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Value chain analysis of different types of maize hybrid seed: a comparative study of public and private sector in Bihar

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Abstract In the Samastipur district of Bihar, one of the top five maize-producing states in India, a study was conducted in 2017–18 to map the value chain of public and private seed systems and estimate the value addition at each successive stage of seed movement. Statistically significant differences were found in gross income, net income, and benefit–cost ratio of maize seed production of single-cross hybrid (SCH) and double-cross hybrid (DCH) with potato intercropping system. Enabling infrastructure and a policy environment, and innovating public–private partnership models across the seed value chain, is necessary for overall sectoral growth.

Keywords Maize seed, value chain analysis, single-cross hybrid (SCH), double-cross hybrid (DCH), quality protein maize, seed production, marketing, Bihar

JEL classification M31, Q12, Q13, Q14, Q16, Q18

Seeds constitute the critical determinant of agricultural productivity and drive all the investment and crop management practices of farmers (Zaidi et al. 2017). Seeds make up one of the most crucial inputs in agriculture; its growth is directly related to the quality and quantity of supply of seeds. In India, maize has become an increasingly important feed and food crop in recent decades.

Since the late 1980s, when the seed laws were liberalized, private companies have captured a significant share of the national market for maize seed (Morris et al. 1998). Now, maize production is dominated by high-yield potential, proprietary hybrids from large and small private seed companies (Morris, Singh, and Pal 1998; Spielman et al. 2011), developed principally to meet the needs of an expanding feed market. The major driver of the feed market is the poultry sector, which itself is driven by changing consumer habits, especially in urban areas (Narayanan, Dalafi, and Gulati 2008; Kumar et al. 2013; Krishna et al. 2014; Prabhakaran et al. 2015).

During 2016–17, India produced around 25.90 million tonnes (MT) of maize grain from 10.20 million hectares (mha) with an average yield of 2.5 tonnes per hectare (Directorate of Economics and Statistics 2017). Bihar is among the top five maize-producing states in India: it produces 2.69 MT of maize from a cultivated area of 0.72 mha at a productivity of 3,732 kg per ha (Figure 1).

In traditional maize-growing areas (Bihar, Uttar Pradesh, Madhya Pradesh, and Rajasthan), maize is most commonly grown in rotation with wheat; in non-traditional maize-growing areas (Karnataka and Andhra Pradesh), it is grown in rotation with chickpea. Intercropping of maize with black gram, green gram, or vegetables is common during the kharif season (Joshi et al. 2005) whereas in some parts of Bihar, maize with potato intercropping is common.

Over the past 30 years, frequent floods in the plains of north Bihar (Kale 1997) have affected thousands of human lives and damaged livestock and assets worth

Figure 1 Season-wise area and productivity of maize in Bihar

Source Directorate of Economics and Statistics (2017)

millions. The state's proneness to flood requires setting up a breeding research programme towards providing farmers a minimum assured income in production environments that have excessive moisture. The public and private sectors must develop and deploy abiotic stress-tolerant cultivars (Prabhakaran et al. 2015), as abiotic stress resistance is one of the key demands in client-oriented plant-breeding programmes (Virk et al. 2005).

The rapid adoption of Bt cotton hybrids, single-cross maize hybrids, and hybrid vegetables led the Indian seed industry to grow at 18% per annum from 2009 to 2016 and reach INR 160 billion in 2016–17. The maize seed sector contributes 11% of the Indian seed industry. The production of hybrid maize seed is dominated by the private sector; five or six multinational companies (MNCs) produce over 75% of the output and about 250 private sector players contribute the rest (FICCI and PwC 2018).

The hybridization in maize crop in India is 60%, though it varies between 23% (Madhya Pradesh) and 100% (rabi maize in Bihar and Tamil Nadu). Small and medium-sized seed companies can produce reliable,

higher-yield varieties that can contribute to the food security and income of poor farmers (Morris, Mekuria, and Gerpacio 2003; Barrett 2008; Langyintuo et al. 2010). For productivity growth, it is essential to use quality seeds with a desirable replacement rate. The seed replacement rate of maize was 90% in 2014–15 and 80.66% in 2015–16 (Govt. of Bihar, 2019).

A value chain is a chain of activities undertaken in the production, processing, marketing, and sales of a product. It is the process in which raw materials are transformed into a finished product that is sold to final consumers (Subedi and De Boef 2013). The term 'value chain' reflects that value is added at each point in the chain. Several studies have been conducted on the maize seed value chain, seed production, value addition at each successive stage, distribution, and the marketing system (Kumar, Krishna and Srinivas 2012; Singh et al. 1995; Morris, Singh, and Pal 1998; Alemu et al. 2008; Reddy 2012). However, most studies are on the value chain of double- and triple-cross maize hybrid seed; only a few compare single- and double-cross hybrids.¹ This paper compares the maize seed value chain of hybrid types like single-cross, double-cross,

¹ A cross between two inbreds or varieties is referred to as a single-cross (A X B, for example). The hybrid progeny obtained from a cross between two inbreds or varieties are referred to as single-cross hybrids (SCH). These produce a uniform plant and have the most heterosis. A cross between four inbred lines or two single crosses is referred to as a double-cross hybrid (DCH); inbred lines A and B make one cross, and lines C and D another. Crossing AB and CD produces a DCH. These seeds might still have segregation and genetic variation in the DCH population (Allard 1999); that is why DCHs do not perform as well as SCHs. Single-cross seeds need only one season for crossing, whereas double-crosses need at least two. The use of less vigorous female inbred lines in the production of SCH seeds leads to low yields of hybrid seeds and higher costs of seed production. The use of single-cross female hybrids in the production of DCH seed leads to higher seed yield and lower seed production costs. But in commercial maize production, the yield of SCH cultivars is much more than that of DCH.

and quality protein maize. The study estimates the economics of the production of single- and double-cross hybrids of maize seed in Bihar. It also analyses the value chain of hybrid types of maize seed under private seed companies and public research institutions.

Data and methodology

Samastipur is one of the major maize-producing districts in Bihar. Several private seed companies and public research institutes are located there. To understand the production and distribution of maize seeds in excess moisture prone areas in Bihar, we chose Samastipur as the site. Messina Seed Pvt Ltd, a small-medium enterprise company, and Rajendra Agriculture Central University (RACU) Pusa, Samastipur, were selected for the study. The study was conducted in Khanpur block of Samastipur district as the company has its seed processing unit there.

A total of 64 maize seed growers—32 each from SCH (MBP-X08) and DCH (MBP-708) cultivars and 10 seed dealers from Messina Seed Pvt Ltd—were selected for understanding the maize seed value chain in the state. Along with seed growers, 32 commercial maize grain farmers were also involved in the study for comparison with seed producers. The required sample size for quality protein maize (QPM) seed producers was not available in the study area; therefore, we did not study the cost of cultivation of QPM. The cost incurred at each successive stage of the maize seed value chain has been estimated on per unit cost and used as a method of analysis.

The study is based on primary and secondary data. Primary data were collected in 2016–17 from the farmers; we used the random sampling method and a predesigned questionnaire, and we worked in close interaction with various stakeholders such as RACU, Pusa, farmers, dealers, and the seed company. Secondary data were collected from the Bihar Agriculture Department and the available literature. The mean comparison *t*-test was used to compare SCH and DCH with different parameters using Stata 12.1 version.

Maize cropping and seed production system

Maize and potato are the major post-rainy crops in the Samastipur region. Farmers prefer to cultivate potato as intercrop in maize. Even in maize seed production,

most farmers follow the potato intercropping system. Because of the climatic conditions, post-rainy season maize takes 150–160 days to harvest and potato takes 80–90 days. So, to get some money in hand to meet their expenses, farmers prefer the maize plus potato cropping system.

In the months of December and January, due to heavy fog per frost, the temperature goes below 5°C–6°C, thereby extending the period of the maize crop. Potato planting precedes in the month of November. Usually, male maize seed is planted first, followed by female maize seed planting by dibbling method manually. Harvesting of potato is done in the month of March before tassel emergence in maize. As harvesting is done manually, earthing up for the maize crop happens simultaneously. The maize and potato intercropping systems are complementary, and more farmers follow it than any other cropping system.

Results and discussion

Profile of sample households

From the survey of maize growers in the study area, it was observed that most of the sampled farmers are older than 45 years; only 4.69% of them were 30 years or younger. About 40% were educated up to high school and nearly 25% of them were illiterate. Of the total male population (200), 56% work in agriculture, whereas only 33.62% of the total females (116) work in agriculture. Regarding the type of house, 42.19% of farmers have pucca houses, 34.38% have semi-pucca houses and 23% have kutcha houses.

In the villages, owning a television set is one of the indications of social and economic status. About 47% of the sample households own a television set, while the rest (53.13%) do not. The mobile revolution has spread irrespective of social and economic wealth indicators. All the households have at least one mobile phone, and 36% (23 household) own smartphones. Mobile penetration has been a great leveller in the study region, and it has become an important information and communication technology tool through which modern agriculture technologies and a good package of practices can be disseminated to farmers in real time.

In terms of landholding, about two-thirds of the sample farmers were smallholders, while the remaining one-third has a landholding of more than 2 ha. On an

Table 1 Total paid-out cost of maize seed production with potato intercropping

Particulars	MBP-X08 (SCH) (N=32)	MBP-708 (DCH) (N=32)	Difference	Overall (N=64)	t value
Total paid-out cost (INR per ha)	1,05,458	99,061	6397	1,02,259	1.81*
Maize seed production (female cobs, q per ha)	63.60	69.28	-5.67	66.44	-3.15***
Female raw cob procurement price (INR per quintal)	2200.00	1300.00	900.00	1750.00	N A
Seed income (INR per ha)	1,39,920	90,064	49,856	1,16,270	16.55***
Grain production (Male cobs in quintal per ha)	10.61	14.24	-3.63	12.43	-5.88***
Grain price (average INR per quintal)	1195	1191	4	1193	N A
Grain income (INR per ha)	12,679	16,955	-4276	14,827	-5.85***
Gross income from maize (INR per Ha) (seed + grain)	1,52,599	1,07,019	45,580	1,31,097	13.70***
Potato production (quintal per ha)	177.84	177.07	-0.77	177.45	-0.11
Potato price received (Average INR per quintal)	353.91	349.38	-4.53	351.64	-0.43
Potato gross income (INR per ha)	62,939	61,865	1075	62,399	0.30
Gross income (Maize + Potato (INR per ha)	2,15,538	1,68,883	46,655	1,93,495	9.01***
Net income from Maize seed production + potato intercropping (INR per ha)	1,10,081	69,823	40,258	91,236	7.20***
BCR of cropping system	2.04	1.70	0.34	1.89	-3.89***

Source CIMMYT field survey, Samastipur (2016–17)

***significant at 1% level *significant at 10% level

average, marginal farmers have a landholding of 0.66 ha, small farmers 1.38 ha, semi-medium farmers 2.37 ha, medium farmers 4.45 ha and large farmers have a landholding of 11.84 ha.

Economics of maize seed production: single-cross hybrid versus double-cross hybrid

The total paid-out costs of SCH and DCH maize seed production of Messina Seed growers are presented in Table 1. The mean comparison *t*-test was used to compare SCH and DCH on different parameters. The paid-out cost for SCH (MBP-X08) was INR 105,458 per ha, while that of DCH (MBP-708) it was INR 99,061 per ha. The overall cost with potato intercropping was INR 102,259 per ha. Significant differences were observed in the paid-out cost of production of SCH and DCH; these differences were due to different combinations of inputs used by farmers.

Raw cob seed production of SCH was 63.60 quintals per ha (female cobs), while for DCH, it was 69.28 quintals per ha. Raw female cob yield of DCH was significantly more by 5.67 quintals per ha than SCH. However, there were differences in the procurement

price of raw cob of SCH and DCH maize hybrids. The procurement price of SCH cultivar (MBP-X08) was INR 2,200 per quintal, while that for DCH (MBP-708) was INR 1,300 per quintal. Such difference in price was due mainly to the reason that yield performance and uniformity of SCH is much better than DCH in field. Female parent cob harvesting is done manually at 30%–35% moisture level in the presence of company personnel. Seed income from SCH maize was significantly higher than that from DCH.

Moreover, the yield of the male parent of DCH was more than SCH by 3.63 quintals. Male parent seed is used as grain for consumption or for the payment of wages in kind. There was no significant difference in the potato yield intercropped with SCH and DCH. The overall gross income from potato was INR 62,399 per ha. The gross income from maize + potato cropping system with MBP-X08 was INR 2,15,538 per ha, MBP-708 was INR 1,68,883 per ha, and overall (including both type of hybrids) was INR 1,93,495 per ha respectively. The net income from MBP-X08 SCH with potato intercropping system was INR 110,081 per ha and from MBP-708 DCH was INR 69,823 per ha.

The differences in gross income, net income and benefit–cost ratio of maize seed production of SCH and DCH with potato intercropping system are statistically significant. The benefit–cost ratio for SCH was 2.04, DCH was 1.70 and overall 1.89. That means a rupee invested in SCH maize seed production with potato gave return of INR 2.04 and DCH maize seed production with potato gave return of INR 1.70. It indicates that seed production of SCH maize is more profitable than DCH. The overall benefit–cost ratio of maize seed production plus potato intercropping was a very remunerative 1.89.

Comparison of hybrid seed and commercial grain production of maize in potato intercropping

The break-up of cost of inputs for hybrid maize seed and grain cultivation has been elaborated in Table 2. Differences have been observed in the use of hired labour; fertilizers like urea, diammonium phosphate (DAP), potash, zinc, sulphur, boron; and of

micronutrients. Seed growers were more aware about fertilizer use than commercial grain farmers.

The average yield of grain farmers was 72.02 quintals per ha; the average price realization of INR 1,203 per quintal. The average yield of potato was 176.41 quintals per ha; the average price received was INR 424 per quintal. Total paid-out expenses for commercial grain production was INR 101,673 per ha, while that of seed production was INR 102,259 per ha. Clearly, there was little difference in the production of maize hybrid seed and maize grain.

The net income from hybrid seed production was INR 91,236 per ha and from grain production was INR 59,844 per ha. The net income from SCH seed production was about 83.95% and from DCH seed production about 16.67%, over and above the paid-out cost in maize grain production with potato intercropping system. Farmers reported that they chose the hybrid cultivars MBP-X08 and MBP-708 and the

Table 2 Comparison of maize seed and commercial grain production in potato intercropping

Particular	Maize hybrid seed production (N=64)		Maize grain production (N=32)	
	Quantity per ha	Expenses (INR per ha)	Quantity per ha	Expenses (INR per ha)
Hired labour (days)	171.18	35,450	200.84	40,732
Machine labour (hours)	9.69	9,664	10.06	7,931
Castor cake (quintal)	3.05	4,268	3.71	5,198
Maize seed (kg)	19.76	5,928	19.30	6,958
Potato seed (kg)	1987.58	20,960	1976.00	20,439
Urea (kg)	471.81	31,134	297.94	1,966
Di-ammonium phosphate (kg)	308.36	7,709	191.43	4,786
Potash (kg)	168.65	1,855	123.50	1,359
Ammonium sulphate (kg)	73.71	737	70.24	702
Zinc (kg)	21.96	1,537	15.82	1,108
Sulphur (kg)	6.68	790	5.02	602
Boron (kg)	6.06	545	4.71	424
Single superphosphate (kg)	3.86	23	nil	Nil
Micronutrient (kg)	2.47	169	nil	Nil
Irrigation (hours)	98.92	7,151	100.73	7,459
Insecticide (kg)	14.91	1,972	10.39	1,621
Weedicide (kg)	1.08	386	0.97	389
Total paid-out expenses (INR per ha)		1,02,259		1,01,673
Gross income (INR per ha)		1,93,495		1,61,517
Net income (INR per ha)		91,236		59,844

Source CIMMYT field survey (2016–17)

open pollinated varieties (OPV) Laxmi and Deoki for consumption, and they chose the rest of the cultivars for commercial purposes—get high yields and trade in the market.

Farmers also elaborated that there is a demand of about 150 truckloads of white maize hybrids of Messina Seed Company from Punjab and Rajasthan. Traders from these states purchase grain of MBP-X08 and MBP-X07 cultivars directly from the nearby villages. Traders say these varieties are good for both consumption and fodder, and they pay more than the minimum support price (MSP). Once the demand is fulfilled, however, the rest of the produce is sold at existing market prices.

Value chain analysis of maize seed

Two maize seed value chains that existed in Samastipur district are given and discussed below: private maize seed value chain and agricultural university maize seed value chain.

Private seed value chain (Messina Seed)

Messina Seed is a small-medium size seed company in Khanpur block of Samastipur district and a pioneer in post-rainy season maize cultivation in south Bihar. It has been producing maize seeds since 1959. Hybrid maize seed production started in 1973 with Hi-starch cultivars like Ganga-2, Ganga-4, Laxmi (OPV), Durga, Krishna, MBP-555, and MBP-111. The company also produces seeds of crops like wheat, paddy, mustard, and vegetables. Maize seed production generates 90%

of the total revenue. The major hybrid cultivars currently produced by Messina are MBP-X08 (white), MBP-708 (white), MBP-X09 (yellow), MBP-X011 (yellow), and OPV Laxmi (white). The company is popularly known for white maize seed production. The seed production of MBP-708 and MBP-X08 takes place at Samastipur. Yellow hybrid maize seed production takes place with collaboration with other private seed companies from South India. Out of the total maize seed production in 2016–17, Messina produced 86% of white seed, 10% of yellow seed, and 3% of OPV seed (Figure 2).

The company produces maize seed in the nearby villages under a formal contract with farmers. It provides parent seeds to the farmers in 2:6 (M:F) ratio at INR 300 per kg. The extension services are provided free. Farmers produce seeds and they have an informal agreement to sell it to the company. During 2016–17, the company bought back maize cob for seed purpose at INR 2,200 per quintal of MBP-X08 and INR 1,300 per quintal of MBP-708 (Table 3). Harvesting of cobs is usually done at 30%–35% of moisture level. Moisture levels are reduced by around 14% through the cob dryers. Seeds are separated from the cob by sheller machines. Again, seed is dried in dryer bins up to 10% moisture level. Conversion factor from cob to seed is 45% to the company.

After considering the conversion cost from cob to seed, the procurement cost to the company is estimated at around INR 4,888 per quintal (54.89%) for MBP-X08

Figure 2 Maize seed market sale of Messina Seed Pvt Ltd (in tonnes)

Source Messina Seed Pvt Ltd (2016–17)

Particulars	MBP-X08 (SCH)		MBP-708 (DCH)	
	Cost (INR per quintal)	%	Cost (INR per quintal)	%
Cob procurement	2,200	-	1,300	-
Raw seed*	4,888	54.89	2,888	41.82
Processing and packaging	1,400	15.72	1,400	20.28
Storage	800	8.98	800	11.59
Marketing cost	1,100	12.35	1,100	15.93
Transportation cost	717	8.06	717	10.38
Total cost	8,905	100	6,905	100

Notes *Raw seed conversion from cob 45%

Source Estimated by authors in interaction with Messina Seed and RACU

their material through distinctive, high-quality packaging observed by Morris et al. (1998). Singh et al. (1995) found that in the private sector, transport to the conditioning plant and conditioning costs accounted for 16% of the total processing cost. In our finding the costs ranged between 15.72% and 20.28%. In the process of sale of seeds, the dealers get a margin of INR 40 per kg on SCH and INR 35 per kg on DCH.

The pack size available for farmers 1 kg for SCH is 4 kg for DCH. The company has a margin of around INR 150.95 per kg on SCH and of INR 86.95 per kg on DCH. Finally, farmers purchase from dealers or retailers SCH seed at INR 280 per kg and DCH seed at INR 190 per kg.

Rajendra Agricultural Central University (RACU) maize seed value chain

Rajendra Agricultural Central University (RACU) produces QPM seed with a few contract farmers in Samastipur. The university provides farmers 3 kg male parent seeds and 5 kg female parent seeds at INR 294 per kg. It purchases raw QPM cleaned seed from farmers at INR 100 per kg. Processing and packaging, done at the university campus, costs INR 4 per kg, while storage costs INR 6 per kg (Figure 3). The RACU sells the seeds directly from its seed counter to the farmers, thereby reducing the transaction cost. The university sells Shaktiman 5 at INR 150 per kg and receives a margin of INR 40 per kg. The university's Laxmi, Deoki, and Suwan composites are the most popular; farmers prefer these for home consumption, but the availability of the seed was found to be low.

The university does not have a buyback policy; therefore, few contract maize seed growers are associated with it, and the dissemination of QPM maize cultivars has not been as much as desired. For the popularization and dissemination of QPM cultivars of Shaktiman 1, 2, 3, 4, and 5, the university has signed a Memorandum of Understanding with the private companies Ankur Seed, Nagpur (Shaktiman 3 and 5); Delta Agri Genetics, Hyderabad (Shaktiman 2 and 4); Sahkari Sahyog Samiti, Jaipur (Shaktiman 3); and GV Seeds, Hyderabad (Shaktiman 4). The university supplies private companies six to eight quintals of parent seeds of these quality protein maize cultivars every year on average.

Marketing and promotion activities

Messina Seed Company has large investments in marketing networks and promotional initiatives. The company has a strong marketing network in the state, with 325 private dealers and 25 cooperatives. It distributes 64% of its maize seeds through dealers; it sells 32% to other companies, 3% to cooperative societies, and only 1% directly to farmers. The company engages in market development activities through various channels, including audio-visual mass media. In relation to promotion, the company mentioned the importance of conducting demonstrations of maize hybrids; it shows groups of farmers the performance of seeds on farms.

Additionally, various forms of mass media and printed literature were often mentioned for publicity. The

company arranged a three-day exhibition every March on their research plot. Approximately 1,000 farmers visit the exhibition. The company also participates in RACU's exhibition every December. On exhibition day, the company discounts the price of maize seed and other products by 25%. To enable efficient marketing of the company's product, the marketing staff is given GPS-enabled mobile phones which helps them in monitoring their staffs' movement and selling activities. Exhibitions and demonstrations constitute the major promotional activities of the company followed by posters and pamphlets. Unloading charges prevailing in the study location are INR 5 per 40-kg-bag (INR 0.13 per kg). The company bears all the cost of transport to dealers. From time to time, the company launches different schemes for dealers to promote sales.

Public seed agencies spend very little on promotion or advertising. Promotional activities of public sector mainly include agricultural extension services; agricultural technology information centre or farmer service centre; farm advisory service; Krishi Vigyan Kendras, and farmers' fairs. All these approaches assume that farmers are fully aware of the attributes of the products and in turn would approach the agencies for more information or buying the product. But private seed companies use the push type of promotional strategy—they reach farmers through different media and explain the products to them.

Challenges faced by Messina Seed Company and maize growers

The Messina Seed Company is well equipped with modern machinery to supply farmers quality seeds. However, high-voltage electricity is not available continuously for 24 hours, and that affects productivity at times. To ensure continuous power supply, the company has been running its machinery using a diesel engine, which increases its operational cost.

The second important challenge for the company is to enhance the sale of yellow hybrid cultivars in Bihar. Messina Seed is a well-known, well-established brand for white hybrids and composites. Recently, the company has also started yellow hybrid seed production in collaboration with other seed companies and markets under their own brand. To attract farmers to their yellow hybrids, the company must conduct extensive field demonstrations and arrange more field days on farmers' fields.

Figure 4 Major constraints faced by maize growers in Samastipur, Bihar

Source CIMMYT field survey (2016–17)

Maize growers face several constraints; these are analysed and presented in the radar map (Figure 4) on a scale of 0–3 (0 means no constraints and 3 depicts the most constraints). Farmers reported that major challenges were uncertain climatic conditions (abiotic stresses) like floods and cold waves. Other major challenges were high prices of seed, low price of grain, insufficient marketing system, fertilizer sale more than maximum retail price, unavailability of electricity at farm level, wild animal, availability of sufficient credit, maintaining isolation distance, and high irrigation cost.

Using a diesel engine to irrigate the field increases the irrigation cost. The moderate constraints were labour scarcity, weed infestation, diseases, and pests. More than 95% of farmers sell their maize to traders in the village. The village traders directly purchase grains from the farm gate or from the farmer's home. They purchase maize at lower price than MSP declared by government. The state government has established Primary Agriculture Cooperatives (PACs) in each Panchayat. The actual involvement of PACs in trading of maize is limited in Khanpur block. Primary Agriculture Cooperatives purchase commodities as per the MSP, but farmers are not willing to sell to them, because PACs purchase as per particular norms like moisture percentage, cleaned grains, no other grains, etc. The most important is that there is no timely payment of commodities to the farmers. As a result, farmers prefer to sell their agriculture commodities even at a lower price to village traders.

Conclusions and recommendations

The study examined the value chain analysis of maize seeds of small-medium enterprises and agriculture universities in Bihar. It is evident from the study that there is a considerable share of local stakeholders in the seed value chain of maize crop in the state. A strong seed distribution system is crucial to deliver the seed of desirable cultivars in time to the farmers. Small and medium enterprises can give farmers price advantages by minimizing the transport cost and delivering quality material suited to regional micro-climatic conditions. Since these enterprises involve local farmers in seed production, maize growers can trust the quality of the seeds sold by local seed companies.

The RACU also has taken the initiative to boost the demand of QPM by collaborating with private seed companies. It offers a win-win value proposition to both RACU and small seed companies that cannot afford to invest in R&D. Thus, small and medium seed companies should collaborate and network with national or international research institutions to get access to quality genetic materials for seed development.

The International Maize Improvement Consortium programme of CIMMYT—Asia facilitated linkages between local seed companies, MNCs, and public research institutes. Collaboration in participatory variety selection allowed local businesses to access cultivars that fit the agroecological context in which they operate and the market demands of their locality.

To expand the maize sector in Bihar, it is necessary to push production through rapid technology adoption; form farmer groups and market linkages; create the enabling infrastructure; innovate public–private partnership models across the seed value chain; and creating an enabling policy environment.

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Appendix 1 The most common maize hybrids and OPV's cultivated in Samastipur

Sl no	Maize cultivars	Type of cultivar	Grain colour	Seed price (INR per kg)
1	MBP-X08	Hybrid	White	280
2	MBP-708	Hybrid	White	190
3	MBP-X09	Hybrid	Yellow	350
4	MBP-X011	Hybrid	Yellow	400
5	DKC 9081	Hybrid	Yellow	350
6	DKC 9135	Hybrid	Yellow	250
7	DKC 900 M Gold	Hybrid	Yellow	250
8	DKC 9142	Hybrid	Yellow	240
9	P3522	Hybrid	Yellow	450
10	P3355	Hybrid	Yellow	450
11	NK-6607	Hybrid	Yellow	325
12	4794	Hybrid	White	200
13	Godfather	Hybrid	Yellow	450
14	CP838	Hybrid	Yellow	250
15	CP808	Hybrid	Yellow	200
16	N-45	Hybrid	White	150
17	N-MX2355	Hybrid	White	230
18	Tripti	Hybrid	White	120
19	Shaktiman-1 to 5	QPM	Hybrid	150
20	Deoki (RACS)	Composite	White	60–70
21	Laxmi (RACS)	Composite	White	60–70
22	Laxmi (Messina)	Composite	White	240

Source CIMMYT field survey (2016–17)