey locations. Fifty two percent of producers interviewed reported sourcing their seed from the rural market, while the agro-dealers are also an important source of seed for 35% of producers. It is likely that some producers reported the rural market while in fact they purchased their seed from an agro-dealer at the rural market. In some cases, agro-dealers have small kiosks where they sell hybrid varieties and other inputs. For maize, producers do not use much informal channels (own field, social network) to acquire seed.

Ten years ago, informal channels were the source of about 20% of the seed used by producers. The rural market - which can be formal and informal simultaneously - was the most common seed source (58%) (Table 20).

Source of seed	Now (N plots)	Now (% of plots)	10 yrs ago (N answers)	10 yrs ago (% answers)
Rural market	296	52	74	58
Agro-dealer	197	35	18	14
Local agent of seed company	38	7	7	6
Neighbor, family or friend	18	3	18	14
Own field	5	1	8	6
Supermarket	3	1		
Certified seed producer	4	1	1	1
Farmer group, cooperative or association	2	0		
Project or program	2	0		
Research institute	1	0	2	2
Total	566	100	128	100

Table 20 Source of seed used by farmers now and 10 years ago

There is a high likelihood that producers do in fact acquire seed at the local market from agro-dealers, since 51% of the producers reported having been convinced to use a certain variety by agro-dealers. Farmers' social networks are also an important factor when it comes to convincing fellow farmers to use certain varieties (36% now, 46% 10 years ago). Other actors, including extension services outside agro-dealers and the social network, have a very limited influence on

producers' variety choice. Companies also have a very limited direct effect on producers. Trust, (Table 16), is key in selecting a variety and therefore it makes sense that producers rely on a closer group of informants when it comes to variety selection.

Source of information	N Total	% S	% M	% Total	N Total	% S	% M	% Total
	Now				10 years ago			
Agro-dealer	144	48	54	51	49	32	42	38
Family, friends, neighbors	101	39	33	36	59	57	46	46
Myself	16	5	7	6	14	17	7	11
Seed company/agent	11	5	3	4	2	2	1	2
NGO	6	2	2	2	1	2	0	1
Extension officer	2	0	1	1	0	0	0	0
Producer group or association	1	0	0	0	2	0	2	2
Seed demo plot from seed company	1	0	0	0	0	0	0	0
The subsidy program	1	0	0	0	1	0	1	1
Total	283	100	100	100	128	100	100	100

Table 21 Source of information relied upon for variety choice, both locations (N 411)

Distance to seed

Famers reported to have access to seed relatively close to their homes, with 7% of producers not having to travel at all to access seed. Eighty five percent had to travel less than 5 km, and 50% travelled a maximum of 1.5 km. Muzaffarpur producers tended to be closer to their seed source (Table 22).

Distance to access seed (km)	Freq. plot total	% plots Samastipur	% plots Muzaffarpur	Total Percent	Cum.%
0	41	6	8	7	7
0.1 to 0.4	98	7	28	17	25
0.5 to 1.4	13	5	0	2	27
1.5 to 1.9	193	43	25	34	61
2.0 to 4.9	137	26	22	24	85
5 to 9.9	84	15	0	15	100

Table 22 Distance travelled by producers to seed in km for recent seasons (N plot 566)

Seed prices

Most producers pay for the seed for their main plot, only in 3% of cases did the producers not pay (16 occurrences on 565 observations/plots, recent seasons). Hybrids are purchased at the highest price of Rs 242 per kg, followed closely by IOPVs at Rs 237 per kg (Table 23). On very few occasions (6) producers paid for local varieties at a significantly lower rate of Rs 27 per kg on average in Samastipur, about triple the price of maize grain. The data for IOPVs is not reliable because of the very low number of observations.

Average price paid for seed when producers engaged in seed purchase (Samastipur)				
	Mean	95% Conf. interval - low	95% Conf. interval - high	N 270
Local variety, open-pollinated seed	27	24	29	5
Improved variety, open-pollinated seed	218	34	401	4
Hybrid seed	226	218	234	261
Average price paid for seed when producers engaged in seed purchase (Muzaffarpur)				
	Mean	95% Conf. interval - low	95% Conf. interval - high	N 276
Improved variety, open-pollinated seed	258	202	313	4
Hybrid seed	268	250	266	272
Average hybrid total	242	236	248	533
Average IOPV total	238	147	327	8

Table 23 Average price paid for seed (Rs) per kg in the past two seasons according to variety type (N plots 546)

4.5 Inputs

Farmers interviewed have reported using fertilizer on virtually all of their main maize plots. Urea was used the most frequently (99%) in the two locations. This is likely to be explained by the fact that urea's price has been fixed by the government and that subsidized plants of urea are also subsidized (Ashar 2015). Because the fixed price is applied to all the urea sold and no matter what crop it is intended for, farmers did not report this as a specific subsidy for fertilizer for maize production. For almost all other inputs, the proportion of producers having used fertilizers on their main maize plot in the last two seasons, was higher in Muzaffarpur than in Samastipur. This does not include NPK and compost which were used on more plots in Samastipur than Muzaffarpur (Table 24). Herbicides and/or pesticides were only used on a few fields, and there were very few recordings of fungicide use.

	NPK	Urea	DAP	MOP	ZS	Manure	Compost	Herb	Pest	Fung
Samastipur	12	98	83	77	47	7	14	6	13	0
Muzaffarpur	9	100	88	90	64	11	9	13	15	1

Table 24 Fertilizer use percentage of harvests (N 566 potential application of inputs on main maize plot, recent seasons)

4.6 Yields

When it comes to yields, hybrids consistently yielded higher, across the two seasons surveyed and across the two locations (Table 25). This is in line with the expectations that hybrids result in higher yields than IOPVs. The yields of the second to last season in Samastipur were lower for all variety types, as compared to the last season. Hybrid varieties performed better in Muzaffarpur than in Samastipur, with a significant difference in means between the two districts in both seasons. Consistently, average yields were found to be higher in Muzaffarpur than in Samastipur, although the difference between locations for IOPVs were not statistically significant (Table 26).

Samastipur last season	Mean yield kg/ha	95% Conf. interval - low	95% Conf. interval - high	N plots
Improved OPV	4635	4147	5123	34
Hybrid variety	5530	5059	6001	101
Samastipur second last season	Mean Yield kg/ha	95% Conf. interval – low	95% Conf. interval – high	N plots
Improved OPV	4101	3635	4567	47
Hybrid variety	4876	4357	5395	83
Muzaffarpur last season	Mean Yield kg/ha	95% Conf. interval – low	95% Conf. interval – high	N plots
Improved OPV	5097	4329	5865	30
Hybrid variety	6383	5937	6828	102
Muzaffarpur second last season	Mean Yield kg/ha	95% Conf. interval – low	95% Conf. interval - high	N plots
Improved OPV	4636	4231	5040	27
Hybrid variety	6703	6240	7167	110

Table 25 Average yields (kg/ha) according to type of seed per season and location (N532)

	Samastipur hybrid last season	Samastipur hybrid second to last season	S. IOPV last	S. IOPV 2 last	S. OPV last	M. OPV last	S. OPV 2 last	M. OPV 2 last
Muzaffarpur hybrid last season	853 *							
Muzaffarpur hybrid second to last season		1827***						
M. IOPV last			462					
M. IOPV 2nd to last				534				
S. Hybrid last					790*			
M. Hybrid last						1052**		
S. Hybrid 2nd to last							664*	
M. Hybrid 2nd to last								2067***

Table 26 T-test for yields controlled by type of seed (recent seasons) rows minus columns, *p-value<=10%, **p-value<=5%, ***p-value<=1%

Virtually all producers interviewed used at least one type of fertilizer on their main maize plot, with urea used on 99% of the plots surveyed (Table 24). Average yields were calculated for

producers who used urea, diammonium phosphate (DAP), muriate of potash (MOP) and zinc sulfate simultaneously for the past two seasons according to the variety type they had used. With the use of the four fertilizers combined, hybrid varieties consistently yielded higher, with the exception of the second to last season in Samastipur, for which overall yields were quite low. Muzaffarpur producers also tends to report higher yields than those in Samastipur, even when producers used the combined four inputs (Table 27). This difference in mean yield is significant (p-value< 5%) for hybrid varieties between the two locations (Table 28).

Yields with MOP, ZS, urea and Dap	Mean Yield kg/ha	95% Conf. interval - low	95% Conf. interval - high	N plots
Muzaffarpur last season hybrid	6538	6030	7047	69
Muzaffarpur 2nd last season hybrid	6426	5847	7005	67
Muzaffarpur last season IOPV	4995	3766	6224	13
Muzaffarpur 2nd last season IOPV	4906	937	8874	4
Samastipur last season hybrid	5643	4960	6325	52
Samastipur 2nd last season Hybrid	4536	3850	5222	32
Samastipur last season IOPV	4738	3626	5851	11
Samastipur 2nd last season IOPV	4228	3387	5068	13

Table 27 Average yields for IOPVs and hybrids per season and location, under the use of all four inputs simultaneously (urea, DAP, MOP, zinc sulfate)

	M. last season IOPV	M. last season Hybrid	M. 2nd last season IOPV	M. 2nd last season Hybrid
Samastipur last season IOPV	-256			
Samastipur last season Hybrid		-896 **		
Samastipur 2nd last season IOPV			-678	
Samastipur 2nd last season Hybrid				-1890***

Table 28 T-test for yields controlled by type of seed (recent seasons) and fertilizer, rows minus columns, *p-value<=10%, **p-value<=5%, ***p-value<=1%

Yield levels do not account for intercropping which was practiced by on average 55% of producers interviewed, (58% in Samastipur and 51% in Muzaffarpur) who intercropped their maize varieties with potatoes most frequently. When comparing yields under different cropping systems, the data indicates higher yields for producers in Samastipur practicing intercropping than those who produced pure-stand. The opposite was found in Muzaffarpur, where higher yields were found for pure-stand maize (+/-1500kg/ha) (Table 29). The yield differences between intercropped and not intercropped is not significant in both locations for the last season, but is for the second to last season (p-value <1%).

Samastipur last season	Mean Yield kg/ha	95% Conf. interval - low	95% Conf. interval - high	N plots
Pure-stand	5076	4226	5926	40
Intercropped	5376	4980	5773	97
Samastipur second to last season	Mean Yield kg/ha	95% Conf. interval - low	95% Conf. interval - high	N plots
Pure-stand	3948	3510	4386	75
Intercropped	5053	4496	5609	65
Muzaffarpur last season	Mean Yield kg/ha	95% Conf. interval - low	95% Conf. interval - high	N plots
Pure-stand	6369	5648	7090	59
Intercropped	5808	5386	6230	74
Muzaffarpur second to last season	Mean Yield kg/ha	95% Conf. interval - low	95% Conf. interval - high	N plots
Pure-stand	6997	6374	7619	73
Intercropped	5445	5023	5866	66

Table 29 Yields (kg/ha) per season and location for pure-stand and intercropped maize

5 Observations and Conclusions

Producers in the two survey locations of Samastipur and Muzaffarpur clearly adopted *rabi* as the main season for growing maize, and the reasons for this are many. New varieties offered on the market with high yield potential are suitable for *rabi* production. With the productivity of other crops like wheat improving, it created space for maize to be grown in the *rabi* season. The *rabi* season offers less erratic climatic conditions than in *kharif,* where monsoon rains lead to heavy waterlogging on the plots which are then better used for rice than maize. The heavy rains also fuel the growth of weeds and increase the incidence of pests and diseases. Growing maize in *rabi* is therefore easier and less risky than in the *kharif* season. Most producers interviewed only engaged in *rabi* production with few producing during *kharif.* Few producers engaged in the spring production, although it is believed to be slowly getting more popular as suggested by Singh *et al.,* (2012) and the key informant interviews. Yet limited evidence of this was found from the survey. The growing market may be an incentive for producers to sow maize also in spring season, but producers are expecting shorter term maturity varieties for improved production in the spring season.

Producers interviewed during fieldwork have shown a clear market orientation with over 60% of harvests sold entirely. The market and the constant demand for maize makes it a relatively safe business for producers to engage in. However, it does not mean that maize is not consumed as well. Like several other places of the world, in Bihar, white maize seems to be more appreciated for its texture and taste for human consumption. In general yellow maize is mostly dedicated to the feed industry. In Bihar, it was reported that QPM is also not seen as 'fit for human' consumption due to its taste which is not widely appreciated. A large share of the hybrid varieties are yellow, while local and improved OPVs like *Lakshmi* are white maize. Less attention has been given to breeding hybrid white maize because of the emphasis of growing maize in Bihar for the poultry industry. Some interviewees indicated that at the moment, white maize is gaining some attention for the starch industry. Yet, currently the white maize grown in Bihar is mostly dedicated to human consumption.

Most appreciated hybrids are from Dekalb (Monsanto) and Pioneer, and these are yellow maize varieties. Most of the varieties from the private sector are produced in other states of India, which means that the seed is sold as TLS in Bihar. In both survey locations, producers are using *Lakshmi* frequently, a white improved OPV which was released by RAU Dholi in 1983. While other varieties such as *Devki* have been bred with the intent of replacing *Lakshmi*, the data collected did not suggest such a shift.

In Samastipur, use for food seems to be more important than in Muzaffarpur which may explain the popularity of *Lakshmi* there. There are a number of producers who are multiplying *Lakshmi* which is available for purchase from agro-dealers. In general, quality seed is widely available and fairly close to producers' home, often purchased from agro-dealers or at the rural market. Trust in the source of the seed and the brand of the seed are important factors when it comes to decision making. Producers buy their seed every season and reported having done so without having access to subsidies for the seed, or other inputs for production. Hence, producers do not hesitate in investing in maize as they know that sales won't be an issue.

The public sector in Bihar now has little to do with the functioning of the seed sector. While it continues to breed and test varieties, the bulk of varieties come from the private sector. Both channels use germplasm from CIMMYT, but also other sources. There is limited interaction between the public and private sectors in the seed value chain, with most activities performed by the private sector with limited involvement of public services. Producers reported sometimes trying new varieties for CIMMYT through the local research actors and giving their observations about the results. However, they perceived receiving limited feedback from the collaboration and no tangible results in terms of new varieties developed. The public sector has an important task in seed certification, but since most of the maize seed used in Bihar is actually produced elsewhere, this doesn't play a very significant role in the Bihari maize seed value chain. The

public extension is perceived as not adapted to producers needs and unable to reach producers in a timely fashion.

Maize production in Bihar appears to be progressing and while there is still room for improvement, the current seed production system led by the private sector, does provide options to producers and has supported producers in developing their engagement in maize production. While progress has been made and maize is increasingly popular among farmers, it is also the advancements in other important crops such as wheat that has allowed producers to profit from maize production. The current role of the public sector is rather limited and most of the access to hybrid seed is driven by the activities of the private sector. The fieldwork yielded limited evidence of informal production of maize seed, which could be produced under the TLS quality control system. Similarly, fieldwork yielded no evidence of the engagement and responsiveness of the seed sector to women's needs in regards to maize production. This is not to say that women are not involved in various stages of maize production, yet actors of the seed sector seem not to focus on the differences and needs which different producers may express. The actions of CSISA in working with women and improving women's positions within the maize value chain, should in part focus on their specific needs, while overall coordination among extension services could be improved and aligned.

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7 Annex: List of interviews

The fieldwork was conducted in collaboration with the consultancy firm New Concept Information Systems Pvt. Ltd (NCIS). The fieldwork lead consultant was Sanjay Tiwari and fieldwork coordination was assured by Subhash Sinha. The KIT-NCIS team worked in close collaboration with Madhulika Singh, Pankaj Kumar and Dr. Malik of the local CIMMYT team for the duration of the fieldwork. Key responsibilities of the consultants, with the support of the CIMMYT team included organization of the workshop, hiring and coordination of enumerators, facilitation of the identification process of key informants, organization of FGDs and translation from local language to English when informants did not speak English. Locations for the survey were selected in consultation with the CIMMYT team.

Activity	Dates	Location	Participants
Stakeholder workshop	August 25th 2015	PUSA Samastipur	25
FGDs	28-29th August 2015	Samastipur / Muzaffarpur	17
Key interviews	28th Aug. to 3rd Sept	Samastipur / Muzaffarpur, Begusarai / Patna	12
Survey	28th Aug. to 3rd Sept	Samastipur / Muzaffarpur,	283

Table 30 Research activities

Workshop invitees

Name	*Designation*	*Discipline/ Representation*	*Organization/Location*
Ajit Kumar Paswan	SMS (Agronomy)	SMS (Agronomy)	Bihar Agricultural University (KrishiVigyan Kendra GandharJehanabad,)
Dr. MithileshKumar Roy	SMS (Agronomy)	SMS (Agronomy)	KVK, Madhepura, (Bihar Agricultural University)
Dr. D.K. Roy	Sr. Scientist	Deptt. of Agronomy,	Rajendra Agriculture University Bihar
Dr. M. Kumar	Sr. Scientist /Maize specialist	Deptt. of Agronomy	Rajendra Agriculture University Bihar
Dr. S. B. Singh	Principal Scientist		Regional Maize Research & Seed Production Centre Kushmahout Farm, Begusarai, Bihar
Ashish Nehra		Monsanto India Ltd.	
Dr Rakesh Mishra		Bioseed	Patna
Nishant Yadave		Bioseed	Purnia
Heera Lal Sah	Regional Manager	Syngenta	
Dr. Rajesh Kumar	Asstt. Professor	Agri. Economics	BAU, Sabour
Prof .P.K.Singh			BHU, U.P.
Dr. Brajendra Kumar		KVK	KhagariaCharvak Socio-economic Development Trust, Vijya Lodge, Kosicosi college, Bihar
S.S. Mundle	Asstt. Professor	Maize Breeder	BAU, Sabour
Dr. Sudhir Kumar Singh	Programme Coordinator	KVK	ShramaBharati, P.O. Khadigram, Distt. : Jamui, Bihar
Shi SadaNand Rai		KVK	Vanvasi, P.O. Adhaura Dist. Kaimur (Bhabua)

Er. Shailendra Kishore Mishra	Programme Coordinator	KVK	Gram Nirman Mandal, Sarvodaya Ashram, Sokhodeora, Distt. Nawada,
D.U.M. Rao	Principal Scientist	Agr. Extension	KVK
Dr. Ratnesh Kumar Jha	Programme Coordinator		KVK, Manjhi, Saran
Devendra Mandal	Programme Coordinator	Scientist	KVK, BAU, BikramGanjRohtas
V.K. Yadav	Maize breeder		IAR, Ranchi
Dr. VishvandueDewadi			ICAR, Bihar, Eastern Region
Sri Surendra Prasad	District Agriculture Officer		Katihar, Bihar
Sri Sarwajeet Kumar	District Agriculture Officer		Muzaffarpur, Bihar
Kishore Rao	District Agriculture Officer		Madhepura, Bihar
JRP Singh	Maize Breeder		

Interviews

Mr. V.N Singh, Director and Mr. Pathank, Bihar Seed Certification Agency, Patna
Ms. Sugandha, Gender Coordinator, CSISA, Patna
Dr. U.M Rao, IARI, Pusa, Samastipur
Dr. Ajay Kumar, Dholi Agriculture College, Dholi, Samastipur
Dr. S.B Singh, Director, Indian Institute of Maize Research (IIMR), Begusarai
Mr. U.K Sharma, NGO Head; Vaishali Agriculture Small Farmers Association, Vaishali
Mr. Nayyar Tanveer, NGO Head, Creative Social Welfare Society, Samastipur
Mr. Anup Tripathi, Director, Masina Beej Pvt. Ltd., Samastipur
Mr. Shiv Narain Singh, Seed Retailer Tajpur Block; Samastipur District
Mr. Kashi Prasad Mehta, Seed Producer, Dholi Village; Samastipur District
Mr. Satish Diwedi, Farmer's Representative; Service Provider and Seed Producer, Sakri Chanpura Village; Samastipur District
Ms. Poonam Kumar, District Programme Coordinator; Bihar Mahila Samakhya Society, Musahri, Muzaffarpur

FGDs

Names of participants (Lohseri Village, Muzaffarpur district)

1. Sunil Kumar Mishra
2. Amodh Mishra
3. Sushil Mishra
4. Rajiv Kumar Mishra
5. Manibhushan Singh
6. Bablu Mishra
7. Awadh Paswan
8. Chottan Sahni

Samastipur (Village name not recorded)

1. Parmanand Pandey
2. Vinod Pandey
3. Rupeshwar Pandey
4. Chandeshwar Thakur
5. Ram lal Manjhi
6. Maheshwar Manjhi
7. Hiredeo Mahta

8. Ashok Das
9. Ramesh Das

Short Meeting with Group of Farmers (Community Members) (Village Sakri Chandpura, Muzaffarpur district)

1. Dinesh Misha
2. Bhola Mishra
3. Umesh Mishra
4. Ashok Mishra
5. Abhishiek Kumar
6. Baijnath Mishra