Public-private partnerships in the development and delivery of crop variety innovations

Lessons from the MasAgro consortium for hybrid maize in Mexico

by

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A hybrid maize demonstration plot by Agricola El Caudillo (Aca). Photo credit: CIMMYT.

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Abstract

Over the last three decades, public-private partnerships (PPPs) in the Consultative Group on International Agricultural Research (CGIAR) emerged as an alternative for the accelerated development and dissemination of crop variety innovations to farmers in developing countries. For many years, PPPs in seed sector development have attracted and continue to attract investments from developed and developing country governments, CGIAR institutions and donor agencies. A general common assumption when implementing PPPs is that small and medium enterprises (SMEs) have the capacity to produce and distribute high-quality affordable seed to low-income farmers in remote markets. A second general assumption is that competitive high-quality high-yielding seed varieties will make their way to farmers without the need to pay much attention to seed distribution and marketing. However, in today's highly concentrated maize seed markets, the challenges of delivering innovations developed through PPPs go far beyond the development of superior materials and the production of high-quality seed. This research uses the experience of the MasAgro consortium, a PPP for hybrid maize in Mexico involving the International Maize and Wheat Improvement Centre (CIMMYT) of the CGIAR, the main Mexican public breeding National Agricultural Research Systems (NARS), the Mexican government, and sixty-nine domestic maize seed SMEs to build evidence of the contribution of PPPs to seed sector development and their limitations for bringing affordable quality seed on a large scale to low-income farmers in developing countries.

Results show that the MasAgro PPP was very successful in generating a large flow of agronomically competitive maize hybrids and SMEs successfully incorporated these varieties into their product portfolios and into the market. However, MasAgro PPP's success in scaling up the dissemination of these varieties has been limited and MasAgro hybrids achieved a limited share of the market. Two possible reasons for the relatively limited market penetration of MasAgro PPP hybrids were explored: the role of agro-dealers in the promotion of seed and their influence on farmers' buying decision-making; and whether brand loyalty and high prices signalling quality affect farmers' willingness to buy new recently released maize hybrids. The review and empirical results show that agro-input retailers may be well placed to influence seed purchasing decisions, but their role is limited by the effect of product quality cues and out-store marketing stimuli influencing farmers' variety choices. The results also indicate that farmers are loyal to the brands of multinational companies, especially Pioneer. Moreover, while a high reference price does not significantly affect a farmer's perceptions of quality of

hybrid maize, a reduced price significantly decreases perception of sacrifice. Brand loyalty and perceived sacrifice have a significant negative impact on perceptions of value and therefore on farmers' willingness to buy new unknown hybrids.

The research argues that PPPs are an effective means for developing and delivering competitive seed varieties to smallholder farmers in low-and-middle-income countries, and SMEs are willing and able to incorporate these varieties into their product portfolios and into the market. However, product quality cues, out-store marketing stimuli, well-positioned brands with prices signalling quality and farmers' brand preferences in highly concentrated markets represent a barrier for domestic SMEs and PPPs to achieve large-scale dissemination of publicly bred hybrids. The development of competitive high-yielding seed varieties is not enough in itself to disrupt concentrated maize seed markets, capture market shares from global market leaders and promote sufficient competition in the maize seed industry. If PPPs are to succeed in their objective of bringing affordable high-quality seed on a large scale to smallholder farmers in developing countries, there is an urgent need to incorporate a marketing perspective along all steps of the plant breeding and dissemination process, to closely examine market structure and private sector marketing strategies, and to adopt a consumer behaviour lens for understanding farmers' adoption and buying decision-making.

The research makes the first attempt to incorporate marketing and consumer behaviour into the conceptualization of seed systems in developing country contexts. It shows how market structure, private marketing and farmers' behaviour influence their development and growth, and the dissemination of improved seed varieties. While it provides some pioneering insights, further research is essential to advance the development of the adoption and seed systems literature in this direction.

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Abbreviations and acronyms

AAA-DT Maize	Affordable, Accessible Asian Drought Tolerant Maize Project
AGFI	Adjusted Goodness of Fit Index
AGRA	Alliance for a Green Revolution in Africa
AMSAC	Mexican Seed Producers Association A.C.
BMGF	Bill & Melinda Gates Foundation
CBD	Convention on Biological Diversity
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Centre
CNFA	Cultivating New Frontiers in Agriculture
CNM	National Maize Commission
CNVV	National Seed Varieties Catalogue
CRADA	Cooperative Research and Development Agreements
CUSMA	Canada-United States-Mexico Agreement
DCE	Department of Experimental Stations
DENUE	National Statistical Directory of Economic Units
DS-SAG	Seed Department of the General Office of Agriculture
DTMA	Drought Tolerant Maize for Africa
GFI	Goodness of Fit Index
GMOs	Genetically Modified Organisms
IARCs	International Agricultural Research Centres of the CGIAR
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IIA	Institute of Agricultural Research
IMIC-LatAm	International Maize Improvement Consortium for Latin America
INEGI	National Institute of Statistic and Geography
INIA	National Institute of Agricultural Research
INIFAP	National Institute of Forestry, Agriculture and Livestock Research
IPRs	Intellectual Property Rights
IRMA	Insect-Resistant Maize for Africa
ITPGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture

LBOGM	Genetically Modified Crops and Biosafety Law
LFFPMN	Federal Law for the Promotion and Protection of Native Maize
LFPCCS	Federal Law of Production, Certification and Commercialization of Seeds
LFVV	Federal Law of Plant Varieties
MasAgro	Sustainable Modernization of Traditional Agriculture
MUSECO	MultiSeed Company
NAFTA	North American Free Trade Agreement
NAIS	Nigeria Agro-Input Support Project
NARS	National Agricultural Research Systems
OEE	Office of Special Studies
OPVs	Open Pollinated Varieties
PASS	Program for Africa's Seed Systems
PPPs	Public-Private Partnerships
PRONASE	National Seed Production Company
QBS	QualiBasic Seed Company
R&D	Research and Development
RMSEA	Root Mean Square Error of Approximation
SADER	Ministry of Agriculture and Rural Development
SCIAN	North American Industrial Classification of Economic Activities
SEM	Structural Equation Modelling
SIL	Syngenta India Limited
SINAREFI	National System of Plant Genetic Resources for Food and Agriculture
SINASEM	National Seed System
SMEs	Small and Medium Enterprises
SNICS	National System for Seed Inspection and Certification
SRMR	Standardized Root Mean Square Residual
STMA	Stress Tolerant Maize for Africa
TRIPs	Trade-Related Aspects of Intellectual Property Rights Agreement
UACH	Autonomous University of Chapingo
UPOV	International Union for the Protection of New Varieties of Plants
WEMA	Water Efficient Maize for Africa
WTO	World Trade Organization

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1. Introduction

Many developing countries have mainly relied on crop variety innovations developed by public sector National Agricultural Research Systems (NARS) to drive productivity growth in agriculture. Developing country NARS working in collaboration with the International Agricultural Research Centres (IARCs) of the Consultative Group on International Agricultural Research (CGIAR) are acknowledged to have made exceptional contributions to plant breeding. The CGIAR and NARS collaboration (CGIAR-NARS led innovation system) led to the development of the semidwarf high-yielding seed varieties during the "Green Revolution" that transformed agriculture in the developing world, substantially increased food production, and globally contributed to improving food security (Evenson and Gollin, 2003; Byerlee and Dubin, 2010). The success of the public sector in the development and dissemination of improved seed varieties during the 1960s and 1970s stems from, to a large extent, the strong interest of governments and donors in investing in agricultural research and the CGIAR system of free exchange of plant genetic resources that facilitated collaborations between national and international research systems.

Until the 1990s, NARS remained dominant in plant breeding in developing countries and provided the main links with the international plant breeding research system. However, the effectiveness and sustainability of the public-sector-led innovation system have been called into question by several related developments. These include:

1) the declining trends in public investment in agricultural research in developing countries since the 1990s (Pray, 2001; Naseem *et al*., 2010);
2) the declining efficacy of NARS in the dissemination of crop varieties reflected in the limited uptake and adoption of new improved seeds (Naseem *et al*., 2010);
3) the enforcement of intellectual property rights (IPRs) in developed nations since the 1960s and their expansion to developing countries in the 1990s (Byerlee and Dubin, 2010), having the effect of restricting free germplasm exchange and plant breeders' innovation capacities (Srinivasan, 2003; Kapur, 2011);
4) the emergence of biodiversity legislation that recognized national "sovereignty over biological resources", which further exacerbated the limitations imposed by IPRs for the access and exchange of plant genetic resources in the international breeding research system (Byerlee and Dubin, 2010; Galluzzi *et al*., 2016), and:
5) growing private sector competition caused mainly by the expansion of multinational companies but also by the increasing breeding capacity of domestic firms (Fuglie, 2016).

In the last forty years, many large agrochemical, pharmaceutical and biotechnology companies merged with or acquired smaller firms with elite germplasm, reputable brands and key biotechnology assets (Spielman *et al*., 2014). Mergers and acquisitions occurring during this period are well documented by Fernandez-Cornejo (2004), Schenkelaars *et al*. (2011) and Howard (2015). According to Deconinck (2020) companies sought to exploit complementarities between seeds, biotechnology traits and crop protection chemicals. By combining these activities in a single company, it would be easier to invest in complementary products, coordinate R&D, marketing and seed distribution channels (Srinivasan, 2003). As a result, three multinational companies (Bayer-Monsanto, Corteva Agriscience and Syngenta) currently account for over 70% of the global seed market (IPES-Food & ETC Group, 2021).

Such levels of concentration have several critical effects on the development of seed industries in developing countries. Existing research highlights the risk that a reduced number of firms could exert market power and monopoly pricing, control technological assets essential for downstream and applied research, and reduce the choice of new and improved crop varieties (Naseem *et al*., 2010). Market concentration is also likely to restrict innovation in plant breeding owing to the effect of patents and other IPR protection laws applied to plants (Srinivasan, 2003). For example, in plant breeding germplasm diversity is essential for the development of new varieties. If a variety is patented, it cannot be used as a cross for the development of new varieties without the permission of the patent holder (Srinivasan, 2003; Kapur, 2011).

Over the last three decades, public-private partnerships (PPPs) have emerged as an alternative to facilitate access to and exchange of plant genetic resources, their use for the development of crop varieties and their dissemination to farmers. PPPs in plant breeding are collaborations between national and international public breeding research centres (NARS and IARCs) and private sector companies for the development, testing, and delivery of improved seed varieties. Plant breeding PPPs leverage the public sector's upstream breeding capacities with private sector strengths for seed production and marketing. Public sector NARS and CGIAR international centres provide strength in crop improvement, access to diverse germplasm collections, and evaluation networks. The private sector contributes expertise in modern breeding technologies, research skills, tools, marketing and seed delivery systems (Byerlee and Fisher, 2002).

PPPs in the CGIAR usually rely on small and medium enterprises (SMEs) for delivering their crop variety innovations. Within PPP arrangements, breeding programmes typically provide free-of-charge access to elite breeding materials, and in return, SMEs multiply and market commercial seed varieties to farmers (Donovan *et al*., 2022). Public-private partnerships are increasingly viewed as a

useful instrument for delivering plant breeding innovations (Byerlee and Fisher, 2002; Ervin *et al*., 2003), promoting seed sector development (Gowda *et al*., 2004), deploying improved genetics at scale to smallholder farmers (Syngenta Foundation, 2021), and thus, enhancing crop production and food security. In many developing countries, where small farmers are the main buyers of seeds, innovations developed through PPPs provide an alternative to varieties offered by multinational companies that usually enjoy substantial price premiums.

This research offers an analysis of the contribution that PPPs can make to the development of national maize seed industries and the constraints on their achievement of large-scale dissemination of new hybrids through SMEs in developing country contexts. The research uses the experience of MasAgro, a PPP in Mexico, to examine innovation in plant breeding and the maize seed industry in a PPP context, to assess the capacities of domestic seed companies to deliver publicly bred variety innovations developed by PPPs, extend the existing research frameworks around PPPs and improve our understanding of their role in advancing cereal seed systems.

The thesis consists of an introduction, a background and context chapter, three main chapters, a conclusion and an appendix. The introduction provided the motivation for the study. The background and context chapter (Chapter 2) explains what PPPs are and their role in agriculture and plant breeding research; describes the CGIAR international plant breeding research system; illustrates the policy context of the maize seed industry in Mexico, its evolution and the changes induced by the MasAgro maize consortium; provides an overview of the importance of maize production in Mexico; gives an account of the research gaps on PPPs; and introduces the objectives and research questions. The central body of the thesis comprises three chapters (Chapters 3, 4 and 5). Chapter 6 summarizes the main findings, makes a conclusion, which highlights the contributions of the thesis to the subject, and suggests some policy and managerial recommendations for the implementation of PPPs.

The appendix contains complementary materials on A. Examples of PPP research consortiums in plant breeding; B. Grain yield linear regression results of MasAgro hybrids compared to multinational, private national and public seed varieties; C. Supplementary information on the composition of sampled MasAgro SMEs' product portfolios; D. The postpurchase intercept survey questionnaire applied to farmers at agro-dealer shops; E. Results of the brand loyalty and price-perceived quality model of hybrid maize seed for single price evaluations and F. Summary of the transcripts of interviews with agro-dealers and seed companies' sales representatives.

2. Background and context

2.1. Public-private partnerships (PPPs)

2.1.1. What is a public-private partnership?

PPPs are collaborations between public and private sector entities in which partners jointly plan and execute mutually agreed-upon activities with a view of accomplishing a common goal while also sharing the associated costs, risks and benefits (Spielman *et al.*, 2007). Such collaborations can range from bilateral cooperation between governments and a private company to multi-partner alliances including governments, private companies, NGOs, agricultural research institutes, extension agencies, universities, foundations, farmer associations, cooperatives, etc. (Hartwich *et al*., 2007a; Ferroni and Castle, 2011).

The central goal of PPPs is to exploit the complementary assets and resources of both sectors. In plant breeding, public sector NARS and CGIAR international centres provide strength in crop improvement, access to diverse germplasm collections and evaluation networks. The private sector contributes expertise in modern breeding technologies, research skills, tools, marketing and seed delivery systems (Byerlee and Fisher, 2002). For the public sector, PPPs represent an opportunity to transfer public technologies to the market by accessing private delivery systems, marketing networks and market information. For the private sector, partnerships afford companies access to public innovations, upstream scientific capacities and the potential to reach new or emerging markets (Byerlee and Fisher, 2002; Ervin *et al*., 2003; Spielman *et al*., 2007).

According to van der Meer (2002), a PPP must have at least one of the following characteristics:

1) Each party must provide the partnership with valuable resources that are essential to the other and necessary to achieve a common goal.
2) The parties must have an overlapping interest.
3) Both parties must have an expected gain that could not be attained when operating on their own.

2.1.2. How PPPs are built and the implications for partners

Before entering a partnership, members must consider their common interest, the cost-benefit relationship for each partner, whether all partners will benefit from their contribution and benefits will outweigh costs, whether the roles, responsibilities and benefits are equally distributed among partners, and if they can ensure that results of the partnership will not produce any conflict

(Hartwich *et al*., 2007b). Hartwich *et al*. (2007a) and Hartwich *et al*. (2007b) suggest the process of creating a partnership involves five different stages:

1. Identification of common interests and objectives. This is an exploration stage where partners identify their common interests, start looking at the costs and benefits of the partnership and agree on the problem to be addressed. At this stage, it is essential to identify the key actors in the value chain and convene all potential partners, identify and analyze technological or market opportunities, analyze the current and potential markets and anticipate and ensure potential funding. The common interests should meet all participant expectations and be sufficiently broad to establish a PPP.
2. Negotiation and design. At this stage, the partners negotiate the legal, financial, and governance framework of the PPP. The specific goals are reviewed and partners establish an organizational structure that facilitates decision-making, distributes the different tasks among associates, and enables information exchange, monitoring and evaluation according to each member's needs and capacities. Ideally, the partnership would be legally formalized. The contract between the partners should stipulate the rules and the obligations of each member to avoid undesired outcomes or conflicts. This includes all financial commitments, legal implications and any IPRs obligations and procedures for using or appropriating R&D results, i.e. allocation of innovations, licencing agreements, rights and royalties, distribution of returns, etc. The IPRs regulations must be in line with any national or international legislation.
3. Implementation. For the successful operation of the PPP, all actors must be fully committed to complying with their designated tasks and obligations. Commitment facilitates knowledge exchange, learning and confidence building between members. All associates may have free and regular access to information about resources used (human, physical, intellectual, financial), project progress and achievements. Ideally, the partnership should provide a mechanism for discussing strategic issues and establishing a mid or long-term PPP vision.
4. Monitoring and evaluating. PPPs must be continuously evaluated. The evaluation can include mid-term and final results assessing the performance of each actor, the partnership's functioning, strengths and weaknesses, leadership, management and administrative efficiency, and synergies produced, as well as the PPP's evolution or adaptation capacities to changing circumstances. Regular assessment can also serve to justify funding, analyze whether the expected outcomes are being generated, how efficiently results are being realized and what the opportunities for improvement are.

5. Termination or extension. When the partnership's timeframe is over participants must decide whether to continue or terminate. Continuation will depend on the members' interest in carrying on, on whether the goals have been achieved, and if the initial problem is still persistent or if new ones have arisen. The partnership may terminate if the partners believe the results are unsatisfactory, have not been obtained efficiently, or do not meet the partners' needs. Often the partnership ends because of the complete lack of funds, the unavailability of sufficient funding or the partners' belief that the initial objectives cannot be achieved without incurring additional costs that they are unwilling or unable to pay.

Establishing a PPP entails benefits but also costs for participating partners arising from the use of human, physical and financial resources. In addition to monetary costs, non-monetary costs arise from the time and effort invested in negotiation, communication, partnership planning, creation, operation, and evaluation. The underlying principle of PPPs is that benefits will outweigh costs as a result of the joint use of assets and resources (Hartwich *et al*., 2007b).

Overall, researchers agree that PPPs are a useful instrument for enhancing the impact of public agricultural research systems (Hall *et al*., 2001), developing and delivering plant breeding innovations (Byerlee and Fisher, 2002; Ervin *et al*., 2003), promoting seed sector development (Gowda *et al*., 2004) and deploying improved genetics at scale to smallholder farmers (Syngenta Foundation, 2021). Partnerships also form the basis of private companies' extension projects and a tool to create value for small farmers through innovation and the activation of value chains (Syngenta Foundation, 2018).

Despite the prospect of multiple benefits, when entering partnership members also face the risks, uncertainties and high transaction costs associated with the different incentives and perceptions of both sectors. Often, the lack of clearly defined objectives and mechanisms for overcoming tensions caused by cross-sectoral mistrust and misperceptions discourage participation in PPPs. In addition, the absence of procedures to ensure commitment and ownership, risk management strategies and legal frameworks for regulating the use and exchange of knowledge and technologies subject to IPR are some of the other major constraints on the success of PPPs (Spielman *et al*., 2007).

2.1.3. PPPs in agricultural research

In agriculture, PPPs have become increasingly popular in the last thirty years. Pray and Fuglie (2001), Pray (2001), Ervin *et al*. (2003), Hall (2006) and Spielman *et al*. (2007) suggest that the popularity of PPPs in this field has been a result of three primary changes in the agricultural sector: the decline and stagnation of public expenditures in agricultural research, especially in developing countries; the growth of private sector investment driven by increasing market opportunities and advanced

agricultural technologies; and the enforcement of stronger intellectual property regulations that favour private investment. In addition, public research institutions facing budget constraints also looked for increasing collaboration with private companies as a way to gain access to financial support from the private sector (Gotret and Patiño, 2004; Gowda *et al*., 2006). As a result, since the early 1990s, several PPPs have been created especially for the development and dissemination of high-yielding, stress-tolerant and nutritionally enhanced seed varieties.

In general, there is a rich literature on PPPs in other sectors, but comparable research does not exist in agriculture. Spielman *et al*. (2010) consider the literature on PPPs as multidisciplinary and disparate. Hagedoorn *et al*. (2000) and Ervin *et al*. (2003) believe the existing evidence is primarily based on case studies, and there is a selection bias since the partnerships studied are often some of the most successful PPPs. Also, while most existing research on interventions supporting private sector engagement in cereal seed systems development involves large companies, we still know little about the role and contribution of SMEs in PPPs (Hall, 2006).

The evidence of PPPs' contribution to crop productivity increases, seed sector development and competition in the seed industry is limited. Some research has been performed to understand the relationship between industry structure, innovation and growth (Spielman *et al*., 2014), but no empirical research exists on the interaction of these factors involving PPPs. It is not clear how PPPs influence seed industry structure (or *vice versa*), whether public-private collaborations encourage or constrain innovation, and what arrangements work best for accelerating industry growth. PPPs in the private sector have also largely been ignored. For example, many national and multinational companies over several years have led partnerships, but these cases generally remain undocumented (see Syngenta Foundation, 2016).

2.1.4. PPPs in technology adoption and seed sector development

For many years, PPPs in seed sector development have attracted and continue to attract investments from developed and developing country governments, CGIAR institutions and donor agencies. A general common assumption when implementing PPPs is that SMEs have the capacity to produce and distribute affordable seed of good quality to low-income farmers in remote markets. However, there have been relatively few empirical evaluations of the capacities of SMEs to incorporate new public seed innovations developed through PPPs into their product portfolios and into the market. In the current global concentrated seed markets, it is not clear whether such collaborations can successfully capture market shares from global market leaders and promote sufficient competition in the seed industry. Several questions remain, whose answers can facilitate

the systematic evaluation of the role of SMEs and PPPs and their contribution to seed systems development and smallholder crop production which underpin large public sector investments.

A second assumption when implementing PPPs is that competitive high-quality hybrids will make their way to farmers without the need to pay much attention to seed distribution and marketing. Nevertheless, despite the successful development of competitive high-yielding, stress-tolerant maize seed varieties based on CGIAR breeding materials either through public NARS or PPPs (Edmeades, 2013; Cairns and Prasanna, 2018), new varieties developed struggle to achieve large-scale distribution, and very often outdated varieties or hybrids of multinational companies dominate the maize seed market (see Spielman *et al*., 2014).

In attempting to explain the low adoption and slow variety turnover, research has largely focused on the agronomic advantage and seed production aspects (Feder *et al*., 1985; Walker and Alwang, 2015) but have generally overlooked downstream issues such as the role of agro-input dealers (Rutsaert and Donovan, 2020) and marketing. Despite the key role of agro-dealers in expanding hybrid maize seed sales and accelerating varietal turnover within commercially oriented maize seed systems, very little rigorous analytical research has been undertaken to explain how they influence farmers' decisions on which seed to purchase, and how they interact with other actors in the seed value chain for marketing improved maize seed. The literature on adoption and seed systems has also ignored the effect of price, brand loyalty, perceptions of quality and perceptions of value on seed variety choices and farmers' willingness to buy improved seeds. Only very recently has the adoption literature started to incorporate marketing insights on the understanding of technology diffusion in agriculture and recognized the role of marketing activities in enhancing adoption (Heiman and Hildebrandt, 2018; Heiman *et al*., 2020). Nevertheless, there is a tremendous marketing research gap in seed adoption and seed systems development studies that needs to be urgently addressed.

2.2. The CGIAR plant breeding research system

The CGIAR is a global network of agricultural research for development established in 1971. The organization comprises 15 international agricultural research centres (CGIAR, n.d) (Figure 1). Each centre develops research on major crops and commodities of critical importance for developing countries, emphasizing crop improvement, conservation and use of plant genetic resources (Plucknett, 1993; Bellon and Morris, 2002).

The CGIAR research system dates from the mid-1940s, when the governments of Mexico and the United States of America (USA), jointly with the Rockefeller Foundation, created the Office of Special

Studies (OEE). A major feature of the OEE was the establishment of international nursery trials, that over time evolved into what is now the current CGIAR breeding research system (Plucknett, 1993; Byerlee and Dubin, 2010). In this system, germplasm access is warranted via two channels: germplasm banks, and the CGIAR breeding programmes (Byerlee and Dubin, 2010; Noriega *et al*., 2013). Anyone in the private or the public sector can request the delivery of seed free of charge from the gene banks. Currently, 11 CGIAR centres hold in trust designated crop germplasm collections for their use by the international community in plant breeding and genetic resource conservation (Table 1) (CGIAR Genebank Platform and Crop Trust, 2019).

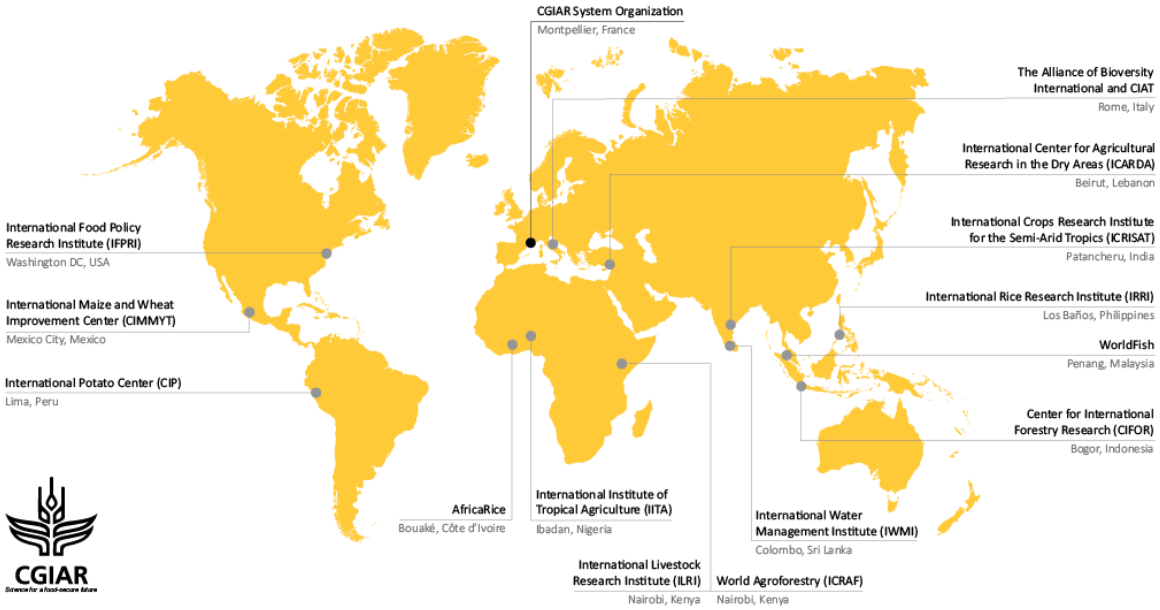


Figure 1 | CGIAR centres. Source: ACIAR (2021).

Table 1. International centres maintaining gene banks, entry year into the CGIAR and crops.

Centre	Year of entry	Crops/commodity
International Maize and Wheat Improvement Centre (CIMMYT)	1971	maize, wheat
International Rice Research Institute (IRRI)	1971	rice
International Institute for Tropical Agriculture (IITA)	1971	cassava, maize, cowpeas, yams soybeans, bananas, plantains
International Center for Tropical Agriculture (CIAT)	1971	beans, cassava
International Crops Research Institute for the Semiarid Tropics (ICRISAT)	1972	sorghum, millets, pigeon peas, chick-peas, groundnuts
International Potato Center (CIP)	1973	potato, sweet potato, other root crops
Biodiversity International	1974	plant genetic resources
International Center for Agricultural Research in the Dry Areas (ICARDA)	1975	barley, lentils, fava beans, wheat, chickpeas
Africa Rice Center	1975	rice

World Agroforestry Centre	1991	multi-purpose trees
International Livestock Research Institute (ILRI)	1995	livestock

Source: Almekinders *et al*. (2019).

In the breeding programmes, CGIAR breeders use germplasm collections in the gene banks to generate improved germplasm, which is then distributed to national and international collaborators for its evaluation. Partners test this germplasm, report back to CGIAR centres information about products performance and request, if interested, experimental materials, elite or advanced lines which are often used to develop locally adapted varieties and hybrids (Byerlee and Dubin, 2010).

This system of open germplasm access and international testing facilitated the development of the first wheat and rice semidwarf high-yielding seed varieties. These varieties were extensively adopted in many parts of Asia and Latin America, leading to the start of the "Green Revolution" in the 1960s[1] (Baum and Lloyd, 1985; Byerlee and Dubin, 2010). In the following years, the dissemination of improved varieties extended to many other regions and crops, contributing equally to important productivity gains and global food security (Pingali, 2012).

The contribution of CGIAR innovations to productivity gains in developing countries mainly through the "Green Revolution" is well recognized (Evenson and Gollin, 2003; Pingali, 2012). The system has nevertheless several clear drawbacks, notably, restricted local adaptation breeding, a weak link with farmers, and insufficient capacity for farm-level variety testing. These limitations usually lead to the development of seeds unsuitable for farmers' needs, poorly adapted to target environments with a deficient performance in farmers' fields (Morris and Bellon, 2004). Moreover, some authors believe the benefits of the CGIAR innovation system have been rather uneven, with clear contributions to production increases in well-endowed production areas, but poor effects in marginal, low-potential production environments (Bellon and Morris, 2002; Pingali, 2012). For instance, results have been poor in the lowland humid and sub-humid tropics of South and Southeast Asia (Zeigler, 1999), sub-Saharan Africa (Lynam, 2011) and rain-fed areas of many countries including Mexico. Within the conservation and scientific community, there are also fears that the adoption of improved varieties would inevitably lead to the loss of crop genetic diversity (Srinivasan *et al*., 2003b).

[1] The "Green Revolution" is a period of extraordinary growth in agriculture during the 1960 and 1970 in which production of cereal crops tripled and most developing countries overcame its chronic food deficits. This period was characterized by high and consistent investment in crop research for the development of high-yielding crop varieties (mainly wheat, rice and maize), infrastructure, markets and appropriate policies for increasing the use of improved seeds, fertilizer, irrigation, and crop protection inputs (Pingali, 2012).

2.3. Evolution and changes of the maize seed industry in Mexico and its legislation

Figure 2 presents the key milestones in the seed sector's development and policy in Mexico. As observed in the figure, the development of the Mexican maize seed industry can be divided into four main stages. An explanation of each stage is given below:

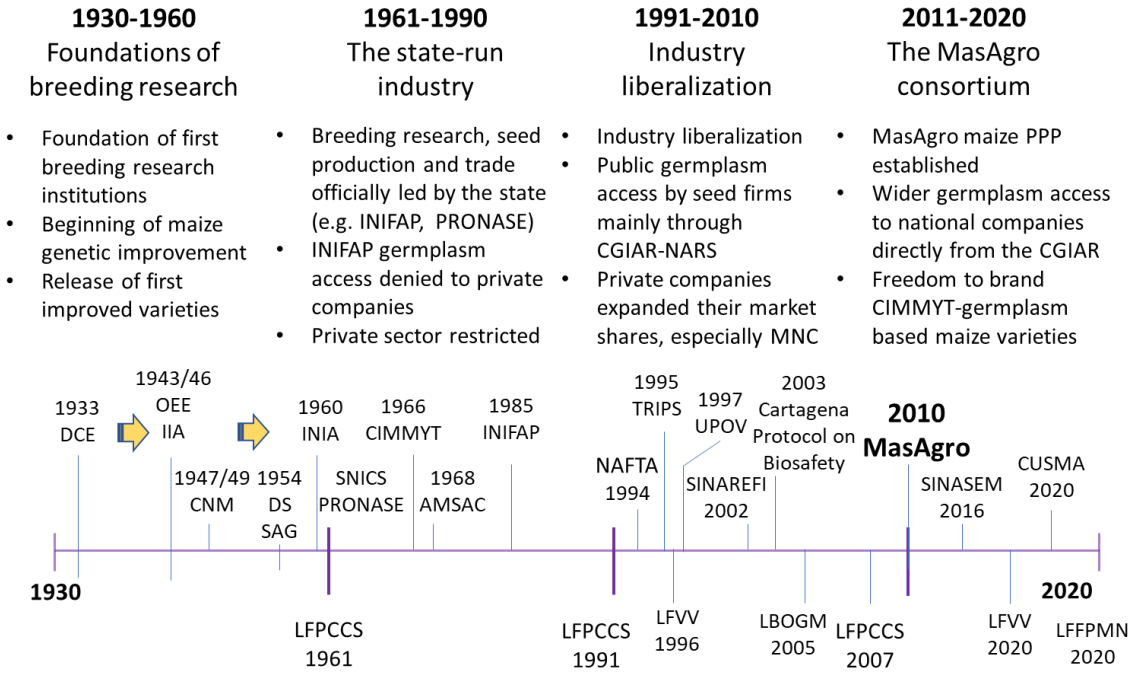


Figure 2 | Timeline of the evolution of the Mexican maize seed industry, 1930-2020. Department of Experimental Stations (DCE), Office of Special Studies (OEE), Institute of Agricultural Research (IIA), National Maize Commission (CNM), Seed Department of the General Office of Agriculture (DS-SAG), National Institute of Agricultural Research (INIA), National Seed Production Company (PRONASE), National Seed Inspection and Certification Service (SNICS), International Maize and Wheat Improvement Centre (CIMMYT), Mexican Seed Producers' Association A.C. (AMSAC), National Institute of Forestry, Agriculture and Livestock Research (INIFAP), North American Free Trade Agreement (NAFTA), Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), International Union for the Protection of New Varieties of Plants (UPOV), National System of Plant Genetic Resources for Food and Agriculture (SINAREFI), Cartagena Protocol on Biosafety to the Convention on Biological Diversity (Cartagena Protocol on Biosafety), Sustainable Modernization of Traditional Agriculture (MasAgro), National Seed System (SINASEM), Canada-United States-Mexico Agreement (CUSMA), Law of Production, Certification and Commercialization of Seeds (LFPCCS 1961, 1991 and 2007), Federal Law of Plant Varieties (LFVV 1996 and 2020), Genetically Modified Crops and Biosafety Law (LBOGM), Federal Law for the Promotion and Protection of Native Maize (LFFPMN). Source: Author.

1930-1960: foundations of the current breeding research system

During the period 1930-1960, the government created several state breeding research institutions which have evolved into the current national agricultural research system (Figure 2). This process started with the creation of the Department of Experimental Stations (DCE) and the establishment of the first formal breeding research programmes in 1933. Breeding efforts were intensified when the Office of Special Studies (OEE) – currently CIMMYT – was established in 1943 with funding from the

Rockefeller Foundation and the DCE evolved into the Institute of Agricultural Research (IIA) – currently the national Institute of Forestry, Agriculture and Livestock Research (INIFAP) – in 1946. As a result of the recently created national research systems, the first improved varieties were released in 1947 and self-sufficiency in corn, beans and wheat was achieved in 1959 (Ayala-Garay *et al*., 2006).

In 1960, the OEE and the IIA were combined to create the National Institute of Agricultural Research (INIA) (Ayala-Garay *et al*., 2006). Simultaneously, the Rockefeller Foundation and the Mexican government created the International Maize and Wheat Improvement Centre (CIMMYT) to promote the success of breeding research on an international level (Baum and Lloyd, 1985).

1961-1990: the state-run industry

The exceptional success of breeding research during the early years of the maize seed industry led the government to enact the first seed law (LFPCCS) in 1961 (Figure 2). With this law, guidelines for seed production, certification and commercialization were introduced. The National Seed Producer (PRONASE) was created to oversee the production, conditioning and distribution of seed, and varietal improvement was delegated to the INIA (currently INIFAP), which was commissioned to maintain a national germplasm bank to ensure the collection and preservation of breeding materials. Along with these research functions, INIA was required to deliver exclusively to the PRONASE foundation seed of elite inbred lines for commercial cultivation. The National Seed Inspection and Certification Service (SNICS) was made responsible for supervising the production, conditioning, and commercialization of seeds (Morris, 1996).

This law restricted private sector participation in the maize seed industry: seed companies could not access public germplasm developed by INIFAP and could not carry out breeding research without permission of the state. Seed imports and exports were strictly controlled. There were also restrictions on seed marketing, and price controls were set up for the private sector, while public seed from the parastatal seed company (PRONASE) was subsidized (Secretaría de Agricultura y Ganadería, 1961). In 1985, the INIA was reorganized into the National Institute of Forestry, Agriculture, and Livestock Research (INIFAP). The INIFAP continued to hold responsibility for national maize breeding research and foundation seed provision exclusively to PRONASE until 1991 (Morris, 1998).

1991-2010: industry liberalization

In 1991, the country lifted restrictions on private sector participation in the seed sector and opened access to INIFAP germplasm to seed companies with the enactment of the 1991 seed law (Morris, 1996) (Figure 2). In the following years, Mexico joined the International Union for the Protection of

New Varieties of Plants (UPOV)[2] and introduced legislation for plant variety protection conforming to the UPOV (1978) Convention to harmonise its seed legislation and comply with international biosafety guidelines[3]. This included the signature of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) in 1995 and the promulgation of the Federal Law of Plant Varieties (LFVV) of 1996. Through the Federal Law of Plant Varieties, the country introduced plant variety protection and committed to ensuring that enforcement procedures were available and effective according to the TRIPS agreement, which requires all member countries of the World Trade Organization (WTO) to provide an effective system of plant variety protection (Srinivasan, 2003). These changes brought Mexican seed laws into line with international intellectual protection (IP) standards (Léger, 2005).

As a result of the 1991 and 1996 seed laws, the maize seed industry went from being a state-run to a private-led industry. National and multinational companies rapidly increased their presence in the seed market. Given the dependence of national seed companies on INIFAP germplasm and the lack of regulations to promote the growth of the national industry, multinational companies rapidly captured most of the maize seed market (Luna-Mena *et al*., 2012).

Furthermore, with the advent of biotechnology in the late 1990s, Mexico modernized its seed legislation in response to the need for providing legal certainty and reliability in this field. In 2003, it joined the Cartagena Protocol on Biosafety to the Convention on Biological Diversity[4]. It also enacted the Genetically Modified Crops Biosafety Law (LBOGM) in 2005, as a response to the commitments acquired in the Cartagena Protocol. The objective of this law was to regulate the use, release, commercialization, import and export of genetically modified organisms (GMOs). With the 2005 biosafety law commercial planting of GM crops was allowed, except for corn. This restriction arises from the fact that Mexico is the centre of origin of maize, and therefore there is strong local resistance which has, up to now, prevented the commercial planting of genetically modified maize.

[2] The International Union for the Protection of New Varieties of Plants (UPOV) is an intergovernmental organization established in 1961 by the International Convention for the Protection of New Varieties of Plants (the UPOV Convention). The UPOV provides and promotes an effective system of plant variety protection (PVP) across its member countries by granting intellectual property rights (IPRs) to breeders of new plant varieties (UPOV, 2011).

[3] UPOV members need to harmonize their seed laws to conform with either the 1978 or 1991 UPOV Convention Act (UPOV, 2011). The principal difference between the 1978 and 1991 act is the researchers' exemption, which allows plant breeders to use protected varieties as an initial source of variation in the development of other new varieties (Srinivasan, 2003).

[4] The Cartagena Protocol on Biosafety to the Convention on Biological Diversity is an international agreement which aims to ensure the safe handling, transport and use of genetically modified organisms (GMOs) resulting from modern biotechnology that may have adverse effects on biological diversity and human health (UN Environment Program, 2022).

The 1991 seed law was also modernized by enacting the 2007 seed act (LFPCCS 2007). The 2007 regulation introduced new categories of seeds, extended the scope of the legislation to include all seeds (improved, native varieties and genetically modified) and ordered the closing of PRONASE. After the promulgation of the 2007 seed act, efforts were made to change the 1996 Federal Law of Plant Varieties and make Mexico conform to the UPOV Act of 1991. However, Mexico continues to follow the act of 1978 (UPOV, 2022). According to this act, the protection of varieties is *sui generis:* that is, it does not use patenting schemes and genetic diversity is privileged, allowing the essential derivation of varieties, as well as the use by farmers of farm-saved seed of protected varieties.

2011-2020: the MasAgro seed consortium

After continuous efforts for increasing maize production and modernizing the seed industry, maize production continued to be low. Maize yields had considerably increased in irrigated areas, from about 2.6 t/ha in 1980 to 7.4 t/ha in 2010, but remained significantly low in rainfed zones – at about 2.0 t/ha (SIAP, 2020a). Improved seeds covered only 40% of the total area planted to maize (SIAP, 2016) despite the considerable number of seed varieties released by the public sector (Angeles-Arrieta, 2000; Luna-Mena *et al*., 2012) and commercialized by private companies. As a response, the Ministry of Agriculture (SADER) and CIMMYT launched MasAgro (Sustainable Modernization of Traditional Agriculture) in 2010 (Figure 2).

MasAgro was a PPP linking the main public maize breeding research institutions with the private sector, intending to develop improved maize seed varieties for their commercialization by SMEs to small-scale farmers in rain-fed zones. Through this initiative, the government aimed to develop a strong and diverse national maize seed sector, substantially increase maize yields, and enhance the country's self-sufficiency in maize. The project had four components (CIMMYT, n.d.):

1. MasAgro biodiversity: aimed to explore and characterize the genetic diversity of maize and wheat to unlock the potential for its use by the international crop breeding research community and facilitate the development of improved seed varieties[5].
2. MasAgro maize: was meant to promote the development and delivery of conventional non-GM corn hybrids, the improvement of native maize varieties and support the consolidation of local seed companies and the national maize seed industry.
3. MasAgro wheat: intended to advance research on wheat genetics and physiology to improve plant structure, and increase both resistance to wheat diseases and yield potential.

[5] See Pixley *et al*. (2018).

4. MasAgro farmer: focused on the promotion of sustainable farming practices and their transfer to farmers through innovation hubs and research platforms where technologies were tested, proved and adapted by farmers[6].

This thesis is concerned with MasAgro maize, also known as the International Maize Improvement Consortium for Latin America (IMIC-LatAm). The objectives of MasAgro maize were: 1) to develop a strong and diverse national maize seed sector able to produce improved maize seeds and deliver them to an additional 1.5 to 3.0 million hectares in rainfed zones, 2) to increase maize yields in that area from 2.2 to 3.7 t/ha by promoting the use of improved seeds and 3) increase national rainfed maize production from 13 to 18/22 MT. The project had a budget of US$138 million (MX$1,656 million) for a period of 10 years (2011-2020) (Turrent *et al.*, 2012).

The last wave of policy changes (2016-2020) in Mexico included the renewal of the North American Free Trade Agreement (NAFTA), now the Canada-United States-Mexico Agreement (CUSMA), which in turn encouraged a debate on the need for amending the 1996 plant variety law to conform to the UPOV (1991) Convention. Although the initiative is still under discussion for approval, Mexico aims to provide additional legal certainty to the private sector and, hence, major opportunities for private investments. The government also enacted the Federal Law for the Promotion and Protection of Native Maize (LFFPMN) in 2020, which seeks to protect native maize for use in production and *in situ* conservation[7] (Figure 2).

2.4. Changes in the maize seed industry with the implementation of MasAgro

Several changes were introduced to the national maize seed industry since the projects' inception, including the organization of domestic seed companies in a PPP to closely work with the main public breeding research institutions (CIMMYT, INIFAP, UACH, etc.) for the development and dissemination of CIMMYT germplasm-based hybrids. Any national seed company with knowledge of seed production and marketing capacities could join the consortium and benefit from the project activities. As of 2019, sixty-nine national seed companies participated in MasAgro. The main changes implemented through this PPP and along the maize seed value chain are described below.

Research and development

Historically, CIMMYT did not develop finished varieties, but instead, it generated intermediate lines and pedigree populations (F1- derived F2s) for further use by NARs and private companies for the

[6] See Monsalvo-Velázquez *et al*. (2014).

[7] Mexico is the centre of origin of maize and is home to 64 different maize landraces (CONABIO, 2020). This maize diversity represents not only a source of variability for plant breeding research, but also an important source of farmers' food security and income.

development of advanced inbred lines and hybrids (Byerlee and Traxler, 1995; Evenson and Gollin, 2009). There was a major shift in CIMMYT's maize breeding research with MasAgro, whereby it started developing advanced inbred lines (F7 onwards), final crosses and final products (hybrids and open-pollinated varieties – OPVs) for provision to national seed companies. For the project period, CIMMYT assumed the role of varietal improvement, an activity that previously was exclusively allocated to NARs, especially INIFAP.

Testing and evaluation

Resembling the CGIAR international testing system (see Byerlee and Dubin, 2010; Noriega *et al*., 2013) the MasAgro consortium evaluated all materials developed by CIMMYT breeders and associates in a multilocation testing network at the national level. Each year the evaluation network was established in the three different mega environments of maize production in Mexico: Tropics (0-900 masl), Subtropics (1000-1800 masl) and Highlands (1900-3000 masl) (CIMMYT, 2012). CIMMYT annually distributed the seed trials to public and private partners in each maize growing mega-environment while partners established the seed evaluation plots and reported back yield results for their analysis[8].

The creation of the MasAgro Seed Evaluation Network allowed public and private partners to identify materials widely and/or locally adapted to production conditions and potential markets before its selection for commercial cultivation. The network gave participants information about varieties' performance that had not previously been accessible to private companies. It is worth noting that, during the period covered by the operations of MasAgro, none of the participating companies or public institutions on their own could have tested on the same scale as they did when they became members of the MasAgro seed evaluation network (San Vicente, 2013).

Registration and certification

To register inbred lines and crosses necessary to form advanced hybrids, inbred parents must be characterized for distinctness, uniformity, and stability during two homologous growing cycles (approximately two years) (Carballo-Carballo *et al*., 2014). Only after this evaluation and characterization period, can inbred parents be used for certified basic or commercial seed production. This process is likely to be onerous and expensive to seed companies; in many cases, companies lack the capacity to undertake it. To accelerate MasAgro hybrids uptake, reduce the burden of variety registration, and lower seed production costs faced by small firms, CIMMYT registered all products developed in MasAgro and provided seed companies with a certificate of

[8] CIMMYT coordinated the experimental design, reception and preparation of seed trials, shipping seed to different locations for assessment, data reception, data analysis and presentation of results.

varietal identity for commercial cultivation[9]. Variety registration granted CIMMYT *de facto* appropriation of developed materials, a major legal shift in CIMMYT's policy implemented during the operations of MasAgro.

Foundation seed production

MasAgro affiliated seed companies could obtain three types of germplasm through their participation in the project: 1) breeders' seed (at least F7- S8 homozygous lines) that could be used by seed firms to maintain and increase original seed stocks, incorporate new lines to their breeding programmes, and generate new crosses and hybrids in combination with their own germplasm, 2) foundation seed, consisting of inbred lines and single crosses, to increase foundation seed stocks, and produce basic or commercial seed and 3) final products (hybrids and OPVs) for production and use in promotion activities, such as demonstration plots, by seed companies (CIMMYT, 2012). There are three fundamental differences in germplasm provision between the traditional CGIAR-NARs channel and the MasAgro PPP. First, unlike INIFAP which supplies only the inbred parents (Virgen-Vargas *et al*., 2016) CIMMYT also provided the breeders' seed so that private companies could access the original source of germplasm and develop their breeding and seed production capacities[10]. Secondly, the provision of promotional seed allowed firms to go to the market at least 1-2 years ahead of a new hybrid's launching, and thirdly, there was a charge for INIFAP foundation seed, while MasAgro seed provision was completely free.

Seed production, marketing and sales

Commercial seed production requires information on the suitability of inbred parents, and on traits that affect this suitability, as well as technical data on crop field management such as adaptation areas, sowing dates, plant density, female to male rows ratio, etc. This information is critical for seed companies producing hybrids from germplasm released by MasAgro, in particular for those who lack the means to develop their own seed production research (Chassaigne-Ricciulli *et al*., 2020). To this end, seed technology was developed and transferred to partner companies. The aim was to recommend production practices to obtain the best hybrids' combinations and performance with the highest seed yield at the lowest production costs. Regarding seed marketing, MasAgro maize germplasm was allocated to SMEs on a non-exclusive and royalty-free basis. MasAgro hybrids can be branded freely by SMEs while non-MasAgro public varieties need to be sold with the name given by the breeding institution. According to some seed business managers, this limitation prevents private

[9] By 7th September 2020, CIMMYT had registered a total of 85 new inbred lines and finished varieties in the CNVV (SNICS, 2020).

[10] All MasAgro public and private members with breeding capacity could access experimental seed from CIMMYT breeding research. The objective was to expand the genetic diversity of breeding programmes and strengthen germplasm exchange (CIMMYT, 2012).

companies from investing in brand, product, and market development: firstly, because investments in market development could be recouped by other companies, and secondly because their firm and brand's reputation could be damaged by other products of inferior quality with the same name.

2.5. Maize production in Mexico

In Mexico, out of the total 7.4 Mha planted to maize, an area of 5.9 Mha (79%) is rainfed and the remaining 1.5 Mha (21%) is irrigated (Figure 3). The country produces 27.4 MT of maize annually (SIAP, 2020a) and is the world's eighth-largest maize producer (FAO, 2020). Out of the total maize production, 13.9 MT is produced in rainfed areas and 13.5 MT in irrigated zones (Figure 4). Maize production in rainfed areas contributes to 51% of the total corn harvest.

Yields range from an average of 2.4 t/ha in rainfed to 8.7 t/ha in irrigated areas (Figure 5) (SIAP, 2020a). The crop is grown in a wide variety of production environments and a continuum of production systems, ranging from traditional polyculture systems, generally associated with own consumption small-scale farming, to high technology irrigated commercial cultivation with intensive inputs. Even within rainfed zones, maize production is very heterogeneous with some farmers attaining yields of about 8.0 t/ha, similar to the irrigation averages, and a majority with average yields below 2.0 t/ha (Donnet *et al*., 2017).

Across the country, more than 2.5 million farmers plant maize annually (Perales and Golicher, 2014). Corn is the country's main staple crop, the basis of the population's diet and a significant source of food security, subsistence and income (Badstue *et al*., 2007). The country produces mainly two types of varieties: white maize generally used for own consumption, which represents 87% of the total, and yellow maize mostly used for animal feed and the oil and starch industries, which constitutes around 13% (SIAP, 2020a; SIAP, 2020b).

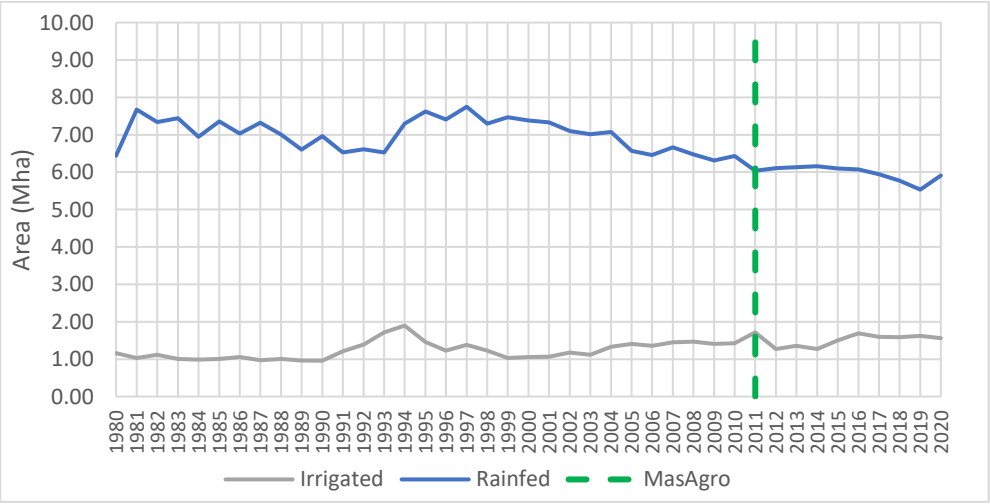


Figure 3 | Area planted to maize, Mexico 1980-2020 (Mha). Source: SIAP (2020).

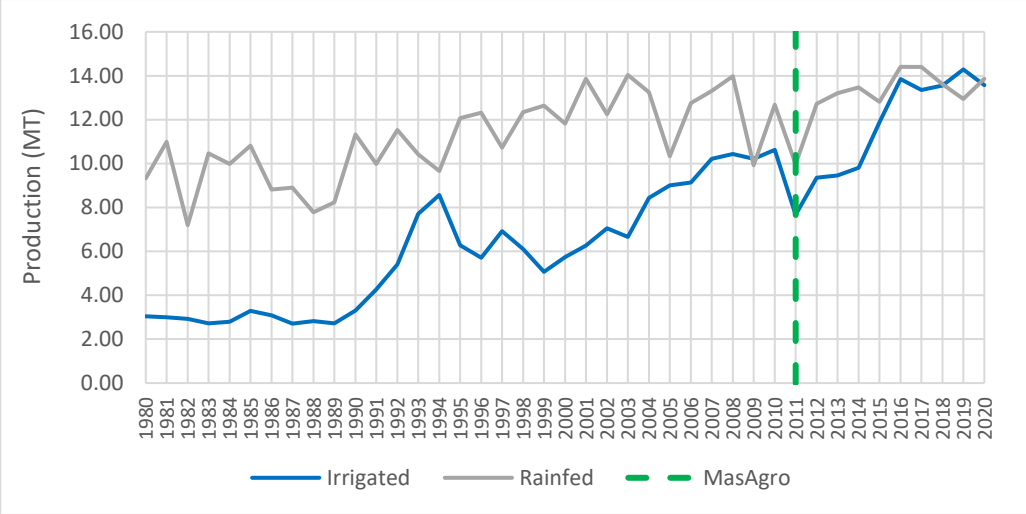


Figure 4 | Maize production, Mexico 1980-2020 (MT). Source: SIAP (2020).

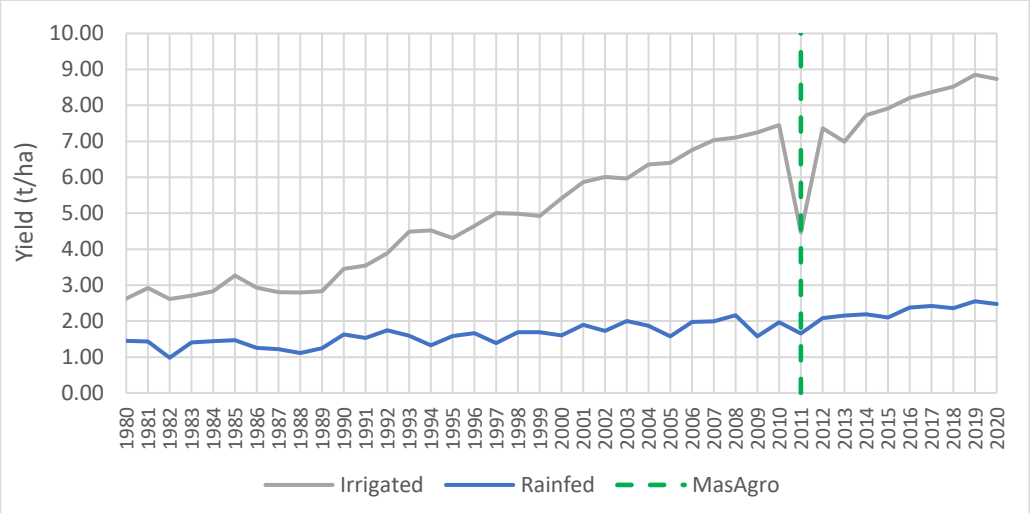


Figure 5 | Maize yields, Mexico 1980-2020 (t/ha). Source: SIAP (2020).

Mexico is self-sufficient in white maize, but it largely depends on maize imports to meet its total consumption needs (44.7 MT). In 2020, Mexico imported 15.9 MT of maize, representing more than a third (about 37%) of its total maize demand and making the country the first worldwide maize importer (Figure 6) (FAO, 2022). This deficit, mainly of yellow maize, is largely explained by the prevailing low productivity levels, resulting from a predominantly rainfed maize production system and the poor adoption rates of improved seeds (40%) (SIAP, 2016; SIAP, 2019; SIAP, 2020). This is despite the considerable number of seed varieties released by the public sector (Angeles-Arrieta, 2000; Luna-Mena *et al*., 2012) and marketed by private companies.

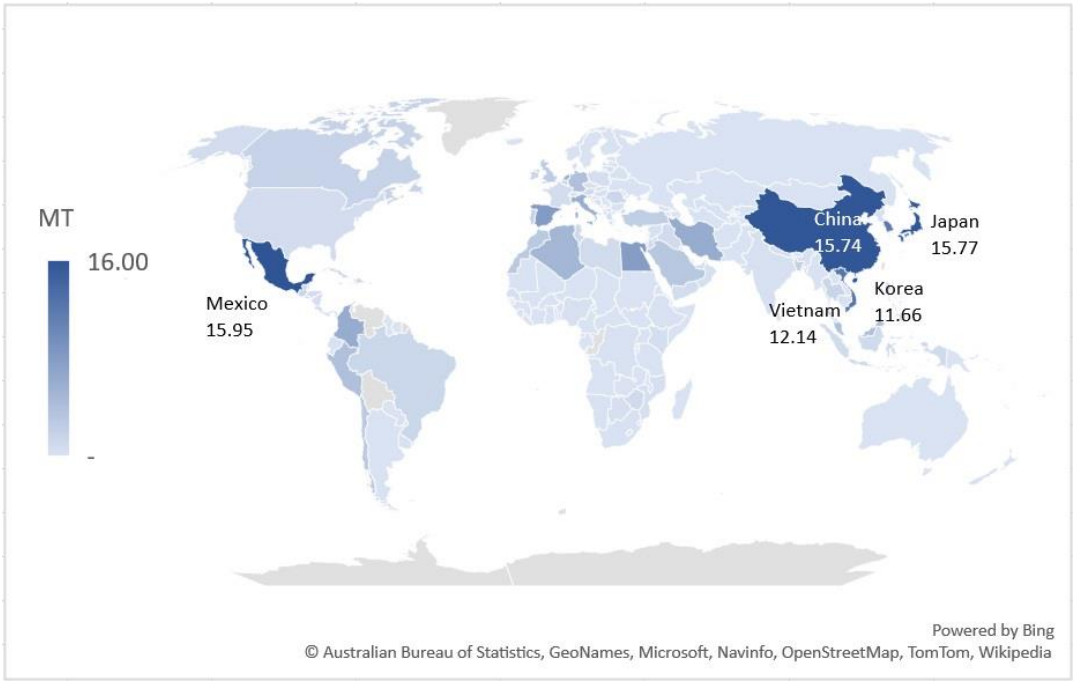


Figure 6 | Global maize imports, 2020 (MT). Source: FAO (2022).

2.6. Objectives and research questions

Based on the experience of the MasAgro seed consortium and the maize seed industry in Mexico, the objective of this research is to evaluate the potential of public-private partnerships for the generation, commercialization and large-scale dissemination of crop variety innovations and seed sector development in low-and-middle-income countries.

This objective leads us to address the following research questions:

1. What is the capacity of PPPs for the development of crop variety innovations that are competitive (in yield terms) with varieties offered by established large players (public sector, private domestic and foreign seed companies) in developing country seed markets?
2. Do PPP SMEs have the capacity to rapidly introduce new varieties developed by PPPs into the market, scale up PPP varieties dissemination and achieve significant levels of market shares in concentrated seed markets?
3. What are the marketing challenges faced by PPPs in the dissemination at scale of PPP varieties?
    a. What is the role of agro-input dealers in expanding the uptake of new PPP varieties by farmers?
    b. How do farmers' loyalty to currently purchased seed brands and price-quality perceptions influence the uptake of new recently released PPP varieties?

3. Capacities of public-private partnerships for the development and dissemination of crop variety innovations

3.1. Introduction

Many large developing countries like India, Brazil and Mexico have relied mainly on crop variety innovations developed by public sector National Agricultural Research Systems (NARS) to drive productivity growth in agriculture. Crop variety innovations from NARS have also underpinned the development of the commercial seed sector in these countries, especially in the initial phases of agricultural development. Developing country NARSs working in collaboration with International Agricultural Research Centres (IARCs) of the Consultative Group on International Agricultural Research (CGIAR) system are acknowledged to have made exceptional contributions to plant breeding and the generation of improved seeds (Evenson and Gollin, 2003). The CGIAR centres and NARS collaboration during the "Green Revolution" led to the development of the semi-dwarf, high-yielding wheat and rice varieties that transformed agriculture in the developing world, substantially increased food production and largely contributed to improving global food security (Evenson and Gollin, 2003; Byerlee and Dubin, 2010). The factors driving the success of the public sector in the development and dissemination of crop varieties in the 1960s and 1970s were, to a large extent, the strong willingness of developing country governments and international donors to invest in agricultural research and the CGIAR system of free exchange of plant genetic resources that facilitated collaborations between national and international research systems.

While NARS remained dominant in plant breeding in developing countries till the 1990s and provided the main links with the international plant breeding research system, the effectiveness and sustainability of the public-sector-led innovation system have been called into question by several related developments. These include 1) the declining trends in public investment in agricultural research in developing countries since the 1990s (Pray, 2001; Naseem *et al*., 2010); 2) the declining efficacy of NARS in the dissemination of new crop varieties reflected in the limited uptake and adoption of new varieties (Naseem *et al*., 2010); 3) the emergence of significant private sector capacity for plant breeding, mainly through multinational seed companies but also in domestic seed firms (Fuglie, 2016); 4) the expansion of intellectual property regimes (IPR) for plant variety innovations in developed countries under the auspices of the International Union for the Protection of New Varieties of Plants (UPOV) and their extension to developing nations through the World Trade Organization (WTO) Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement (Byerlee and Dubin, 2010). This had the effect of restricting the free exchange of plant genetic

resources and the capacity of breeders to build on protected innovations (Srinivasan, 2003; Kapur, 2011); and 5) the emergence of biodiversity legislation in developed and developing countries based on the Convention on Biological Diversity's (CBD) principles of "sovereignty over biological resources" which may not be aligned with the principle of free international exchange of plant genetic resources enshrined in the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (Byerlee and Dubin, 2010; Galluzzi *et al*., 2016). These developments have led to a re-examination of crop variety innovation and dissemination strategies in developing countries.

Over the last three decades, PPPs have emerged as an alternative model to accelerate variety development and dissemination to farmers. PPPs leverage the public sector's upstream plant breeding capacities with private sector strengths for seed production and marketing. PPPs seek to assign a larger role to domestic companies in seed sector development and encourage emerging plant breeding capacity in the private sector. In many developing countries, where small farmers are the main buyers of seeds, innovations developed through PPPs provide an alternative to varieties offered by multinational seed companies that usually enjoy substantial price premiums and may be unaffordable to low-income farmers.

For many years, PPPs in seed sector development interventions have attracted and continue to attract investments from developed and developing country governments, CGIAR institutions and donor agencies. A general common assumption when implementing PPPs is that small and medium domestic seed enterprises (SMEs) have the capacity to produce and distribute affordable seed of good quality to low-income farmers in remote markets. However, several questions remain, whose answers can facilitate the systematic evaluation of the role of SMEs and PPPs and their contribution to seed sector development. For example: Can SMEs successfully incorporate new seed innovations developed through PPPs into their product portfolios and into the market? Can PPPs contribute to the development of vigorous local seed industries, accelerating variety development, variety turnover and dissemination of new varieties to achieve crop productivity increases? Can PPPs deliver on broader development goals related to seed systems development and smallholder crop production which underpin large public sector investments? There have been relatively few empirical evaluations of seed sector PPPs that address the above questions.

This chapter examines the performance of the MasAgro consortium in Mexico, a PPP for hybrid maize varieties involving the International Maize and Wheat Improvement Centre (CIMMYT) of the CGIAR, the main public breeding NARS, the Mexican government and sixty-nine small and medium domestic seed companies over the period 2011-2019. The assessment addresses the following research questions:

1. What was the contribution of the MasAgro maize PPP to the development of new hybrid maize varieties in the Mexican maize seed industry over the period 2011-2019?
2. How did MasAgro maize hybrids compare in terms of yield with hybrids of private national and multinational companies and the public sector?
3. How did participation in MasAgro influence the variety portfolios of participating seed companies?
4. What was the impact of MasAgro on the hybrid maize seed market and the uptake of improved varieties and yields in rainfed areas of Mexico?

The analysis aims to assess the capacities of SMEs to deliver publicly bred variety innovations through PPPs and build evidence of the contribution that PPPs can make to seed sector development in developing countries. It intends to derive lessons from the MasAgro experience that can inform the design and implementation of PPPs in other developing countries where the private sector plays (or can potentially play) a key role in cereal seed multiplication and delivery. The analysis is structured as follows. Firstly, in section 3.2 we design a conceptual framework to understand maize variety innovation and delivery through PPPs; section 3.3 provides the context of the study; section 3.4 presents the data and methods; section 3.5 presents the results; section 3.6 discusses the findings and section 3.7 is the conclusion.

3.2. The role of PPPs in plant breeding and cereal seed systems

Fuglie and Toole (2014) identify four different mechanisms for public and private sector collaborations: 1) research grants, whereby governments usually fund private research; 2) patent licenses, where public research agencies develop and patent a technology and then transfer the rights for its use to a private company; 3) the Cooperative Research and Development Agreements (CRADA) model, in which a public research institution and single company jointly develop a new technology with a commercial application; and 4) research consortiums, which involves one or more public sector partners and several private companies undertaking joint research. CGIAR centres have explored all of these partnerships (see Syngenta Foundation, 2021b; PRWeb and Newswire, 2016; Niebur, 2009) but the consortium model is probably the most common form of collaboration. The main distinctive attribute of research consortiums, compared to other PPPs as well as to current public technology transfer and private delivery approaches, is their ability to bring together public breeding programmes and private seed delivery systems.

In maize seed systems, CGIAR centres traditionally generate improved germplasm for further use by NARS (CGIAR-NARS route) and private companies (private route) for the development of advanced inbred lines and hybrids (Byerlee and Traxler, 1995; Evenson and Gollin, 2003). In the CGIAR-NARS

route (Figure 7a), NARS are recipients of CGIAR (IARC) germplasm for further development and evaluation. NARS are then the main technology diffusers and foundation seed providers to private seed companies, which in turn are seed multipliers. NARS and private companies mainly work separately, with private seed firms mostly acting as receivers of technology, knowledge and information. In countries with low and middle incomes, few private seed companies have the capacities to invest in their own plant breeding research. Those with plant breeding capacity will usually skip the CGIAR-NARS route, making their own germplasm improvements and variety evaluation directly, accessing genetic resources from the CGIAR or other national/international sources (Figure 7b). However, the capacity for innovation in individual domestic seed firms may be limited. In public-private research consortiums (Figure 7c) public sector entities provide a broad range of elite breeding materials to domestic seed companies to stimulate their collective plant breeding capacity while exploiting the strengths of private sector firms to commercialize varieties in competitive markets. NARS, then, no longer remain the principal technology providers but continue their engagement in breeding and variety evaluation while private companies are expected to develop their breeding capacities and generate their own varieties.

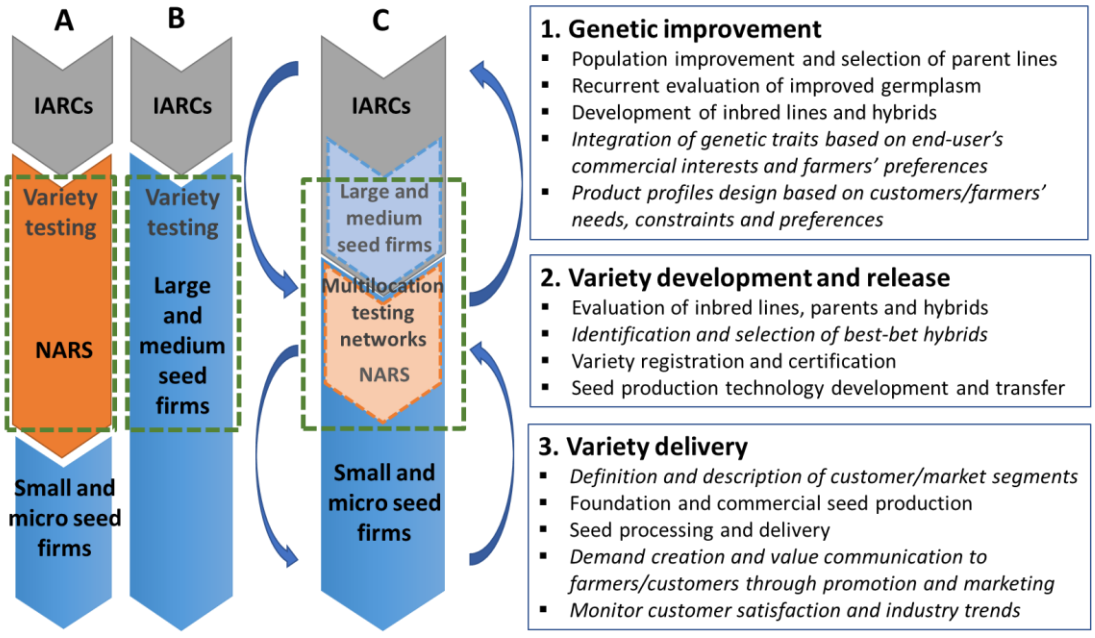


Figure 7 | Crop germplasm improvement, evaluation, and delivery through a) the CGIAR-NARS route; b) private route; and c) public-private research consortiums that incorporate a marketing-oriented perspective along the entire maize seed value chain. Source: Author, based on Atlin *et al*. (2017), Andorf *et al*. (2019) and Kotler and Keller (2012).

The plant breeding and seed delivery systems of consortium PPPs may vary by country, crop, and programme, but they generally involve three main core components (Figure 7).

1. Genetic improvement: through the plant breeding component, consortium PPPs provide direct and continuous access to elite breeding materials and/or finished varieties generated by CGIAR or NARS breeding programmes to domestic private companies, thus relaxing germplasm restrictions imposed by IPR and facilitating germplasm transfer. An important incentive for domestic seed companies is their ability to access CGIAR/NARS improved germplasm as most private SMEs in low-and-middle-income countries do not have the capacity to invest in plant breeding research. SMEs may similarly be able to use elite cultivars from CGIAR/NARS in their own breeding research for the development of follow-on innovations, for which they may seek intellectual property protection. Participating domestic firms also benefit from their ability to refresh their variety portfolios, yielding higher margins and economic returns.
2. Variety development and release: consortium PPPs take advantage of the public and private sector infrastructure to extensively evaluate new potential varieties in multilocation testing networks and adapt germplasm to different agroclimatic conditions, target environments and management practices. Multilocation testing networks (MTNs) allow partners to identify materials widely and/or locally adapted to production conditions and potential markets before the selection of best-bet hybrids for commercial cultivation. MTNs are expensive and difficult to conduct and small breeding programmes in developing countries are often unable to establish them at a sufficient scale to provide reliable yield information (Atlin *et al*., 2017). Therefore, their use provides SMEs with essential information about varieties' performance that is otherwise inaccessible. PPP consortiums usually involve the development of seed production technology and their transfer to partner companies. Some will also register their seed variety innovations to facilitate hybrid uptake by SMEs.
3. Variety delivery: consortium PPPs foster the integration of dynamic breeding programmes and seed delivery systems capable of continuously deploying new varieties extracted from germplasm collections, stimulating varietal replacement and increasing crop yields. Public partners may provide foundation seed to private companies to accelerate commercial seed production and engage in the promotion and dissemination of new varieties. The variety delivery component is fundamental for achieving the impact of plant breeding research in the international agricultural research system.

Several examples illustrate the use of the consortium approach for hybrid seed development and delivery (Appendix A). These include the ICRISAT sorghum, pearl millet and pigeon pea Hybrid Parents Research Consortia in Asia (Gowda *et al*., 2006), the Humanitarian Golden Rice (Potrykus, 2010), many diverse Rice Research Consortiums in Asia and Africa (GRiSP Global Rice Science

Partnership, 2013) and many different partnerships in maize, such as the Insect-Resistant Maize for Africa (IRMA) (Tefera *et al*., 2016), the Water Efficient and Drought Tolerant Maize for Africa (WEMA/DTMA) (Edmeades, 2013), the Stress Tolerant Maize for Africa (STMA) (Simtowe, 2019), the Affordable, Accessible Asian Drought Tolerant Maize Project (AAA-DT Maize) (Syngenta Foundation for Sustainable Agriculture, 2021b), the MasAgro maize consortiums for Latin America, Asia and Africa, etc.

Experience shows the strong capacities of PPPs for developing new crop variety innovations. Thanks to the ICRISAT Hybrid Parents Research Consortia, a great deal of germplasm has been shared with public and private partners, and companies developed and disseminated a diverse number of seed varieties using ICRISAT-bred materials (Gowda *et al*., 2004; Mula *et al*., 2007). From 2006 to 2016 the DTMA project developed more than 200 drought-tolerant maize varieties in collaboration with national seed systems in thirteen countries across Africa. Project affiliated companies produced 60,000 t of those varieties (Abate, 2016). Over the same period, the Program for Africa's Seed Systems (PASS), in collaboration with NARS in eighteen African countries, developed and released 600 seed varieties of different staple crops, producing 120,000 t of certified seed annually (AGRA, 2017). While data on innovations developed are usually made available by NARS, information about varieties' uptake and commercialization by private companies remains scarce. Very little is known about the performance of varieties developed through PPPs compared to varieties developed by multinational companies and their impact on seed markets.

3.3. The maize seed industry and the MasAgro consortium for hybrid maize

3.3.1. The maize seed industry in Mexico

Breeding research started with the establishment of the first formal breeding research programmes in 1933 (see Figure 2, section 2.3). During the period 1930-1960, the government created several state breeding research institutions which have developed into the current national agricultural research system. Breeding intensified when the Office of Special Studies (OEE) - currently CIMMYT - was established in 1943 and the DCE evolved into the Institute of Agricultural Research (IIA) - currently the National Institute of Forestry, Agriculture and Livestock Research (INIFAP) - in 1946. Self-sufficiency in corn, beans and wheat was achieved in 1959 (Ayala-Garay *et al*., 2006). The exceptional success of breeding research during the early years of the maize seed industry led the government to enact the first seed law in 1961 (LFPCCS 1961). This law restricted private sector participation in the maize seed industry: seed companies could not access public germplasm developed by INIFAP and could not carry out breeding research without permission from the state. Seed imports and exports were strictly controlled. There were also restrictions on seed marketing

and price controls were set up for the private sector, while public seed from the parastatal seed company (PRONASE) was subsidized (Secretaría de Agricultura y Ganadería, 1961; Morris, 1998).

Despite many restrictions imposed on the private sector in Mexico between 1961 and 1990, private companies - principally multinational seed companies - have been actively engaged in the maize seed industry since the 1960s (Echeverría, 1990) and have consistently captured a substantial share of the maize seed market since the 1970s. Between 1970 and 1989, private companies maintained on average a 53% share of the maize seed market. After the liberalisation of the seed industry in 1991, the private sector increased its market share from 58% in 1991 to 87% in 1996. Multinational companies accounted for 70% of total sales, national companies had 17% and the public sector 13%, mainly through the government-backed company PRONASE. Over the period 1970-1996 the share of PRONASE in the maize seed market declined from 48% to only 12% (Morris, 1998). The government-backed company was closed by the enactment of the 2007 seed law.

With the opening of the seed sector to the private sector, the liberalisation of seed policy and seed imports and the enactment of the plant variety protection legislation, the maize seed market in Mexico has over time become highly concentrated and dominated by multinational seed companies. Over the period 2011-2019 private seed companies marketed an average of 90,963 t annually (4.55 M sixty-thousand bags)[11] of improved maize seed (Table 2). Imports and exports, which are mainly attributed to multinational seed companies, averaged 13.1% and 13.7% respectively of the commercial maize seed market. In 2019, domestic companies had a share of 23% while three multinationals (Bayer-Monsanto, Corteva Agriscience and Syngenta) captured the largest shares of the maize seed market with 77% of total seed sales (Figure 8). One single firm (Bayer-Monsanto) accounted for 60% of seed sales. The same multinational companies capture over 70% of the global seed market (IPES-Food & ETC Group, 2021).

Table 2. Improved maize seed sales in Mexico, 2011-2019 (t)

Firm type	2011	2012	2013	2014	2015	2016	2017	2018	2019
Other national	1,859	2,132	5,431	2,715	1,547	4,620	5,308	981	794
MasAgro	13,155	14,508	16,807	19,355	21,283	22,389	21,619	20,464	21,987
Multinational	57,262	47,206	72,234	77,098	76,550	75,044	69,169	71,584	75,565
Total[1]	**72,276**	**63,846**	**94,472**	**99,168**	**99,380**	**102,053**	**96,096**	**93,029**	**98,346**

Source: combined data on maize seed production statistics of the SNICS 2011-2019 (SNICS, 2019) and the MasAgro seed marketing survey 2013-2019 (CIMMYT, 2019a). Information on OI 2016/17, PV 2017 (2017 sales year) and OI 2017/18 (part of 2018 sales year) seed production seasons are missing, and these years contain some estimations.

[11] The most common bag presentation is the sixty-thousand seed bag. Depending on the size of the seed, a bag weighs 20kg, 18kg or even 14kg.

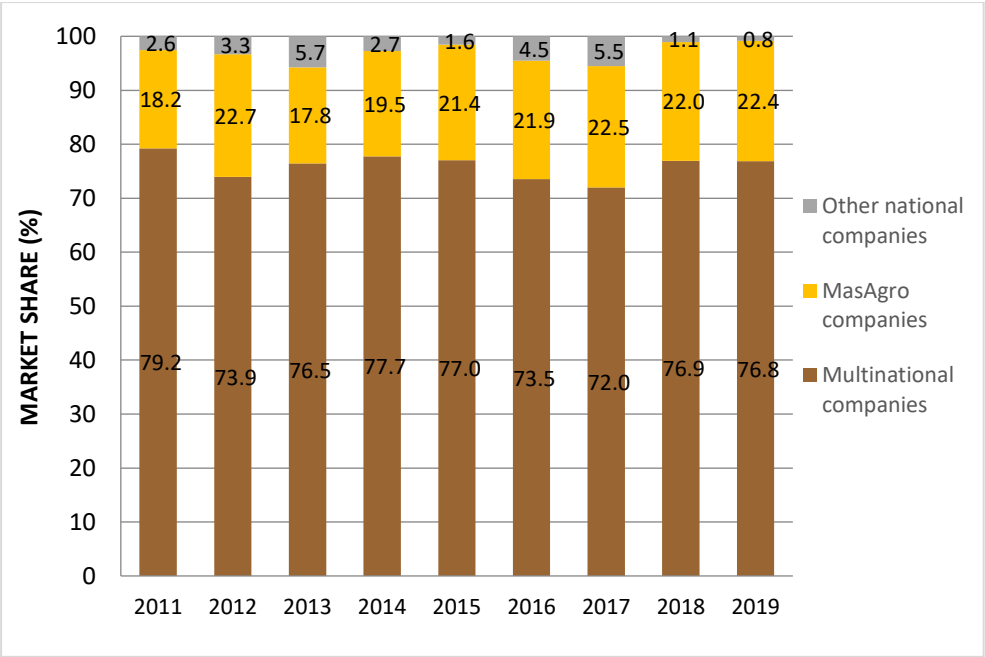


Figure 8 | Market shares of multinational and national seed companies in the Mexican maize seed industry, 2011- 2019. Source: multinational companies from SNICS official seed production statistics 2011-2019 (SNICS, 2019) and official import and export data from the Mexican Ministry of Economy 2011-2019 (Secretaría de Economía, 2019); national firms from MasAgro seed marketing survey 2013-2019 (CIMMYT, 2019a) and SNICS official statistics 2011-2019 (SNICS, 2019). Public sector seed production is added to the "Other national companies" category as they represented only about 5% of total sales of this group and 0.5% of total national maize seed sales during the study period.

3.3.2. The International Maize Improvement Consortium for Latin America (IMIC-LatAm)

MasAgro maize was one of the four components of the Sustainable Modernization of Traditional Agriculture (MasAgro) project, a joint initiative of the government of Mexico and CIMMYT implemented between 2011-2019. The overall programme objective was to substantially increase maize yields and enhance the country's maize self-sufficiency by promoting the use of sustainable farming practices and the adoption of improved seeds among small and medium-scale farmers in rain-fed zones. The programme consisted of four components: MasAgro biodiversity, MasAgro maize (IMIC-LatAm), MasAgro wheat and MasAgro farmer[12].

This chapter is concerned with MasAgro maize, whose specific objectives were: 1) to develop a strong and diverse national maize seed sector able to produce and deliver improved maize seeds to an additional 1.5 to 3.0 Mha in rainfed zones, 2) to increase maize yields in that area from 2.2 to 3.7 t/ha by promoting the use of improved seeds and 3) increase national rainfed maize production between 5 and 9 MT (CIMMYT, n.d.).

The key features of the MasAgro maize consortium included:

[12] See Pixley *et al*. (2018) and Monsalvo-Velázquez *et al*. (2014).

1. Development of advanced inbred lines, crosses and final promotional hybrids for their direct allocation to private companies on a non-exclusive and royalty-free basis.
2. Evaluation of advanced germplasm materials and selection of best-bet pre-release hybrids in a multilocation testing network.
3. Variety registration, foundation seed provision, training and hybrid seed production technology transfer by CIMMYT to seed firms to speed up hybrid uptake.
4. Segmentation and targeting, marketing support in product portfolios' design and easing branding restrictions for facilitating scaled-up marketing.

Any national seed company with knowledge of seed production and marketing capacities could join the consortium and benefit from the project's activities. As of 2019, sixty-nine national seed companies were participating in MasAgro. Table 3 shows a summary of the main changes encouraged by the MasAgro PPP along the different stages of the maize seed value chain. The table summarizes the key issues faced at each stage, how these issues were addressed through the MasAgro PPP and the anticipated impacts.

Table 3. Changes in the maize seed sector in Mexico with the implementation of MasAgro.

Value chain component	Before 2010	Problem/limitation	After 2010	Anticipated/potential impacts
Research and development (R&D)	CIMMYT developed intermediate inbred lines for further use by NARS, especially INIFAP, and private companies, in the creation of final hybrids.	Public germplasm was only available to local seed companies through NARS.	CIMMYT developed advanced inbred lines and final hybrids for direct use by national seed companies. Double Haploids (DH) and molecular marker technologies were used and transferred to seed companies.	Direct and wider access to germplasm by national companies. Enhanced breeding capacities. Potential competition between CIMMYT and NARS in maize breeding. Potential disincentive to private companies for investing in their own R&D pipeline.
Testing and evaluation	Testing of public and private materials developed by NARS and seed firms was performed separately. Public NARS cultivars were provided to seed companies for commercial production.	Seed companies did not participate in the testing and selection of public hybrids, having limited knowledge of the products' adaptation and performance.	Public and private hybrids were jointly tested by CIMMYT, NARS and private companies in a multilocation testing network and selected for commercial production.	Increased information exchange about product performance. Broader scale evaluation of seed varieties. Products well suited and adapted to local conditions and target markets.
Registration and certification	Inbred lines and finished varieties were described and registered for plant breeders' rights by NARS. CIMMYT did not describe and register its seed varieties.	CIMMYT did not protect breeders' rights in its seed innovations. Lengthy and expensive variety description process	New products developed in MasAgro were registered and protected for plant breeders' rights by CIMMYT. Companies could seek	Faster adoption of new hybrids by seed companies. Registration and certification process for seed firms eased and accelerated.

		for seed firms using public germplasm.	IPRs over MasAgro's follow-on innovations.	
Foundation seed production	Foundation seed was produced by NARS and provided to seed companies for hybrid production and commercialization.	Foundation seed shortages were a major limitation. Firms could not access breeders' seed.	Foundation seed was produced by CIMMYT for provision to seed companies at no cost. NARS continued to produce and sell it to seed firms.	CIMMYT complements NARS' foundation seed provision. Access to breeder's seed for enhanced long-term private breeding capacities.
Seed production	Seed production technology was available to seed companies from NARS.	Persistent poor and heterogeneous seed quality.	Seed production technology of new hybrids developed and transferred by CIMMYT to seed companies.	Enhanced production capacities of small and medium seed companies. Seed quality improved.
Marketing and sales	Seed companies were required to sell public varieties under the name given by the breeding institution.	Heterogeneous quality and risk of marketing the same hybrid. Lack of incentives for brand, product & market development.	Freedom for naming and branding new CIMMYT-germplasm based hybrids.	Higher incentives for brand, product & market development, and product differentiation.

Source: Author

Thus, the MasAgro maize PPP can be seen as a response to the challenges experienced in the CGIAR-NARS model of variety development and dissemination, reflected in the limited uptake of improved varieties in only 40% of the maize-growing land in Mexico, notwithstanding the huge public investments in plant breeding made over several decades.

3.4. Data and methods

3.4.1. Hybrid development

To examine the contribution of MasAgro maize to the development of new hybrids, firstly varieties were classified into five categories based on the entity responsible for development or the proprietary holder 1) MasAgro (hybrids developed by CIMMYT and made available to MasAgro), 2) Private MasAgro (hybrids developed by consortium seed companies using MasAgro lineage), 3) Public (hybrids developed by INIFAP and other public NARS), 4) Private national (hybrids developed by national seed companies using proprietary germplasm), and 5) Multinational (hybrids developed by multinational seed companies). Secondly, the number of variety releases in each category was quantified using the following data sources: 1) the MasAgro seed evaluation network (CIMMYT, 2019b) to count the new hybrids released by the MasAgro maize PPP; 2) the MasAgro seed marketing survey (CIMMYT, 2013-2019) to obtain the number of new Private MasAgro hybrids developed by affiliated firms; and 3) official varietal releases information from the National Seed Varieties Catalogue (CNVV) (SNICS, 2020) to obtain the number of varieties released by public

research institutions, private national and multinational seed companies[13]. A combined Excel dataset was generated and the frequencies for each seed category were obtained using STATA 17.

Grain yield (GY) of new MasAgro hybrids and other seed categories were obtained from data provided by the MasAgro seed evaluation network (CIMMYT, 2019b). The original panel database contained N=897 observations. These data were previously processed and analyzed for differences of means for GY using analyses of variance (ANOVA) and combined analyses of variance by CIMMYT's Subtropical, Tropical and Highlands maize breeding programmes (maize mega-environment) as described by Torres-Flores *et al*. (2017). We used a sub-dataset (n=341) containing GY of the top two white (W) and yellow (Y) hybrids evaluated by the subtropical (ST), tropical (LT) and highlands (HL) MasAgro seed evaluation networks in 2011-2019. Only the two best hybrids for each category, colour and mega-environment were selected for comparison, given that only the top one or two commercial multinational checks are used in the MasAgro seed trials network each year. The number of Private MasAgro hybrids and Open Pollinated varieties (OPVs) in the MasAgro multilocation trials was too little to be included in the analysis. OPVs were also excluded to ensure that the comparison included only maize hybrids.

Subsequently, the GY of MasAgro, Public, Private national and Multinational hybrids was compared across all years (2011-2019) for each colour – yellow and white maize – and agro-climatic zone – subtropics, tropics and highlands – using ordinary least-squares (OLS) regression.

The linear multiple regression model used was:

$$GY_i = \beta_0 + \beta_1 ORI_i + \beta_2 ORI_i * MEGA_i * COL_i + \beta_3 Year_i + \varepsilon_i$$

where:

GY_i = is the grain yield response (t/ha) of the *ith* hybrid.

β_0 = is the intercept.

$\beta_1 ORI_i$ = is the origin of the *ith* hybrid (1= MasAgro, 2=Multinational, 3=Private National, 4= Public).

$\beta_2 ORI_i * MEGA_i * COL_i$ = is the interaction between origin, mega-environment (1=Highlands, 2= Subtropical, 3= Tropical) and colour (1=White, 0=otherwise) for the *ith* hybrid.

$\beta_3 Year_i$ = is the evaluation year of the *ith* hybrid.

ε_i = is a random error assumed to be *i.i.d.* and normally distributed.

[13] The MasAgro seed marketing survey is an annual survey administered to project-affiliated seed businesses to monitor the uptake and commercialization of MasAgro hybrids by affiliated firms. The number of seed companies that responded to the seed marketing survey each year was: 2013 (n=30), 2014 (n=24), 2015 (n=39), 2016 (n=42), 2017 (n=42), 2018 (n=52), 2019 (n=59).

GY values for each hybrid category (ORI) and colour (COL) in each mega-environment (MEGA), the mean differences, and p-values were calculated using margins and pairwise comparisons. Margins with pairwise comparisons yield the differences of the means across categorical variables along with significance tests and confidence intervals for the means, a feature that is not obtained from the linear regression results alone. In both cases, for the regression and the pairwise comparison, we added an interaction effect between the categorical predictors (ORI $*$ MEGA $*$ COL) to measure the difference in mean differences among the different categories. The analysis was performed using STATA 17.

3.4.2. Hybrid uptake and variety turnover

To assess the capacity of sampled companies to use and commercialize new seed innovations developed by MasAgro maize we used four indicators of the consortium firms' performance as suggested by Cucculelli and Ermini (2012) and OECD/Eurostat (2018). These indicators are 1) the number of new-to-firm, new-to-product portfolio seed varieties introduced into the market by seed companies, 2) the number of follow-on products developed by seed companies using MasAgro lineage (Private MasAgro hybrids), 3) sales of new MasAgro products relative to the total firm's sales, and 4) product portfolio turnover for the period 2011-2019. New-to-firm, new-to-product portfolio refers to varieties introduced by a firm for the first time into its portfolio of seed varieties but likely already sold in the market by another company.

Data on MasAgro seed companies were obtained from three different sources. The first was the annual MasAgro seed marketing survey (CIMMYT, 2019a) administered from 2013 to 2019 to project affiliated seed businesses. The second was a cross-sectional survey of 39 MasAgro seed companies in 2015 (the MasAgro germplasm impact survey) (CIMMYT, 2015). These datasets were combined into an Excel database of 38 companies having a minimum of six to seven years of variety-wise sales information. To these 38 firms, a survey (the Product portfolio survey) was distributed in 2020 to cover existing information gaps, especially the 2011-2013 seed sales, company size and the product's first year of introduction to the market. Out of all firms contacted, seven did not respond to the product portfolio survey. Therefore, we obtained a sample of 31 companies with information on seed sales disaggregated at the variety level. Where necessary, information about the variety's characteristics was obtained from data retrieved from seed companies' websites and promotional leaflets.

3.4.3. Hybrid commercialization and MasAgro maize effect on the seed industry

Information on seed sales by our sample companies was complemented by seed production statistics provided by authorities of the National Seeds Inspection and Certification Service (SNICS)

agency (SNICS, 2019). These data contain variety-wise sales information on national companies not participating in MasAgro and all multinational firms operating in Mexico for the autumn-winter (OI) 2010/11-2014/15, OI 2018/19 and spring-summer (PV) 2011-2015 and 2018-19 seed production seasons (sales years 2011-2015 and 2019)[14]. With these data and the information collected from the MasAgro seed marketing survey (n=31 OI 2010/11-2018 and PV 2011-2019) (CIMMYT, 2019a), we assembled a final database showing detailed seed production and sales figures for the entire maize seed industry for our study period.

These data have two limitations: 1) not all national companies register their seed production with the SNICS, a drawback that was compensated by the inclusion of variety-wise information on domestic companies available from MasAgro, and 2) variety-wise information on OI 2015/16 and PV 2016 (2016 sales year), OI 2016/17 and PV 2017 (2017 sales year) and OI 2017/18 (part of 2018 sales year) for non-MasAgro companies are missing: therefore, the market shares for these years contains some estimations. Despite these limitations, we consider these data as a unique dataset, given the difficulties of collecting variety-wise production or sales statistics from the private sector[15].

Finally, using the classification of hybrid maize described in 3.4.1, we estimated the market share of different actors in the maize seed industry for the period 2011-2019. Seed imports and exports, attributed to multinational companies were used to adjust seed sales of multinational firms using official statistics from the Mexican Ministry of Economy 2011-2019 (Secretaría de Economía, 2019).

3.4.4. MasAgro seed companies sample description

We classified sampled companies (n=31) into three groups based on 1) maize seed sales, as medium (≥ 1,000-5,000 t of seed sales), small (≥ 200-1,000 t) and micro enterprises (<200 t); 2) the number of employees, following the guidelines of the North American Industrial Classification of Economic Activities (SCIAN)[16], and 3) breeding research capacities, i.e., whether the firm had an established breeding research programme and its product' portfolio reflected this by recording its own proprietary hybrids. For example, some firms showed year-on-year fluctuations below or above our sales size thresholds. If a firm had the minimum number of employees required to be classified as

[14] The commercial seed of a company in year *i* is produced in two seasons: autumn-winter (OI) and spring-summer (PV). For example, the 2011 commercial seed was produced in OI 2010 and PV 2011.

[15] Although variety-wise information on OI 2015/16 and PV 2016 (2016 sales year) was also unavailable, the figures were available in aggregated version.

[16] The North American Industrial Classification System (SCIAN) is used by the government to classify its economic activities and businesses and generate statistics and economic measurements to compare its economic activity with Canada and USA. It is widely used and recognized by the National Institute of Geography and Statistics (INEGI). It distinguishes four businesses sizes based on its number of employees: micro enterprises (1-10 employees), small (11-30 employees), medium (31-100 employees) and large (200-251 employees).

medium or small according to the SCIAN and showed sales fluctuations, the number of proprietary or public hybrids in its product portfolio was verified. If the firm had mostly private varieties in its product portfolio, it was classified as medium in size. This was the case with two relatively well-known companies with established breeding capacities but high sales fluctuations. If the firm depended mostly on public hybrids or had no private varieties, it was classified as small.

Table 4 shows our final sample composition and relevant descriptive statistics. Micro enterprises comprise more than half of the seed firms sampled. Medium companies have been in the market for almost twice as long as small and micro seed businesses. They employ four times more staff than small firms and ten times more than micro enterprises, with similar trends for the mean seed firm sales. Medium seed companies account for the largest share of sales (54%), whereas small businesses participate with 29% and micro with 17%. From the product portfolio composition (maize varieties by germplasm type), it is evident that medium-sized companies have more proprietary hybrids, unlike small and micro seed firms that depend largely on public materials to sustain their portfolios.

Table 4. Overview of MasAgro maize sampled seed companies (n=31).

Company size	Firms	Mean years in operation	Mean number of employees	Mean seed sales (2011-2019)		Maize varieties by germplasm type (%)		
				t	%	Private	Private with public[1]	Public[2]
Medium	5	26.2	82.6	5,954	54.2	41.1	21.2	37.7
Small	8	14.9	22.9	3,183	29.0	6.6	11.6	81.8
Micro	18	14.6	8.2	1,840	16.8	14.6	10.1	75.3
Total/average	31	16.5	24.5	10,977	100.0	20.8	14.3	64.9

[1] Own proprietary hybrids containing one or more inbred lines or improved populations from CIMMYT.
[2] Includes hybrids developed in CIMMYT for MasAgro.
Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author).

As in our sample, the national maize seed industry in Mexico is predominantly composed of micro-enterprises, a lesser number of small seed businesses and a few medium-sized firms. None of the national seed businesses operating in Mexico is considered large (>5,000 t of seed sales). Only multinational companies such as Bayer-Monsanto and Corteva Agriscience fall into this group, while Syngenta is considered medium. We estimate that MasAgro affiliated companies account for approximately 85-90% of the total market share captured by national companies. Our sample (n=31) represents about 62% of maize seed sales of MasAgro affiliated businesses and nearly 60% of sales of domestic companies in the maize seed industry.

3.5. Results

3.5.1. Hybrid development

3.5.1.1. Variety releases

MasAgro maize developed a total of 226 maize hybrids and OPVs during 2011-2019 for allocation to private companies. Varieties developed were predominantly three-way white hybrids for the tropics (39%), highlands (35%) and subtropics (26%). OPVs accounted for a small proportion of varieties developed (Table 5). Considering the figures of maize variety releases of the SNICS (2020), the number of MasAgro hybrids developed substantially outstrips the total of hybrids generated by multinational seed companies during the last ten years and is nearly double the number of varieties released by INIFAP in the last 30 years (see Espinosa *et al.*, 2010). MasAgro maize similarly developed a greater number of seed varieties than INIFAP and the other public NARs together, in a significantly shorter period of time (Figure 9). During the period 2011-2019, MasAgro and multinational companies were the main sources of maize seed varieties in Mexico (Figure 10). Affiliated companies generated a total of 32 private hybrids using MasAgro lineage.

Table 5. MasAgro hybrid maize release records, 2011-2019.

Mega-environment	Hybrids developed	Cross-type					
		Single		Triple		OPVs	
		White	Yellow	White	Yellow	White	Yellow
Subtropical	60	4	8	29	19	-	-
Tropical	87	15	14	30	25	3	-
Highlands	79	9	6	27	24	12	1
Subtotal		*28*	*28*	*86*	*68*	*15*	*1*
Total	226		56		154		16

Source: MasAgro seed evaluation network 2011-2019 (CIMMYT, 2019b).

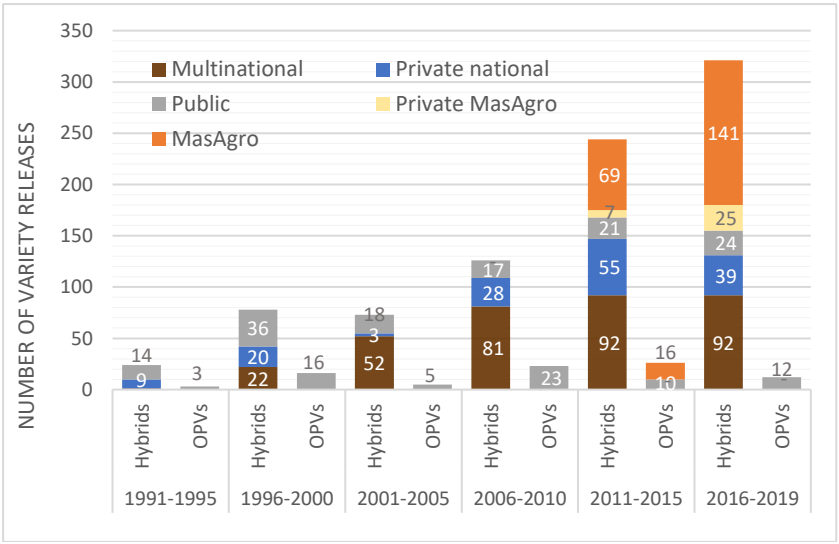


Figure 9 | Maize seed variety releases in Mexico, 1991-2019. Source: CNVV, last updated 7-September-2020 (SNICS, 2020); MasAgro seed evaluation network 2011-2019 (CIMMYT, 2019b); MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a).

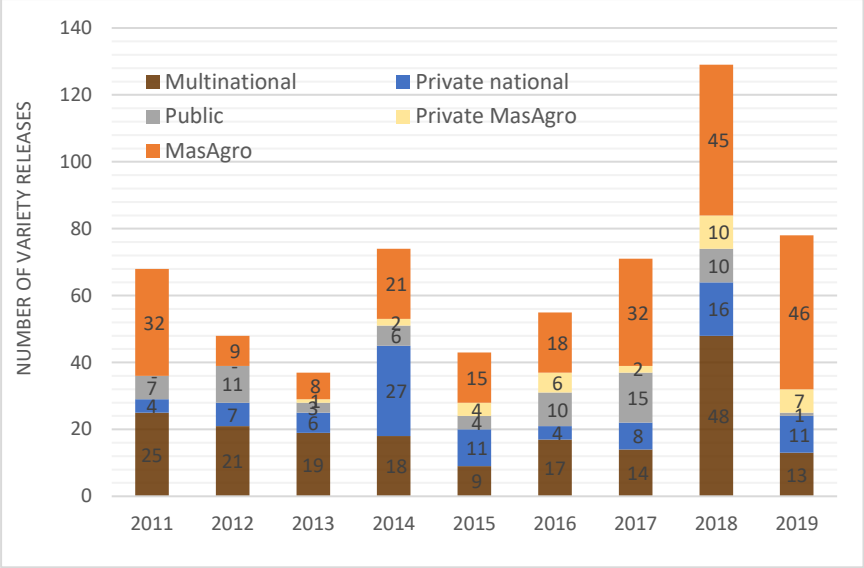


Figure 10 | Maize seed variety releases by CIMMYT for MasAgro, public NARS, national and multinational seed companies, 2011-2019. Source: CNVV, last updated 7-September-2020 (SNICS, 2020); MasAgro seed evaluation network 2011-2019 (CIMMYT, 2019b); MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a).

3.5.1.2. Variety performance

Figure 11 shows the mean GY (t/ha) of white and yellow MasAgro hybrids compared to multinational, private national and public hybrids tested in the MasAgro seed evaluation network in 2011-2019. GY mean results, GY differences, and p-values obtained from margins pairwise comparisons across categories are shown in Appendix B, Table B1. Only a few private MasAgro hybrids have been tested in the MasAgro network, so they are excluded from this analysis.

Overall, subtropical hybrids showed the highest GY (8.34 t/ha white and 7.99 t/ha yellow) among all mega-environments. In this mega-environment, multinational white and yellow hybrids maintained a slight yield advantage over MasAgro of about 0.5 t/ha and 0.8 t/ha ($p<0.05$) respectively. Private national materials similarly showed higher yields than MasAgro although differences between yellow hybrids were too small and not significant. Public hybrids had the lowest mean GY. Multinational and national companies were established more than fifty years ago in the subtropical states of West and Northern Mexico while the CIMMYT subtropical breeding programme was discontinued in 2010 and re-started operations with MasAgro. This helps to explain the advantage of private varieties over MasAgro.

In the Highlands, MasAgro white hybrids had the highest yield (7.01 t/ha) followed by private national, public and multinational hybrids, but no significant differences was observed. For yellow maize, multinational hybrids had the highest yield (6.62 t/ha), but there was no significant difference with MasAgro and private national materials. Public hybrids yielded significantly less than MasAgro

(0.8 t/ha p<0.01), multinational (1.1 t/ha p<0.05) and private national (0.6 t/ha ns) hybrids. Finally, white and yellow MasAgro hybrids in the Tropics outperformed all other categories with an average GY of 7.09 t/ha and 6.41 t/ha respectively. White MasAgro hybrids yielded on average 0.6 t/ha more than private national (p<0.05) and public varieties (p<0.01). Yellow MasAgro hybrids had 0.8 t/ha (p<0.01) more than private national hybrids. For both white and yellow hybrids, there was no significant difference between tropical MasAgro and multinational hybrids.

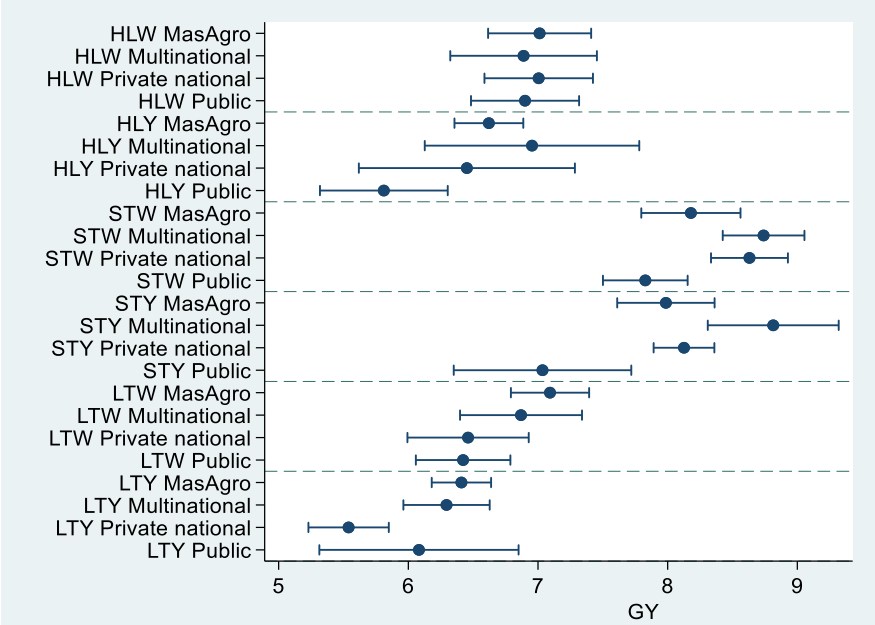


Figure 11 | Average grain yield (t/ha) regression results of MasAgro, multinational, private national and public hybrids evaluated in the Highlands (HL), Subtropical (ST) and Tropical (LT) MasAgro seed evaluation networks in 2011-2019. R-squared= 0.7037, Root MSE= 0.7800. Bars capture 95% confidence intervals. W=White, Y=Yellow. Source: MasAgro seed evaluation network (CIMMYT, 2019b).

The large number of recently released hybrids from MasAgro represented an opportunity for domestic seed firms to modernize their seed offering and expand their market shares. We next examine the uptake and commercialization of MasAgro hybrids by the consortium companies in the sample (n=31) and the impact of the introduction of MasAgro hybrids on the product portfolios and seed sales composition of these companies.

3.5.2. Hybrid uptake and variety turnover

3.5.2.1. Product portfolios composition

Multinational hybrids are not MasAgro hybrids and are therefore excluded from the analysis of the uptake of varieties by sampled companies. In 2019, our MasAgro sampled companies sold a total of 322 commercial maize seed varieties, more than double the number of varieties they sold in 2011 (Table 6). Out of the 322 maize seed varieties, 121 were MasAgro (37%), 94 were public (29%) mostly from INIFAP, 85 were private national (26%) and 22 were private hybrids developed by seed

companies from MasAgro lineage (6.8%). Note that the same MasAgro hybrid may be sold under different brand names/nomenclatures by different consortium companies. Similarly, the same public variety can be sold by two different companies but under the same name/nomenclature. That said, all the MasAgro varieties derive from 41 MasAgro hybrids; Public varieties came from 44 varieties developed by INIFAP and 9 developed by other public research institutions. Overall, the number of products in the consortium companies' portfolios has increased since 2011, notably MasAgro and private national hybrids.

In terms of sales, sampled companies increased their seed sales almost threefold (Table 6). MasAgro hybrids and Private MasAgro hybrids showed year-on-year increases since 2012, representing 22% and 7.3% of seed sales by 2019. Sales of private national hybrids remained at an average of 52% of total sample sales and the share of public varieties fell sharply from 53% in 2011 to 27% in 2019.

Table 6. Product portfolio composition of maize varieties and composition of maize seed sales by seed category, 2011-2019 (n=31).

Seed category	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Products in portfolio								
MasAgro	-	3	8	31	53	82	81	92	121
Private MasAgro	-	-	1	2	3	10	12	23	22
Private national	56	63	59	64	68	84	80	87	85
Public	88	108	115	97	104	91	89	90	94
Total	***144***	***174***	***183***	***194***	***228***	***267***	***262***	***292***	***322***
	Percentage of sales[1]								
MasAgro	-	0.05	0.46	7.52	12.72	12.12	15.56	12.83	22.07
Private MasAgro	53.53	52.28	34.96	37.31	31.26	30.39	29.05	24.56	27.27
Private national	46.47	47.67	64.27	53.00	55.65	55.63	52.37	53.60	43.41
Public	-	-	0.31	2.17	0.37	1.86	3.03	9.00	7.26
Total	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***
Total sales (t)	**5,019**	**6,002**	**9,953**	**12,090**	**11,832**	**12,618**	**12,090**	**12,250**	**13,589**

Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author). [1]Percentage of sales refers to each category of seed sales relative to total sales of sampled companies.

Seed sales of our sampled companies consisted predominantly of white (79%) three-way (66%) hybrids (88%) for the subtropical (49%), tropical (33%) and highland (19%) markets. In Appendix C, Supplementary Tables C1-C3 show the number of maize varieties and the percentage of seed sales by product type (hybrid or OPV), mega-environment and company size. The number of hybrids in companies' portfolios almost tripled while OPVs remained stable during the study period. The share of OPVs, in number and percentage of seed sales, decreased from 28% to 8%, in contrast to hybrids, whose share expanded from 72% to 92% (Appendix C, Table C1). The number of products by mega-environments more than doubled in all categories but sales of subtropical hybrids still accounted for

most of the total sales by 2019, suggesting companies did not move from their traditional subtropical markets toward markets for tropical and highland varieties (Appendix C, Table C2).

Finally, Appendix C, Table C3 shows details by company size and seed category. Medium-sized firms relied mostly on their own hybrids, with an average of 84% of seed sales over 2011-2019 coming from proprietary sources (private national and private MasAgro). MasAgro maize project leaders consider these companies have medium to high breeding capacities, therefore what they usually look for from public institutions are inbred lines to incorporate into their breeding programmes. Yet by 2019 they introduced up to 17 MasAgro hybrids, which represented 12% of their seed sales.

Small and micro seed businesses, in contrast, remained heavily dependent on public breeding research. Together, public and MasAgro materials represented around 76% of total products and sales for these companies over the study period. The number of public varieties in small companies' portfolios stayed approximately constant, but sales dropped from 84% to 40%. In contrast, they introduced up to 45 MasAgro hybrids, which by 2019 accounted for 28% of their seed sales. As for micro seed businesses, the number of public varieties increased from 40 in 2011 to a maximum of 58 in 2013, which then decreased to 49 in 2019. Sales in this category declined from 73% in 2011 to 50% in 2019. These companies introduced 59 new hybrids from MasAgro (almost half out of the total 121), which by 2019 accounted for 35% of their seed sales. In terms of the introduction of new proprietary hybrids, there were signs of innovation activity among all company groups. Nevertheless, although proprietary hybrids increased, sales of these hybrids dropped among medium and micro-enterprises.

The results of this section show that 1) medium, small and micro seed companies successfully incorporated new MasAgro hybrids into their portfolios and replaced OPVs with new hybrids; 2) small and micro seed firms still depended to a great extent on public varieties over the study period, and 3) the number of private varieties developed from MasAgro lineage accounted for a very small share of seed sales of consortium companies, reflecting the limited success of the PPP in stimulating follow-on variety innovations among SMEs. As observed from the year-on-year increases in the number of private hybrids, the provision of inbred lines at no cost and royalty-free to seed companies has not disincentivized R&D investment amongst domestic seed companies owing to as suggested by Donnet *et al*. (2017b unpublished communication).

3.5.2.2. Product portfolios turnover

Figure 12 shows the number of seed varieties in sampled companies' portfolios by germplasm source and year of introduction to the market. Over the study period (2011-2019) a total of 532 seed varieties were sold. MasAgro and private national hybrids represented on average 56% and 19% respectively of the products introduced in the last six years (2014-2019). On the other hand, the products launched between 2011 and 2013 and earlier were mainly public (56%) and private national varieties (40%).

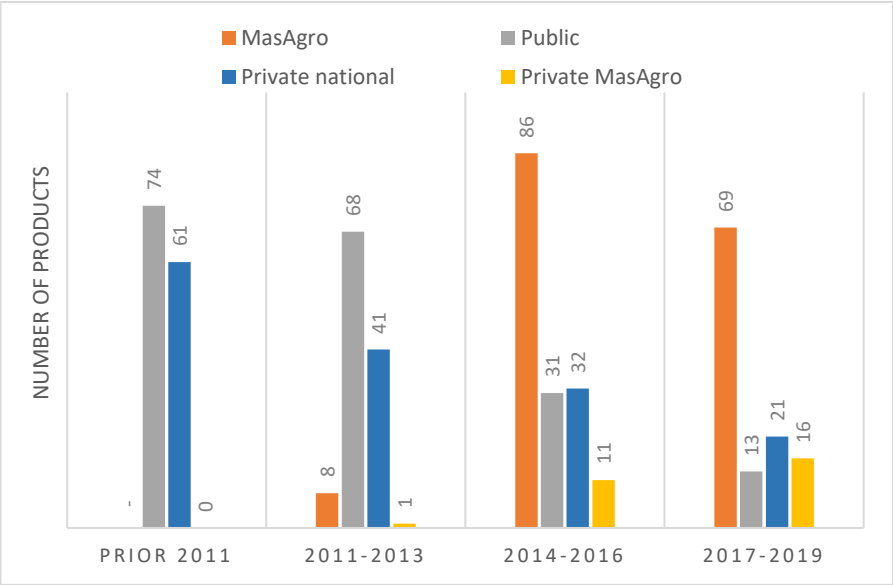


Figure 12 | Product portfolio composition of maize varieties by germplasm source and year of introduction to the market, 2011-2019 (n=31). Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author).

The number of seed varieties in product portfolios and the percentage of sales by the age of varieties for 2011-2019 are shown in Table 7. The number of products in all age groups increased as a result of product portfolio expansion. The share of seed sales of varieties aged over 9 years increased from 20% in 2011 to 32% in 2019. On average, varieties older than 9 years represented about 30% of the total varieties in product portfolios during the study period. In terms of seed sales, in 2011 varieties launched in the last three years accounted for 10%. By 2019, varieties introduced in the previous three years accrued a 20% share. Varieties aged 4-9 years accounted for the largest share of seed sales by sampled companies.

Overall, these results indicate that 1) participation in MasAgro allowed consortium companies to maintain a more diverse and renewed portfolio of seed varieties, but old cultivars were not completely replaced and sales of products older than 9 years were still persistent, and 2) as

consortium companies sourced their varieties mainly from MasAgro and their own breeding efforts, the introduction of new public materials into product portfolios in the last six years lagged.

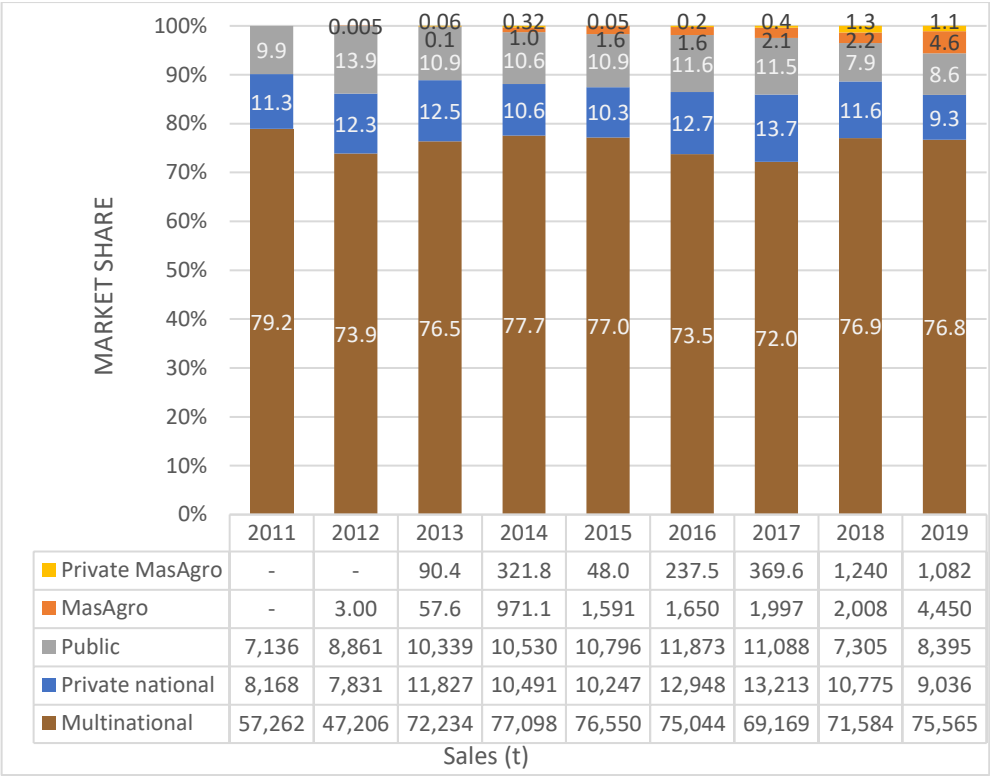
Table 7. Product portfolio composition of maize varieties and composition of maize seed sales by varieties' year of introduction to the market, 2011-2019 (n=31).

Variety age	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Products in portfolio								
0-3 years	38	72	91	43	85	133	34	60	103
4-6 years	54	54	44	59	61	56	102	114	104
7-9 years	37	34	30	47	35	33	52	50	53
10-12 years	6	6	6	28	28	25	33	30	29
15 years	2	2	4	7	5	5	23	21	20
>15 years	7	6	8	10	14	15	18	17	13
Total	***144***	***174***	***183***	***194***	***228***	***267***	***262***	***292***	***322***
	Percentage of sales[1]								
0-3 years	10.18	18.76	30.67	12.84	21.81	21.49	3.00	8.55	20.39
4-6 years	41.73	43.97	24.76	21.65	33.24	37.84	24.17	27.54	25.00
7-9 years	27.97	18.02	12.30	29.55	13.35	15.73	35.06	26.73	22.67
10-12 years	4.79	1.19	2.81	11.43	11.19	9.37	13.71	15.63	13.33
15 years	6.22	5.20	6.63	1.60	1.74	1.05	9.68	8.86	10.12
>15 years	9.12	12.85	22.82	22.93	18.68	14.53	14.38	12.69	8.48
Total	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***
Total sales (t)	**5,019**	**6,002**	**9,953**	**12,090**	**11,832**	**12,618**	**12,090**	**12,250**	**13,589**

Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author). [1]Percentage of sales refers to each category of seed sales relative to total sales of sampled companies.

3.5.3. Hybrid commercialization and MasAgro maize effect on the seed industry

Figure 13 shows market shares of MasAgro, private MasAgro, public, private national and multinational hybrids obtained from seed production and sales figures for the entire maize seed industry in Mexico for the period 2011-2019. As of 2019 forty-eight affiliated seed companies commercialized forty-seven MasAgro and thirty-two private MasAgro hybrids. By 2019 these hybrids accounted for 5.7% of total maize seed sales. All other seed categories experienced a slight decline in market shares between 2011 and 2019: public varieties dropped from 9.9% to 8.6%, private national from 11.3% to 9.3% and multinational from 79.2% to 76.8%. Nevertheless, multinational hybrids consistently maintained their leadership in the maize seed market, accounting for roughly 77% of total maize seed sales.



	2011	2012	2013	2014	2015	2016	2017	2018	2019
Private MasAgro	-	-	90.4	321.8	48.0	237.5	369.6	1,240	1,082
MasAgro	-	3.00	57.6	971.1	1,591	1,650	1,997	2,008	4,450
Public	7,136	8,861	10,339	10,530	10,796	11,873	11,088	7,305	8,395
Private national	8,168	7,831	11,827	10,491	10,247	12,948	13,213	10,775	9,036
Multinational	57,262	47,206	72,234	77,098	76,550	75,044	69,169	71,584	75,565

Sales (t)

Figure 13 | Market shares of MasAgro, private MasAgro, public, private national and multinational hybrids in the Mexican maize seed market, 2011- 2019. Source: multinational from SNICS official seed production statistics 2011-2019 (SNICS, 2019) and official import and export data from the Mexican Ministry of Economy 2011-2019 (Secretaría de Economía, 2019); private national and public from MasAgro seed marketing survey 2013-2019 (CIMMYT, 2019a) and SNICS official statistics 2011-2019 (SNICS, 2019); MasAgro and private MasAgro from MasAgro seed marketing survey 2013-2019 (CIMMYT, 2019a).

Domestic seed companies participating in the consortium received a strong stimulus from MasAgro maize and the changes introduced to the maize seed industry. During our study period (2011-2019) the growth in seed sales by sampled companies was 34%. Sales of micro seed firms grew 46%, those of small firms 18% and medium firms 16%. The maize seed industry grew at an average annual rate of 3.9% over the same period.

In the context of the objectives of the MasAgro maize programme, the MasAgro hybrids' market share in 2019 represented 0.27 M additional ha planted to new CIMMYT-germplasm based hybrids or 0.44 Mha if assessed from the additional seed produced by partners companies in 2019 compared to their 2011 seed sales[17]. This suggests that the programme fell considerably short of its objective of increasing the area planted to improved maize hybrids by 1.5 to 3.0 Mha. According to official statistics of SIAP (2020a), maize production increased 9.6 MT (6.6 MT in irrigated and 3.0 MT in

[17] i.e., in 2019 sales of MasAgro hybrids amounted to 276,558 seed bags which at a rate of 1 bag/ha, would cover 0.27 Mha with MasAgro hybrids. Alternatively, in 2019 affiliated companies sold an additional 441,576 bags of hybrid maize compared to their sales figures in 2011: in other words, an area of 0.44 Mha was sown with improved varieties produced by MasAgro companies.

rainfed areas) from 2011 to 2019. On the other hand, the average grain yield increased from 2.4 to 4.1 t/ha (1.6 to 2.5 t/ha in rainfed zones). If assessed by total area (irrigated and rainfed), the objectives of improving maize production by 5-9 MT and increasing maize yields from 2.2 to 3.7 t/ha were met. However, production and yield increases depend on many factors and there is no evidence to attribute such productivity increases to MasAgro[18].

Finally, one of the MasAgro maize objectives was to develop a strong and diverse national maize seed sector. It was expected that the provision of direct access to elite breeding material, finished varieties and training in modern breeding technologies would enable seed companies to develop their own breeding capacities. Affiliated companies developed thirty-two hybrids using MasAgro lineage, suggesting some degree of spillover from public R&D to the private sector, but overall, the follow-on plant breeding capacity of domestic firms sampled appears to have been limited.

3.6. Discussion

Our analysis shows that the direct transfer of elite breeding materials and finished maize hybrids directly by CIMMYT to domestic seed companies was very successful in generating a large number of agronomically competitive commercial hybrids between 2011 and 2019. The number of hybrids brought to the market through MasAgro substantially outstripped the total of hybrids generated by multinational seed companies during the same period and was nearly double the number of varieties released by public breeding research institutions in the last thirty years. Across several years of multilocational variety trials, MasAgro hybrids out-yielded public, private national and private multinational white and yellow seed varieties in the Tropics and the Highlands. Seed companies responded positively by successfully incorporating new hybrids into their seed offering and into the market. The project was of special relevance for small (≥ 200-1,000 t sales) and micro seed companies (<200 t), which in 2019 introduced 50% and 37% respectively of the total hybrids developed by MasAgro maize.

The commercialization of a large number of competitive varieties within a relatively short time shows that MasAgro maize was successful in leveraging CIMMYT's strength in plant breeding with the marketing agility of domestic seed firms in the private sector. Specifically, the consortium provided seed companies with 1) a wider, direct and continuous access to breeders' seed and advanced germplasm generated by CIMMYT breeding programmes adapted to target specific environments and local markets; 2) prompt and opportune access to quality foundation seed; 3) training and transfer of seed production technology; and 4) support in product portfolio design as well as the ability to brand public CIMMYT germplasm-based hybrids. These key elements were

[18] Note that yield increases could have similarly been due to the efforts of multinational companies.

supported by a targeting and segmentation strategy to orient sales towards areas with the lowest yield and greatest immediate potential impact to encourage rapid dissemination of new hybrids.

Despite the successful adoption of new MasAgro hybrids by seed companies, by 2019 a fifth of the varieties in the consortium firms' product portfolios, representing 32% of their seed sales, were over 9 years old. Older varieties were mostly hybrids from private national companies (45%), public hybrids (36%) and public OPVs (19%). The retention of a substantial share of older varieties in product portfolios may reflect the challenges that seed firms face in scaling up the production of seeds of new varieties, and in popularizing and marketing new seeds among farmers when yield and agronomic advantages over their usual seeds are only slight (Witcombe *et al*., 1998). Where hybrid seeds are concerned, firms may also face a steep learning curve in switching to the production of complex new hybrids. Assured and relatively stable markets for existing hybrids that are popular among farmers may also reduce the incentives for seed firms to bring about rapid variety turnover (Atlin *et al*., 2017). However, the experience of MasAgro maize shows that small firms have the willingness and capability for rapid introduction of new hybrids when access to elite material and foundation seed is guaranteed along with technical training for seed production and enabling seed policies, even in concentrated markets with fierce competition from multinational seed companies.

MasAgro appears to have brought about a significant shift away from public varieties among participating seed firms towards MasAgro hybrids. Although INIFAP and other research institutions continued to develop improved seed varieties at approximately the same pace as during the previous twenty years (SNICS, 2020), variety sourcing from public national institutions dropped by more than 80% (Figure 12). Besides, none of the public maize varieties released by NARS in the last ten years appears to have been taken up by the consortium seed companies. This is a matter of concern for the development of the domestic seed sector in Mexico for two reasons. Firstly, because micro and small seed companies do not have the research capacity to develop their own proprietary hybrids. This means that SMEs will continue to be dependent on external sources of germplasm and hybrids and may not be able to sustain their growth if interventions such as MasAgro are no longer available[19]. Secondly, because except for variety testing, the consortium largely worked independently of public institutions that historically led breeding research in the maize seed industry.

Finally, MasAgro maize made important contributions to reinvigorating the growth of domestic seed companies, but the programme appears to have fallen short of its overall objective of expanding the

[19] MasAgro was officially launched for a ten-year period (2011-2020) but 2019 was the last year of continuous regular funding. Since 2020 the project's funding, activities and continuity have been uncertain. In 2021 the programme was renamed Crops for Mexico.

area under improved varieties in rainfed regions. Very likely companies directed most of their efforts toward developed irrigated markets, where production increased 6.6 MT and yield incremented 4.4 t/ha compared to 3.0 MT and 0.9 t/ha in rainfed areas (SIAP, 2020a). This may reflect the reluctance of SMEs to move away from mature markets in irrigated zones and invest in emerging and potential rainfed maize seed markets. Another contributing factor may have been the lack of integration between MasAgro maize and the MasAgro farmer hubs. New hybrids developed by MasAgro maize would be tested in innovation hubs, the physical infrastructure designed by the MasAgro farmer component to facilitate the dissemination of new hybrids and other sustainable farming practices. The hubs included a research platform, where new technologies were tested and validated by scientists; farmer modules, where producers accompanied by a technician adopted and demonstrated the benefits of the new technology; and extension areas, where adopters in their own plots extended the use of innovations beyond farmer modules (see Camacho-Villa *et al*., 2016). The basic principle of the hubs was that all actors in the maize seed value chain could interact and create strategic networks and alliances facilitating long-lasting technology adoption processes. In the initial years of the consortium, the limited product uptake by seed companies could have prevented seed firms from interacting in the hubs. However, even in the last years of the consortium activities, there appears to have been little interaction between MasAgro maize and MasAgro farmer, and both components essentially worked independently of each other. The lack of integration between breeding and delivery systems, especially those involving downstream actors such as agro-dealers, extension agents and farmers, may have limited the uptake of MasAgro hybrids.

The experience of MasAgro maize highlights the challenges that PPPs face in accelerating variety development and delivery in the context of similar developing country seed systems. These constraints are, primarily:

a) The limited plant breeding capacity of small domestic seed firms that may restrict the potential for follow-on innovation using elite germplasm accessed from international and national research institutions such as CIMMYT or NARS. This may mean that SMEs remain perpetually dependent on external sources of germplasm for renewing their product portfolios.
b) The inability of SMEs, even when they are part of a collective consortium, to significantly increase their market shares in highly concentrated markets. Even when PPPs breeding programs deliver competitive new varieties and bring them to market, the dominant players in concentrated markets may retain their leadership and their market shares might remain largely unaffected.

c) The challenge of moving away from breeder-led interventions for variety improvements towards a much tighter focus on marketing and delivery. This breeder-led paradigm dominates seed sector interventions despite the recognition of the importance of marketing in seed systems development (Morris, 1996; Louwaars and De Boef, 2012; Donovan *et al.*, 2022). The key challenge for PPPs is marketing and delivering new hybrids in concentrated maize seed markets in head-on competition with global market leaders. This calls for moving away from the predominant breeder-led approach to make way for a marketing-oriented paradigm focusing on efficient seed delivery and a close examination of the marketing strategies of the leading market players.

3.7. Conclusion

The experience of MasAgro maize shows that the private domestic seed sector in developing country contexts can be an effective instrument for accelerated dissemination of crop variety innovations developed by international and national public sector research organizations. This is feasible if SMEs are supported on a sustained basis with access to elite germplasm, foundation seed, training and transfer of breeding technology in an enabling seed marketing and regulatory policy environment. However, while PPPs working with domestic private seed companies have strong capacities for developing and commercializing competitive crop varieties, they face significant challenges in marketing these innovations in highly concentrated markets. The case of MasAgro has shown that the development of competitive high-yielding hybrids alone is not enough to disrupt concentrated markets, capture market shares from global market leaders and promote sufficient competition in the seed industry. If PPPs are to succeed in their objective of advancing the development of formal maize seed systems and bringing affordable quality seed on a large scale to low-income smallholder farmers in developing countries, there is an urgent need to incorporate a commercial and marketing-oriented perspective along all steps of the plant breeding and dissemination process (Figure 7).

4. In-store seed purchasing decisions, implications for marketing and scaling hybrid maize seed sales through agro-dealers

"The marketer's task is to understand what happens in the consumer's consciousness between the arrival of the outside marketing stimuli and the ultimate purchase decisions" (Kotler and Keller, 2012).

4.1. Introduction

The CGIAR has a long tradition of breeding for crop improvement as a strategy for increasing maize productivity and global food security. The CGIAR centres in collaboration with public sector NARS have achieved exceptional advances in plant breeding since the "Green Revolution" in the 1960s and 1970s (Evenson and Gollin, 2003; Byerlee and Dubin, 2010; Renkow and Byerlee, 2010). During the last three decades, PPPs in the CGIAR have similarly played a crucial role in the development and delivery of improved hybrids. However, despite the successful development of competitive high-yielding, stress-tolerant maize seed varieties based on CGIAR breeding materials either through public NARS or PPPs (Edmeades, 2013; Cairns and Prasanna, 2018), new varieties developed struggle to achieve large-scale distribution and very often outdated varieties or hybrids from multinational companies dominate the maize seed market (see Spielman *et al*., 2014). This is despite the proven on-farm agronomic advantage of CGIAR-germplasm materials over commercial privately bred cultivars (Setimela *et al*., 2017; Worku *et al*., 2020) and the large investments made by governments and donors to promote the diffusion of improved seeds (Byerlee *et al*., 2002; Pardey *et al*., 2013).

In attempting to explain low adoption and slow variety turnover research has largely focused on the agronomic advantage and seed production aspects (Feder *et al*., 1985; Walker and Alwang, 2015) but have generally overlooked downstream issues such as marketing and the role of agro-input dealers in the promotion of improved seeds. Agro-dealers are a potentially important channel for achieving increased scale and efficiency in seed distribution (Rutsaert and Donovan, 2020). Agro-input dealers are for many smallholders in many developing regions the main source of improved seeds (Erenstein and Kassie, 2018; Access to Seeds Foundation, 2019). They are crucial in making new varieties available and supplying other inputs for crop production, as well as providing farmers with credit for input purchases, technical assistance and information about new technologies and agronomic practices (AGRA, 2017). They are also considered to be the first to receive feedback from farmers and to be well positioned to assess seed demand, influence farmers' seed choices or modify farmers' seed preferences (Ramaswami *et al*., 2009).

Over the last two decades, development organizations and donors (IFDC, 2015; USAID and IFDC, 2015; AGRA, 2017; AFAP, 2019; CNFA, 2021a) have widely promoted agro-dealers as a key instrument for encouraging private sector investments in efficient agro-input distribution networks. Strong agro-dealer networks are expected to support smallholder farmers' access to affordable high-quality seed, accelerate new technologies' transfer to farmers by strengthening technical knowledge about crop varieties, and support a significant increase in the demand for agro-inputs by stimulating the adoption of improved hybrids (IFDC, 2012; AGRA, 2017; IFDC, 2017). Through agro-dealers, many countries have established input subsidies voucher systems (Chinsinga, 2011; Odame and Muange, 2011a) linked agro-dealer initiatives to local seed industry development projects, and disseminated improved crop varieties among smallholder farmers (AGRA, 2017; CNFA, 2021b; CNFA, 2021c). For example, the National Accelerated Agricultural Input Access Program (NAAIAP) in Kenya and the National Agriculture Inputs Voucher Scheme (NAIVS) in Tanzania established subsidies voucher systems, while the West African Seed Alliance (WASA) and AGRA's Program for Africa's Seed Systems (PASS) integrated agro-dealer and seed industry development projects.

In Mexico, in line with seed industry liberalization reforms implemented in the 1990s, agro-dealer networks' development was left to the private sector. With the expansion and consolidation of multinational companies in the last three decades, it is reasonable to believe that larger companies are the main suppliers of agro-dealer shops and agro-dealers are primarily an outlet for market leaders' hybrids. This represents a barrier to entry for small and medium seed enterprises (SMEs) trying to consolidate their distribution networks and expand their seed sales through agro-dealer shops.

In the previous chapter, we observed how MasAgro hybrids outperformed white and yellow multinational, private national and public tropical hybrids tested in the MasAgro seed evaluation network during 2011-2019. MasAgro hybrids also outyielded or closely competed with multinational, private national and public varieties in the subtropics and the highlands. The MasAgro maize PPP was very successful in generating a large flow of agronomically competitive commercial hybrids and SMEs successfully incorporated those materials into their seed offering and into the market. However, by the end of the project in 2019, MasAgro hybrids had a modest market share of 5.7% whereas multinational hybrids continued to occupy 77% of the maize seed market.

This chapter examines whether agro-dealers account for one of the possible reasons for the limited market penetration of MasAgro hybrids and their inability to capture a significant market share despite their competitive or superior yield advantage. It examines the role of agro-dealers in influencing farmers' seed purchasing decisions and explores their potential and constraints for

achieving scale of new hybrids developed through PPPs and delivered by SMEs. The analysis focuses on three research questions:

1. How do farmers make decisions when purchasing seed from agro-dealers and how do agro-dealers influence farmers' seed decision-making?
2. How do agro-dealers engage with farmers and seed companies to promote and sell improved seeds?
3. What are the implications of the findings for marketing hybrid maize seed and expanding sales by SMEs?

The purpose of this chapter is to draw implications for the dissemination and expansion of sales of PPP varieties. The outline is as follows. Section 4.2 provides an overview of the role of agro-dealers in the dissemination of improved seeds. Drawing upon research on marketing, consumer behaviour retailing and technology adoption, section 4.3 reviews the factors affecting seed purchases and agro-dealers' influence on farmers buying decision-making. Although several factors can influence and explain farmers' purchasing decisions, the analysis focuses on two major aspects: 1) seed attributes and quality cues affecting buying behaviour and the marketing of hybrid maize seed, and 2) the effect of marketing stimuli and the in-store environment. Section 4.4 provides an overview of the study area and the context of this research. Section 4.5 explains the sampling and data collection methods. Section 4.6 presents the results. Section 4.7 discusses the implications of the findings for achieving a greater scale of improved seeds developed by PPPs and delivered by SMEs through agro-dealer networks; and section 4.8 is the conclusion.

4.2. Agro-dealers' role in the dissemination of improved seeds

Agro-dealer development programmes were first initiated in Africa in the early 2000s. After the successful implementation of Zimbabwe's Agro-dealer Programme (2000-2005) by Cultivating New Frontiers in Agriculture (CNFA), the model was established in Kenya, Mali, Malawi and Tanzania (CNFA, 2021a). Several countries built on CNFA's experience and supported by governments and international donors, agro-dealer development programmes became widespread across the continent. Since their inception, agro-dealer development programmes have emphasized one or more of the following components: 1) the creation of extensive agro-dealer networks to increase smallholder farmers' access to affordable high-quality inputs, 2) training agro-dealers in business management and technical knowledge of new crop varieties and other technologies to accelerate their transfer to farmers, 3) strengthening agro-dealers' capacity to create business linkages with suppliers and financial institutions to ensure access to inputs and credit, and 4) stimulating demand for improved inputs and production practices through promotion and marketing (AGRA, 2017; IFDC,

2017; CNFA, 2021b). Except for a small number of projects in Asia, development efforts for agro-dealers are concentrated in Africa[20].

Agro-dealers, or private input stores that sell improved seeds, crop chemicals, fertilizers and other farm implements to farmers, are seen as a key instrument for redefining the private sector's role in revitalizing agriculture and fostering the development of a private sector-driven input system (Chinsinga, 2011). Besides supplying agro-inputs, agro-dealers create linkages with other actors along the seed supply chain. On the one hand, they interact upstream with research centres, seed suppliers and financial institutions to ensure access to new technologies, inputs and credit. On the other hand, they interact downstream with seed companies, extension providers and farmers for the promotion and dissemination of new improved varieties (Odame and Muange, 2011b). The creation of agro-dealer networks is expected to create interest in inputs sector development and encourage private sector investments in efficient agro-input distribution systems. Well-functioning agro-dealers can similarly support a significant increase in the demand for agro-inputs and stimulate the adoption of new improved crop varieties (IFDC, 2012; AGRA, 2017).

Despite the key role of agro-dealers in expanding hybrid maize seed sales and accelerating varietal turnover within commercially oriented maize seed systems, very little rigorous analytical research has been made to understand how they support farmers in their decisions on which seed to purchase. Decision-making has been widely investigated in non-shopping situations and outside the store, consequently, neglecting the influence of agro-dealers on buying decision-making. In other sectors, such as food retailing, consumer engagement in in-store decision-making has received a substantial amount of attention (Inman *et al*., 2009; Bell *et al*., 2011). However, attempts to understand consumer decision-making in seed systems and agro-input stores are very limited. This is surprising, given the importance of agro-dealers as a means for the distribution of seeds and other agricultural inputs, and their long-standing use by large-scale companies to promote and sell hybrids.

There is also limited knowledge of how agro-dealers interact with other actors in the seed value chain for marketing improved maize seeds. Although for large agribusiness this might be a fairly clear matter, this knowledge gap persists, representing a major issue for smaller companies and the international development community when implementing projects intended to enhance the adoption of new hybrids. It is therefore also important to know how agro-dealers interact with seed

[20] See the Market Development in the Fertilizer Sector of Bangladesh - Katalyst I (IFDC, 2013), Agro-input Microfranchise Networks in Rural Bangladesh - Krishi Utsho (Akram, 2015), and the Dry Zone Agro-Input and Farm Services Project (IFDC, 2016).

companies and the firms' view of the use and potential of the retail space for the promotion and distribution of seed.

The evidence also suggests that the agro-dealer's store is not the main point where seed companies create awareness of seed varieties. Instead, companies use out-store marketing directed towards end-users through lead farmers, demonstration plots, field days and the radio to communicate with their seed-buying clients (Rutsaert and Donovan, 2020). In-store engagement of farmers with agro-dealers has also been found to be low. When entering the shop a few customers ask for information or pay attention to available seeds, and agro-dealers barely attempt to influence farmers' variety choices (Muindi and Adam, 2020; Rutsaert and Donovan, 2020). Farmers plan their seed purchases outside the agro-dealer (Muindi and Adam, 2020), highlighting the need for understanding in-store decision-making while accounting for other potential factors shaping farmers' decisions before they step into the shop.

4.3. Conceptual framework

4.3.1. Seed attributes and quality cues affecting buying behaviour and marketing

Consumers (farmers)' evaluation of quality is based on objective and subjective attributes[21]. As opposed to objective quality, which refers to the product's technical measurable excellence, subjective or perceived quality refers to the consumer's evaluation of a product's performance based on perceptions, feelings or beliefs (Olson, 1972; Zeithaml, 1988; Steenkamp, 1990). Subjective product evaluations can be better understood by distinguishing between search, experience and credence goods[22]. In search and experience goods, quality is observable either during the search process before purchase or after the purchase. In contrast, for credence goods quality is unobservable even after a purchase is made (Nelson, 1970; Darby and Karni, 1973; Auriol and Schilizzi, 2015). Typical examples of search attributes in hybrid maize seed are external physical characteristics such as price, brand, packaging, seed colour and seed size (usually specified on the package). Examples of experience attributes are the plant's aspect (height, structure), corncob size, cob coverage, lodging and rot resistance, drought tolerance, yield performance, and germination rate. Finally, credence attributes of hybrid maize include yield stability, safety and environmental impact associated attributes, the grain's nutritional value and the genetic material contained in the seed.

[21] The terms "farmers" and "consumers" are used interchangeably as purchasing seed is a consumer choice, even if seed is a production input rather than a consumer good (Auriol and Schilizzi, 2015).

[22] Search goods are products whose quality can be ascertained during the search process before purchase; experience goods are products whose quality can be judged only after purchase or experience; credence goods are commodities whose quality cannot be evaluated in normal use or even after consumption or experience but whose attributes have a perceived value for customers (Nelson, 1970; Darby and Karni, 1973).

The distinction between experience and credence attributes is not simple particularly, when the quality must be discerned during use but only after a considerable period of time, if the good is used in combination with other goods of uncertain quality (e.g. fertilizer or crop protection inputs) to produce a measurable output (e.g. grain), or in production processes in which the output depends on several interrelated factors (Darby and Karni, 1973). For example, in the case of a new high-yielding stress-tolerant maize hybrid a farmer can easily find out its price, but it is more difficult to determine its performance in response to specific soil conditions, crop management practices, unpredicted rainfall and potential pest and diseases outbreaks. Farmers will only discover the experience attributes of a seed by trialling. In addition, a farmer will be able to assess the cultivar's credence quality only after several years of continuous use under similar consistent biotic and abiotic conditions. In the event of a low rainfall year, the farmer will be uncertain whether the performance of the seed was owing to the lack of rain or the seed itself. Consequently, farmers will make inferences and create perceptions of quality based on available evidence or cues.

The salience of experience and credence attributes of improved hybrids makes it difficult for farmers to assess seed quality at the point-of-purchase. In markets of experience and credence goods, while quality is well known by the supplier, consumers often lack sufficient knowledge to assess whether the product will satisfy their needs. This information asymmetry (i.e., hidden, unavailable or non-existent reliable information for consumers about a product sold in the market) creates uncertainty and the need for seed suppliers to signal quality (Auriol and Schilizzi, 2015; Giannakas and Fulton, 2020; Gilligan and Karachiwalla, 2021) [23] on the one hand, and the use of quality cues by farmers to predict product performance on the other (Bearden and Shimp, 1982; Akdeniz *et al*., 2013).

Quality cues are information stimuli that can be learned before a product is purchased and are associated by consumers with a product's objective quality (Olson, 1972; Steenkamp, 1990). Olson (1972) classifies quality cues into extrinsic cues which are attributes related to a product but not inherent to it (e.g., price, brand) and intrinsic cues which are a product's indivisible characteristics providing a functional benefit (e.g., good yield). As in the distinction between search, experience and credence goods, intrinsic attributes in contrast to extrinsic cues are unobservable and may not be known before consumption or experience (Steenkamp, 1990). According to Zeithaml (1988) consumers depend primarily on intrinsic cues in the presence of search goods or when intrinsic attributes have a high perceived value. Consumers base their purchase decisions primarily on extrinsic cues when 1) quality is difficult to assess, as in the case of experience or credence goods, 2)

[23] Several mechanisms are used by suppliers to signal quality, for example warranties, certification, labelling (Auriol and Schilizzi, 2015; Giannakas and Fulton, 2020; Gilligan and Karachiwalla, 2021) and branding (Kim, 2012).

information about intrinsic attributes is unavailable or inadequate, or 3) consumers have time constraints or no interest in evaluating the intrinsic cues. When search cost is high, consumers may concentrate on one or two extrinsic cues that are easy to process, such as brand, price or package, and neglect other cues and quality attributes that could be learned before purchase. Besides, as consumers learn through experience, their information searching declines over time and they become more likely to engage in repeat purchases (Heiman *et al*., 2001). In repeat purchase situations, Hoyer (1984) suggests consumers rely on previous product information stored in memory but also on judgments of brand which occur in the postpurchase decision stages. Ultimately, farmers are consumers and are continuously exposed to stimuli from marketing and quality cues which affect their behaviour and buying decision-making.

Seed quality attributes also raise difficulties for seed companies marketing hybrid maize seed. This is especially a limiting factor in the retail space since as a result of the experience and credence quality of improved seeds, most quality assessments take place outside the store. The marketing of hybrid seeds is further complicated by their perishable quality. Any seed marketed in one year must have been produced the previous season and the supplier (the seed company or the agro-dealer) must sell out all stock (Burer *et al*., 2008) to avoid seed quality decline (mainly germination rates and seed health). In addition, sales usually take place once a year and the sales window is very short, ranging from one month to a maximum of three. This chapter argues that seed quality attributes largely shape the marketing strategies in the maize seed industry, and marketing stimuli and quality cues influence decision-making at agro-dealers' shops. Drawing on marketing research and the relatively recent small body of literature concerned with this subject in agricultural adoption and seed systems, the following section provides an overview of marketing tools used by seed companies for the promotion of hybrids, the role of the in-store agro-dealers' environment in marketing seeds and the effect of both on farmers' purchase decision-making.

4.3.2. Marketing stimuli and the in-store environment

Through marketing, seed producer companies communicate their offer and product attributes, facilitate learning about new hybrids, and encourage consumers to buy or adopt improved seeds. Table 8 shows the different marketing tools used in the maize seed industry for the promotion of hybrids. We classify these tools first as out-store and in-store according to where they mainly exert a stimulus. Out-store tools activate stimuli outside the store, making customers construct an idea of what they want to buy before stepping into the shop (Bell *et al*., 2011). In-store tools activate stimuli in the shop that trigger in-store decision-making and elicit unintended purchases (Inman *et al*., 2009). These tools are further classified as prepurchase, purchase and postpurchase marketing tools

according to the stage of the purchasing process where they have a major impact. To guide our analysis we consider an integrated view of the adoption and buying decision-making process drawn from the adoption (Pannell *et al*., 2006; Pannell, 2007; Weersink and Fulton, 2020), marketing and retailing (Puccinelli *et al*., 2009; Kotler and Keller, 2012) literature, which we divide into six different phases: awareness (or need recognition), information search through non-trial evaluation, information search through trial evaluation, adoption (or purchase decision), revision (or repurchase) and dis-adoption.

As shown in Table 8, most marketing tools used in the maize seed industry are out-store prepurchase information tools (demonstrations plots, seed samples, trade shows, salespeople, advertisement, brands) and only a few are in-store prepurchase (brands, price premiums), in-store purchase (packaging, seed displays, promotions, discounts) and out-store postpurchase (after-sales field visits). Some tools may play a role out-store as well as in-store or in one or more phases of the purchasing process. For example, brands provide information about quality that is accessible out-store and in-store and is essential before making a purchase decision, but equally important during the purchase and the postpurchase stages, e.g., in reducing search cost, signalling quality and maintaining loyalty.

Seed companies also use a combination of pull and push strategies. In a pull strategy, manufacturers directly communicate their offering to end-users through advertising, promotions and other types of communications to persuade consumers to seek the product in the store, so inducing retailers' demand. A push strategy uses the retail environment and offers incentives to channel intermediaries to carry, promote and sell the product to end consumers (Kopp and Greyser, 1987; Ailawadi *et al*., 2009; Kotler and Keller, 2012). In contrast to a push strategy, which is appropriate in markets with low brand loyalty, where the brand choice is made in the store, and product attributes are well understood, a pull strategy is used when consumers are brand loyal, can differentiate between brands and choose the brand before going to the shop (Kotler and Keller, 2012).

The seed industry relies heavily on pull marketing, as reflected by the number of out-store pre-purchase information tools and the size of the sales force deployed outside the store (field salespeople) to promote hybrids, but similarly on push marketing, given the provision of incentives (sales commissions) to agro-dealers to promote their brands in the store. It is worth noting that, despite the importance of marketing in the diffusion of hybrids, most tools categorized below (and how farmers react to their stimuli) remain undocumented in either the agricultural adoption or seed systems literature.

Table 8. Marketing tools in the maize seed industry and their main role in the promotion of improved hybrids.

Tool type	Marketing tool	Main role	Primary effect
Out-store marketing tools			
Prepurchase	Demonstration plots and field days.	Enable farmers to observe and learn about seed attributes and performance. Create awareness and stimulate curiosity.	Reduce prepurchase risk and uncertainty (Ert *et al*., 2016). Stimulate purchases.
	Seed samples	Facilitate initial trials (Heiman *et al*., 2020). Enable farmers to learn and experience before purchasing (Heiman and Hildebrandt, 2018).	Reduce prepurchase risk and uncertainty (Heiman and Hildebrandt, 2018). Increase demand (Ert *et al*., 2016). Enhance adoption and purchases (Bawa and Shoemaker, 2004; Heiman *et al*., 2001).
	Trade shows	Showcase and demonstrate products. Facilitate interaction between sellers and potential customers.	Increase firms' sales. Reduce prepurchase uncertainty.
	Field salespeople	Encourage purchases. Introduce new products into the market. Persuade farmers to try new seeds. Provide technical and sales training to seed retailers. Establish demonstration plots. Monitor after-sales performance.	Increase firms' sales. Ensure product performance. Create awareness. Increase customers' satisfaction and loyalty.
	Advertisement (radio ads, billboards)	Provide information about seed attributes, performance, prices, and location (Heiman and Hildebrandt, 2018). Persuade, create awareness (Sun, 2011). Tie desires to brands (Heiman and Hildebrandt, 2018).	Generate favourable emotions, influence farmers' attitudes, feelings, and decisions (Meyers-levy and Malaviya, 1999; Tellis, 2003). Create prestige and brand image (Ackerberg, 2001). Strengthen brand loyalty (Dick and Basu, 1994).
	Brands	Reduce risk (Heiman and Hildebrandt, 2018). Predict and guarantee product performance/quality (Kim, 2012).	Signal quality (Heiman and Hildebrandt, 2018).
Postpurchase	After-sales field visits	Monitor seed performance. Provide technical assistance.	Increase customers' satisfaction and loyalty.
In-store marketing tools			
Prepurchase	Brands	Reduce search cost and risk, increase trust (Kotler and Keller, 2012; Heiman and Hildebrandt, 2018).	Signal quality (Heiman and Hildebrandt, 2018). Simplify decision-making (Kotler and Keller, 2012).
	Price premiums	Increase trust and perceived value.	Signal quality (Grewal *et al*., 1998).
Purchase	Promotions, discounts	Encourage unexpected purchases (Inman *et al*., 2009). Increase perceived value (Grewal *et al*., 1998; Chapman and Wahlers, 1999).	Stimulate switching behaviour. Increase satisfaction (Chapman and Wahlers, 1999).
	Brands	Reduce search cost and risk (Kotler	Signal quality (Heiman and

		and Keller, 2012; Heiman and Hildebrandt, 2018).	Hildebrandt, 2018).
	Product packaging, seed displays	Provide information about product attributes. Demonstrate products. Encourage purchases.	Activate cues or reminders of out-store information and advertisement (Kotler and Keller, 2012).
	Sales commissions	Incentivize retail sales engagement. Encourage retailers' marketing.	Create retailers' loyalty.
	Advertisement (posters, leaflets, counter, floor and wall ads)	Provide information about seed attributes, performance and price (Heiman and Hildebrandt, 2018). Persuade, create awareness (Sun, 2011).	Generate favourable emotions, influence farmers' attitudes, feelings, and decisions (Meyers-levy and Malaviya, 1999; Tellis, 2003) Strengthen brand loyalty (Dick and Basu, 1994).
Postpurchase	Brands	Increase satisfaction (Kotler and Keller, 2012).	Maintain consumers' loyalty (Aaker, 2012).

Source: Author.

4.3.2.1. The role of agro-dealers

Finally, information gathered outside the store may be available in the consumer's memory but not accessible for recall without the proper retrieval cues or reminders. For this reason, in-store marketing is critical to influencing purchases. The information delivered by in-store marketing tools, and the reminders they provide of advertising or any other information already found outside the store, are key determinants of consumer decision-making (Kotler and Keller, 2012). The support of agro-dealers during the buying decision process is an in-store stimulus and therefore they should mainly play a role in the purchase decision and information search stages through their interaction with farmers in the shop. Depending on their engagement in demand creation activities, e.g., demonstration plots and field days, they can also influence awareness and information search stages outside the store.

4.4. The maize seed supply and distribution system in Mexico

In Mexico, the role of agro-input dealers in seed industry development has been largely overlooked by research and policymaking. From 1961 to 1990 plant breeding research, production and distribution of seed were carried out by the public sector (Morris, 1998). With the enaction of the 1991 seed law, the state transferred seed production and marketing functions to private companies, including the development of seed distribution and agro-dealer networks. To date, while the government maintains a role in maize breeding research and quality assurance, the production and distribution of seed is fundamentally a private sector activity.

According to official data sources, in 2018-2019 about 98-118 companies produced and commercialized certified improved maize seeds (SNICS, 2019; Córdova-Téllez, 2019). Producer

companies distribute their seed through a) agro-input dealers (33.5%), b) government offices which usually provide free seed to farmers (26.3%), c) directly to farmers through sales representatives and independent sales agents working on a commission basis (19.5%), d) directly to farmers through their own distribution outlets (16.7%), and e) producers' organizations or cooperatives and lead farmers (4.0%) (Figure 14) (CIMMYT, 2019a). A few companies are developing their distribution networks through lead farmers, although multinational companies such as Pioneer have presumably used this channel for over several years.

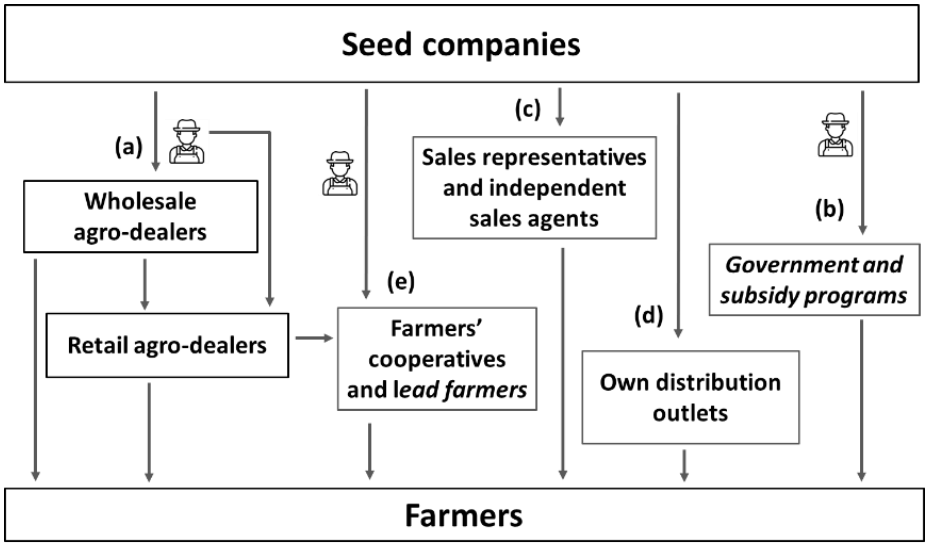


Figure 14 | Structure of the maize seed supply and distribution system in Mexico. = sales representatives. Source: Author, based on data of the MasAgro seed marketing survey, 2019 (CIMMYT, 2019b).

Seed supply and seed purchases at agro-dealers take place in a highly concentrated market. Following liberalization of the maize seed industry, the private sector increased its market share from 58% in 1991 to 87% in 1996 (Figure 15a). Multinational companies' seed sales rocketed to 70% in 1996 and have maintained, even increased, their leadership in the Mexican maize seed market for over the last thirty years. The maize seed industry has also become highly concentrated (Figure 15b). In 2019, two multinational companies (Bayer-Monsanto and Corteva Agriscience) accounted for over 75% of the Mexican maize seed market. One single firm (Bayer-Monsanto) captured 60% of seed sales, raising concerns about market power and monopoly pricing.

In fact, the price of improved maize seeds in Mexico is presumably the highest in the global maize seed market. Seed prices vary among regions and states, seed type and colour. However, the average retail price of a certified hybrid maize seed bag in Mexico is USD$ 106.6 (USD$ 5.6/kg). A bag produced by national firms is USD$ 82.7 (USD$ 4.1/kg) compared to USD$ 131.8 (USD$ 6.6/kg) for seed produced by multinational companies (SNICS, 2017a). In the USA, for example, a non-GM

maize seed bag cost USD$ 80 (USD$ 4.0/kg) (Hybrids SureFlex, 2021), while in Zambia the most expensive hybrid costs USD$ 60.8 (USD$ 3.04/kg) and in Zimbabwe farmers pay up to USD$ 28.4 (US$ 1.42/kg) for a bag of seed (Langyintuo *et al*., 2010).

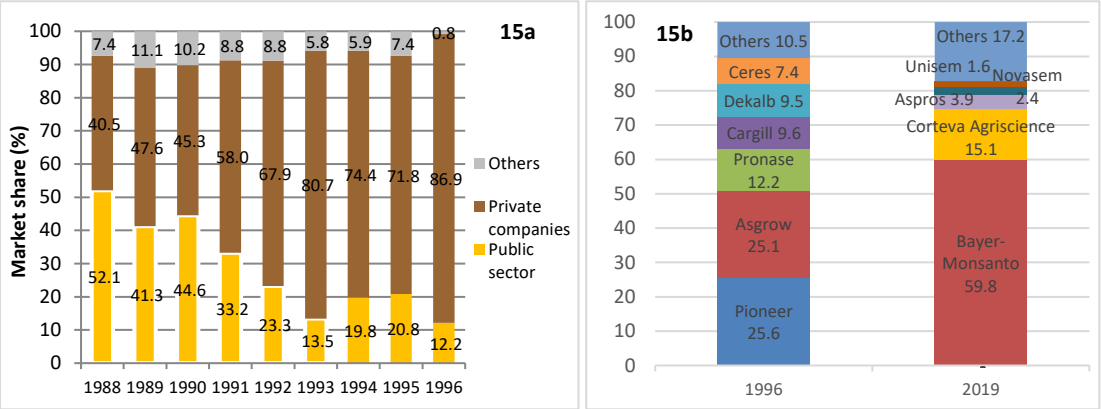


Figure 15 | Market shares of public, private national and multinational seed companies in the Mexican maize seed industry. Figure a) 1988-1996 (left), Figure b) 1996 vs 2019 (right). Source: CIMMYT-Maize breeding impact survey, unpublished data (Morris, 1996); Morris, (1998); SNICS official seed production statistics (SNICS, 2019); official import and export data from the Mexican Ministry of Economy 2011-2019 (Secretaría de Economía, 2019); MasAgro seed marketing survey (CIMMYT, 2019a). In 2018 Bayer purchased Monsanto, including its brands DeKalb, Asgrow and Cargill. In 2018 Dow and Dupont merged to create DowDupont and become Corteva Agriscience in 2019. Corteva Agriscience retained the brand Pioneer.

4.5. Data and methods

4.5.1. Study area

Data were collected during the 2019 spring-summer maize cropping season in La Frailesca, Chiapas Mexico (Figure 16). Chiapas ranks first among the states in the area planted to maize (0.69 Mha) and eighth in terms of maize production (1.25 MT). In the state, more than 95% of the total area planted to maize is rainfed (SIAP, 2020a). The use of improved seeds is only 32% (SIAP, 2016). The yield gap is about 5.1 t/ha if compared to other states such as Jalisco, the second most important maize producer, whose average rainfed productivity is 6.8 t/ha (SIAP, 2020a). Its remarkably low yields and its place as first in the area under maize cultivation represent an opportunity for seed companies to expand their seed sales, and for the government to increase the use of hybrid maize specifically adapted to rainfed conditions.

Within Chiapas, we selected the region of La Frailesca based on its contribution to maize production in the state (15%) and the number of agro-dealers offering a diverse quantity of seed products of national as well as international brands. We then concentrated on the municipalities of Villaflores, Villacorzo and La Concordia (Figure 16), which together account for over 90% of the area planted and maize production in the region (SIAP, 2020a).

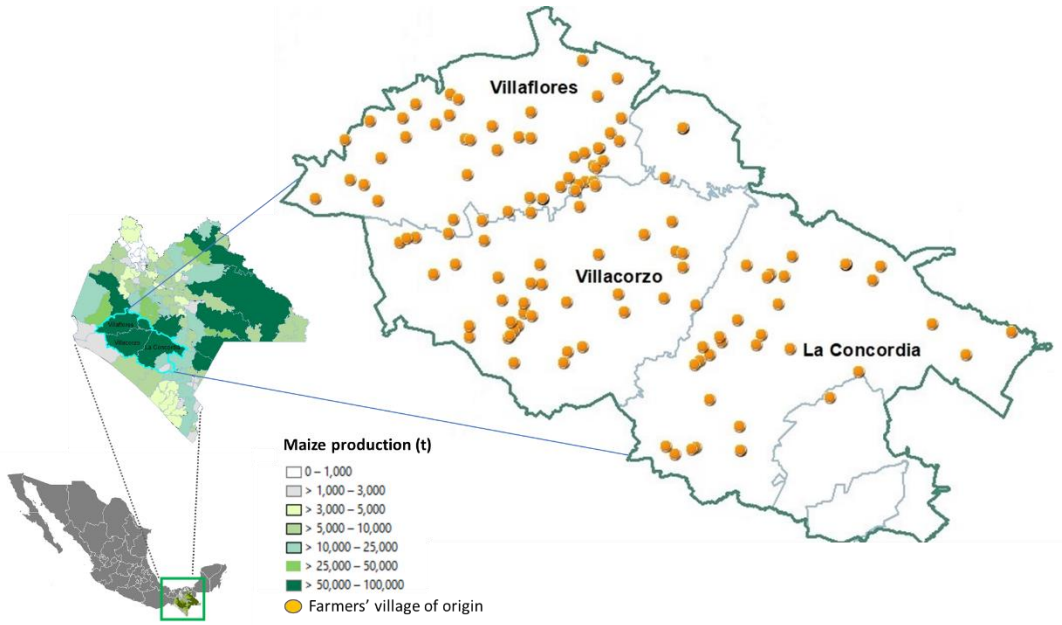


Figure 16 | Agro-dealers study area location and intercepted farmers' village of origin. Source: 2019 maize seed production statistics (SIAP, 2020a); Post-purchase intercept interviews with farmers at agro-dealers.

4.5.2. Data collection methods

Three complementary methods were used to gather information on seed purchases and the interaction of agro-dealers with farmers and seed companies to promote and sell improved seeds. Ethical clearance was followed in CIMMYT before data collection.

4.5.2.1. Farmers intercept interviews

A 20-25 minute intercept interview (Appendix D) was conducted with seed clients (n=391) who had just purchased or had previously purchased from agro-dealers at least one bag of maize seed. A list of agro-dealers (N=36) was obtained from the National Directory of Economic Units (DENUE) of the National Institute of Statistics and Geography (INEGI, 2018), the National Seed Inspection and Certification Service (SNICS, 2017b) and the MasAgro seed marketing survey (CIMMYT, 2019a). This original list was amended (N=63) by an exploratory fieldwork trip before the start of the seed sales season in February-March 2019. Only 28 stores were confirmed to sell improved maize seeds. From these, a sample of 9 agro-dealers was chosen and maize seed customers were intercepted when coming out of the store.

The survey was carried out during the seed sales peak season (from 13-29th June 2019) using tablets and the Google ODK software. The team moved in advance to Chiapas to test and contextualize the study. The questionnaire was tested with maize seed customers in selected shops in the region and adapted to the local context and the farmers' language. The intercept interview covered four topics:

1) Socioeconomic and farming characteristics: farmers' village and municipality of origin, gender, age, education, sources of income, farming area (rainfed and irrigated), area planted to maize, and experience (years) using improved maize seeds;
2) Maize seeds purchased including the variety's precise name, number and size of bags bought, price, expected yield, stated preference and associated attributes that could have influenced the purchase decision, i.e., whether the seed came with some credit or technical assistance, or as part of a technological package. Preference and associated attributes were captured as dummy variables: 1 if yes and 0 otherwise;
3) Reasons for continuing to buy the same variety of maize seed or changing it, with reference to the intrinsic and extrinsic attributes of hybrid maize seed identified in the conceptual framework, i.e., yield, drought tolerance, pest and disease resistance, brand, price, etc. Farmers could mention as many reasons as they could recall for selecting their seed variety. Each reason listed was treated as a dummy variable: 1 if mentioned as a reason to buy and 0 otherwise; and:
4) Engagement with the agro-dealer and information exchange during the purchase. A process-tracing subsection of the questionnaire (Appendix D, Q3) was designed to find out the influence of the agro-dealer on farmers' buying decision-making. The tracing questions captured farmers' decision-making from prior arrival to the store (Q3.1. Before coming into the shop, how sure were you about the variety you wanted to buy?) to how they engaged in-store with the agro-dealer in information searching (Q3.3. Did you ask the store attendant to recommend you a variety? Q3.4. Did the store attendant recommend a variety/brand? They similarly examined whether farmers received advice from the agro-dealer (Q3.4. Did the store attendant recommend a variety?) and followed this assistance to make their final choice (Q3.5. Did you follow his/her recommendation?). Except for Q3.1., which is categorical, the answers were dummy variables. Furthermore, farmers were asked whether they demanded or received any other information from the agro-dealer about the seed purchased or other available maize brands in the store (Appendix D, Q3.6- and Q3.9).

Table 9 shows the number of farmers interviewed at each study site and store. We looked for the representativeness of urban and rural as well as large and small shops, ensuring the representativeness of all sizes and types of seed clients. Villaflores was allocated the highest survey number because it had the highest commercial activity and turnout of farmers. All shops had at least 4 different maize seed varieties in stock and, except for one store, at least 3 brands on offer.

Table 9. Agro-dealers study sites and sample size description.

Municipality	Study site/town	Location	No. of products on offer	No. of brands on offer	No. of farmers surveyed	No. of seed varieties/ transactions
Villaflores (n=187)	Villaflores	Urban	12	5	81	99
	Villaflores	Urban	4	3	89	107
	Villaflores	Urban	9	4	17	20
Villacorzo (n=110)	Villacorzo	Urban	12	5	38	48
	Villacorzo	Urban	10	5	29	39
	San Pedro Buenavista	Rural	21	6	43	59
La Concordia (n=94)	Independencia	Rural	10	4	31	36
	Independencia	Rural	12	4	38	57
	Independencia	Rural	5	1	25	35
Total					391	500

Source: Post-purchase intercept interviews with farmers at agro-dealers.

4.5.2.2. Agro-dealer interviews

Semi-structured interviews were conducted with owners, store managers or employees of agro-dealer shops. The interviews were carried out by the end of the maize seed sales season (from 22 June to 02 July) and directed to the shops selected for conducting the intercept interviews with farmers. Eight out of the nine agro-dealers where we intercepted customers agreed to participate in the interviews. We then selected three more for a total of eleven out of the twenty-eight stores confirmed as selling maize seeds in our study area. The agro-dealer interview lasted about 60 minutes and covered five topics:

1) Agro-dealer characteristics: including the number of years in operation, years selling improved maize seed, number of employees, property type (own business, chain store, franchise, etc.), number of branches and exclusivity agreement with seed suppliers, if any, etc.;
2) Maize seed supply and sales: including every in-store variety's exact name, supplier, bag presentation, price, number of bags sold and sales trend. This section also inquired about other inputs sold and their relative importance to the business's returns, the most profitable varieties, clients, supply availability issues if any and supply agreements with seed providers;
3) Promotion and marketing activities: this section identified the agro-dealers' activities in promoting and selling hybrid maize seed, their involvement with seed suppliers in seed marketing and the incentives received from seed companies to stock and promote their seed varieties. It also captured the factors considered by agro-dealers when stocking a maize hybrid and the changes introduced in the store to increase sales;

4) Information exchange and transfer with suppliers and farmers: this identified the main sources and type of information about seed varieties received and exchanged with suppliers and farmers; and finally:
5) Challenges faced by the agro-dealers when seeking to increase their maize seed sales: inquired about the internal and external factors limiting seed sales and the capacity of businesses to sustain growth.

Interviewees were selected for their knowledge and experience of seed sales. Most respondents reported being very involved in seed procurement, promotion, marketing and sales and having high to very high knowledge of seed sales. The majority had a bachelor's degree in agronomy, veterinary science or livestock production. The stores interviewed were mostly independent private businesses that had been established for an average of 18 years (17.7 years selling maize seed) and employed 3.8 people on average, with a maximum of 9. The youngest shop had been founded 3 years previously, and the oldest 50.

4.5.2.3. Seed company interviews

Semi-structured interviews were conducted with sales representatives of Corteva Agriscience and five national companies out of the eleven seed firms found to operate in the study area. Interviewees were fully involved in distribution, promotion and marketing, and reported that they had regular to very high knowledge of seed sales. The interview lasted around 60 minutes and covered the following topics:

1) Current maize seed offer and sales trends: including the variety's exact name, price, number of bags sold, sales trend and clients;
2) Seed distribution and marketing: identified the companies' distribution channels, the incentives offered to different channels to stock and sell their seeds, their supply agreements, promotion and marketing strategies to encourage the dissemination of hybrids and their interaction with agro-dealers and farmers for the promotion of seeds; and:
3) Challenges faced by the seed company when seeking to promote their seeds and increase sales.

4.5.3. Data analysis

Survey data were cleaned and analyzed using STATA 17. Farmers' socioeconomic and farming characteristics as well as purchasing decision-making at agro-dealers were analyzed at farmer level (N=391). Seed purchases and farmers' selection of seed were examined at seed transaction level (N=500). Information gathered from interviews was processed and analyzed in Excel. Three main

qualitative themes were identified to explain the interactions of agro-dealers, seed companies and farmers in the seed supply chain: 1) seed supply and distribution, 2) agro-dealers' promotion of seed, and 3) seed companies' marketing activities.

4.6. Results

4.6.1. Farmers' characteristics

Farmers interviewed were predominantly male, were on average 51 years old and had a low level of education (Table 10). The majority depended on maize to obtain their income, 40% worked in animal husbandry, 30% produced other crops and some were employed in farming activities. Maize growers in our sample cultivated on average 13.9 ha (own and rented) and planted about a third (4.7 ha) of this area with maize. Farmers in the region were commercial and market-oriented, producing on average 6.1 t/ha, which is high compared to the national (2.5 t/ha) and state (1.7 t/ha) average maize production in rain-fed conditions. The two main producer states, Sinaloa and Jalisco, for example, typically produce 11.1 and 6.6 t/ha respectively under irrigation (SIAP, 2018). Socioeconomic and maize farming characteristics among the study sites are overall homogeneous but farmers in La Concordia had larger areas under maize and improved seeds.

Table 10. Intercepted farmers' socioeconomic, farming and purchasing characteristics (N=391). Variety switchers, brand switchers, preference and repurchase commitment N=500.

	Mean	Villaflores	Villacorzo	La Concordia
Male respondents (%)	98.5	97.9	99.1	98.9
Age (years)	51.5	52.2	51.8	49.8
Education (%)				
No formal education	21.7	20.3	25.5	20.2
Elementary school	44.0	47.1	41.8	40.4
Secondary school	17.1	16.6	14.5	21.3
High school or technical training	10.0	10.2	9.1	10.6
University	7.2	5.9	9.1	7.4
Sources of income (%)				
Maize production	99.0	98.9	98.2	100.0
Other crops	28.3	26.7	39.1	19.1
Animal husbandry	39.5	30.5	45.5	42.6
Farm labourer	13.5	17.1	12.7	10.6
Farming characteristics				
Farming area (ha)	13.9	12.3	15.8	15.0
Area under maize (ha)	4.7	4.5	4.4	5.5
Area planted to improved seed (ha)	4.6	4.4	4.3	5.5
Average expected yield (t/ha)	6.1	6.1	6.2	6.1
Purchasing practices (%)				
Years using improved seed	9.9	9.8	10.1	10.0
Multi-variety buyers	28.6	24.1	29.1	37.2

Multi-brand buyers	17.7	15.5	21.8	17.0
Variety switchers	22.2	28.3	18.5	15.6
Brand switchers	18.4	24.8	15.1	10.9
Preference	85.8	92.5	80.8	79.7
Repurchase commitment (≥2 years)	72.0	65.9	76.0	78.1
Repurchase commitment (≥3 years)	48.4	36.7	52.1	64.8
Repurchase commitment (≥5 years)	21.8	11.9	26.3	32.6

Source: Post-purchase intercept interviews with farmers at agro-dealers.

Regarding seed use, farmers in our population sample bought improved seeds every year. Less than 7% indicated they had used improved seeds for only two years. Improved varieties have been used in the area for an average of 10 years and a maximum of 40 years. Accordingly, farmers were experienced in using hybrids, were fully aware of what was on offer and the vast majority could recap their preferred varieties by exact name. Almost a third of our sample reported buying more than one variety (multi-variety buyers) and about a fifth bought multiple brands (multi-brand buyers). A fifth of the farmers also switched from one variety (variety switchers) and from one brand to another (brand switchers) from the previous year. Most farmers (86%) mentioned having bought their most preferred variety (preference). In addition, almost 72% committed to buying the same seed (repurchase commitment) for at least two years while nearly 50% had bought the same product for a minimum of three years. Repurchase commitment was higher in the rural study sites Villacorzo and La Concordia while switching was more frequently observed in Villaflores (Table 10).

4.6.2. Seed purchases and drivers for the selection of seeds

4.6.2.1. Seed purchases

Table 11 shows an overview of the main seeds purchased by intercepted farmers at selected agro-dealers, while Figure 17 offers details of the market share and price of each variety found in the survey. Pioneer and Brevant are brands of Corteva Agriscience while Dekalb and Cristiani belong to Bayer. Products with the PAS and SKW acronyms are recently developed MasAgro hybrids. In the 2019 spring-summer maize cropping season in La Frailesca, farmers purchased a total of 38 seed products sold under 10 different brands offered by 8 seed companies - three multinational (Corteva, Bayer and Syngenta) and five nationals.

All varieties purchased were private hybrids except for Tuxpeño amarillo and VS536, both public OPVs. Farmers bought on average 3.3 bags of seed at an average price of MXN$ 2,296 (US$ 120.8) for a bag containing sixty thousand seeds. The top five varieties bought - all from multinational companies - accounted for 70% of all buying transactions whereas the top ten - including two private national hybrids (RW5000 and PAS535) - represented 86%. One single variety (P4082W) captured

34% of seed purchases. It is worth noting that sales of Pioneer's most recently maize hybrid (P4028W), released during the year of this study, ranked fourth in market share, even above DK390 and nearly as DK7500 which had been on the market for seven and six years respectively.

A further examination of seed purchases by brand shows that Pioneer was the brand most frequently bought (64.7 %), followed by Dekalb (16.7%), American seeds (5.3%), Proase (5.0%) and Syngenta (4.9%) (Figure 18). Together, purchases from multinational companies represented 88%: those from Corteva Agriscience 65.2%, mainly of Pioneer (64.7%); Bayer 17.8%, mostly of Dekalb (16.7%); and Syngenta 4.9%. The share of recently developed MasAgro hybrids, of which eight were bought by farmers, represented 6.0% of total seed purchases. Pioneer was the most expensive brand (MX$2,397 - USD$ 126.2) but was nevertheless the most frequently purchased brand.

Table 11. Overview of maize seed varieties purchased during the 2019 spring-summer season in La Frailesca, Chiapas (N=500).

Total number of different maize varieties purchased						38
Number of different brands purchased						10
Average number of bags purchased (SD)						3.3 (4.2)
Average age of variety since release (SD)						5.7 (4.9)
Average price in MXN$ of seed varieties purchased (SD)						2,296 (344)
Variety name	Brand	Colour	Age (years)	Av. price (MXN$)	Expected yield (t/ha)	Share by transaction size (%)
Top 10 varieties purchased from multinational companies						
P4082W	Pioneer	White	10	2,333	5.99	33.72
P3966W	Pioneer	White	7	2,418	6.07	14.30
DK7500	Dekalb	Yellow	6	2,163	6.58	8.73
P4028W	Pioneer	White	1	2,714	6.77	7.76
DK390	Dekalb	White	7	2,299	6.36	5.82
P4226	Pioneer	Yellow	7	2,261	6.33	4.79
Impacto	Syngenta	Yellow	6	2,191	6.55	2.97
Sorento	Syngenta	White	6	2,163	5.83	1.61
DK447	Dekalb	White	2	2,487	6.18	1.58
30F35	Pioneer	Yellow	9	2,298	7.00	1.51
Top 10 varieties purchased from national companies						
RW5000	American	White	4	1,956	5.59	3.70
PAS535	Proase	Yellow	2	1,600	7.00	3.03
PAS110	Proase	White	3	2,100	5.67	1.03
PAS540	Proase	White	4	1,525	6.50	0.73
RW4000	American	White	8	1,960	5.33	0.73
RW5001	American	White	4	1,867	5.33	0.67
SKW502	Reycoll	White	4	2,033	5.67	0.55
ZR27	Zarco	White	8	1,700	6.50	0.42
SKW505	Reycoll	White	4	1,900	7.00	0.24
PAS524	Proase	White	4	1,850	8.00	0.18

Source: Post-purchase intercept interviews with farmers at agro-dealers.

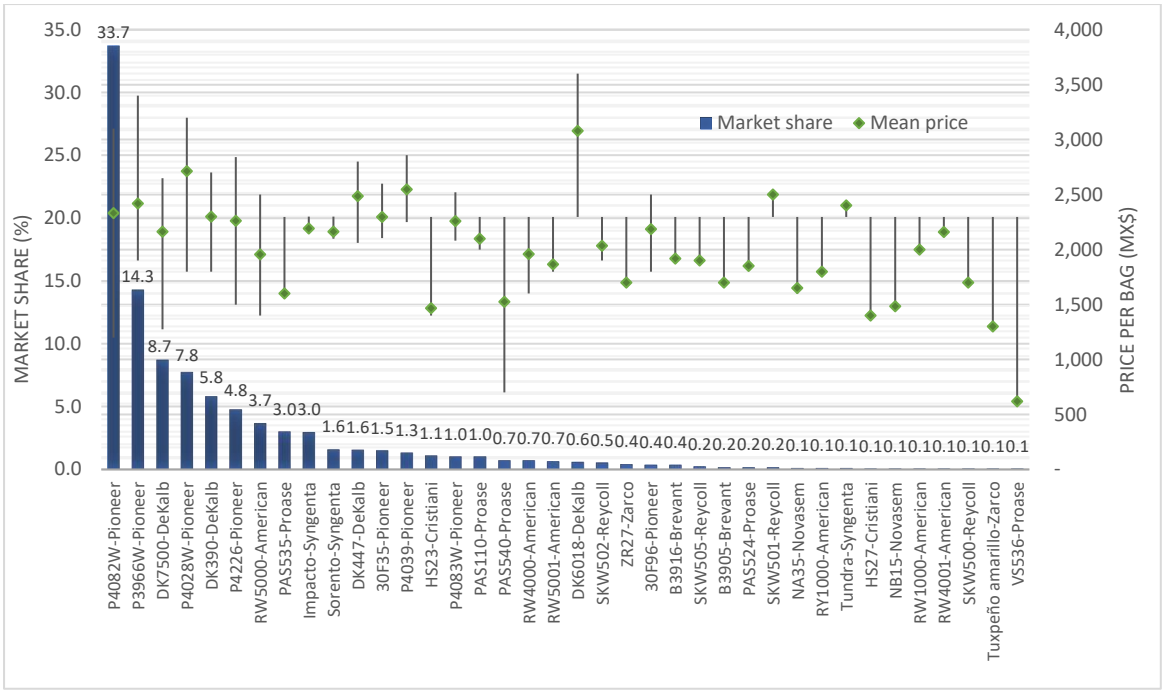


Figure 17 | Market share and price of maize seed varieties purchased during the 2019 spring-summer season in La Frailesca, Chiapas (n=467). n is the number of observations for bags of sixty thousand seeds found in the survey; grey lines indicate the maximum and minimum price of each variety. Source: Post-purchase intercept interviews with farmers at agro-dealers.

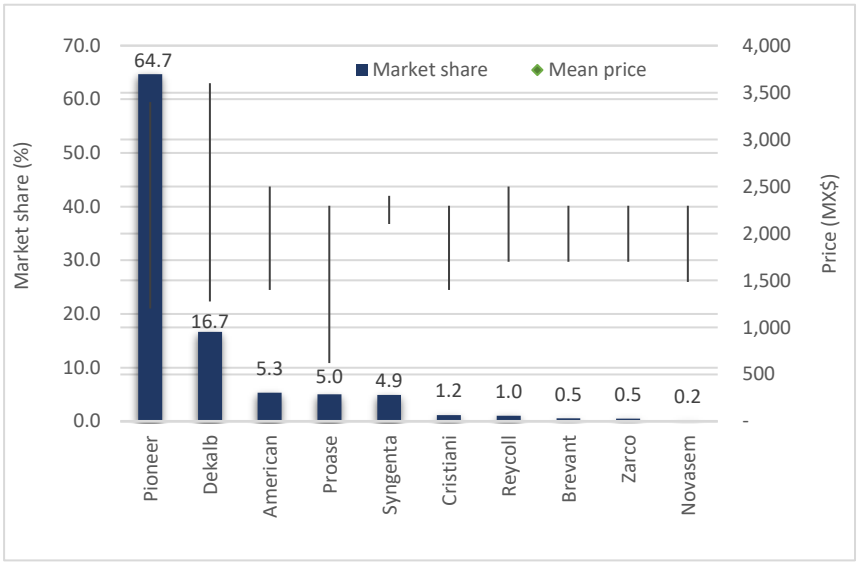


Figure 18 | Market share and mean price of maize seed brands purchased (n=467). n is the number of observations for bags of sixty thousand seeds found in the survey; grey lines indicate the maximum and minimum price of each brand. Source: Post-purchase intercept interviews with farmers at agro-dealers.

4.6.2.2. Drivers of farmers' selection of seed

Figures 19 and 20 show the main drivers for the selection of seed at agro-dealers. Farmers listed their reasons for continuing to buy the same seed or changing variety. Each reason given was processed as a dummy variable (1 if mentioned as a reason to continue to buy, change seed or not

to buy their most preferred variety and 0 if otherwise). For three-quarters of all varieties purchased farmers decided to continue buying the same seed (n=374) and for the rest, they changed the seed they bought the previous season (n=126) (Figure 19). Out of the total number of seeds purchased, a small proportion (n=70) were not the farmers' most preferred seed (Figure 20).

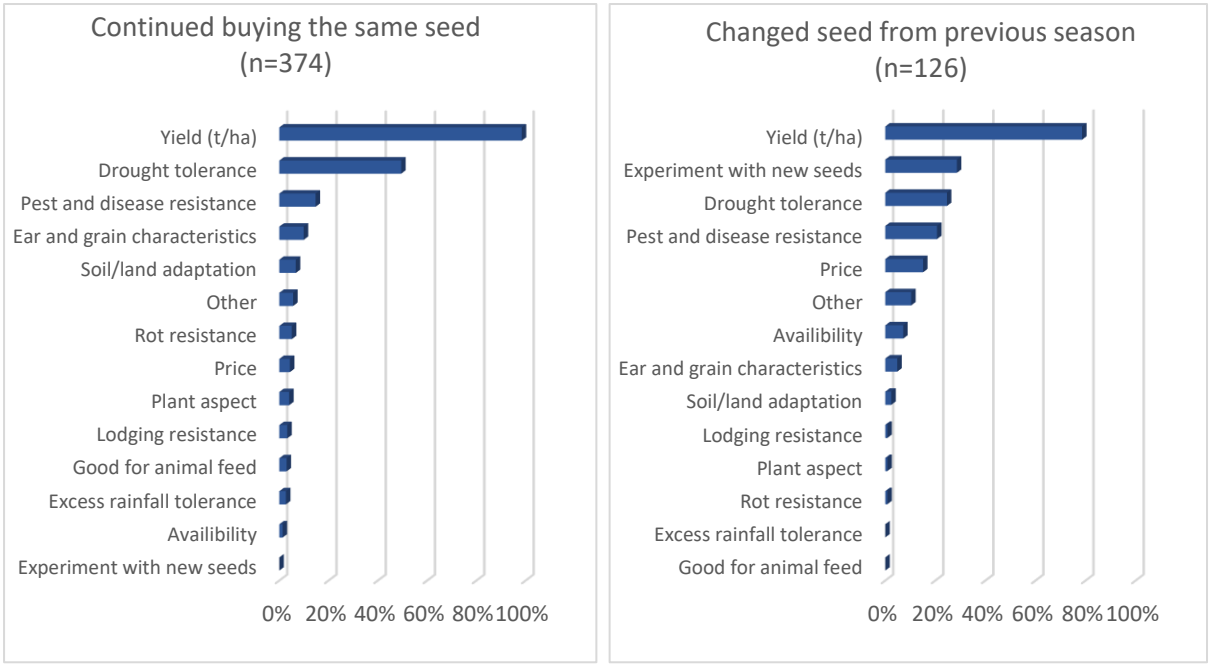


Figure 19 | Drivers of farmers' selection of seed at agro-dealers (N=500). Source: Post-purchase intercept interviews with farmers at agro-dealers.

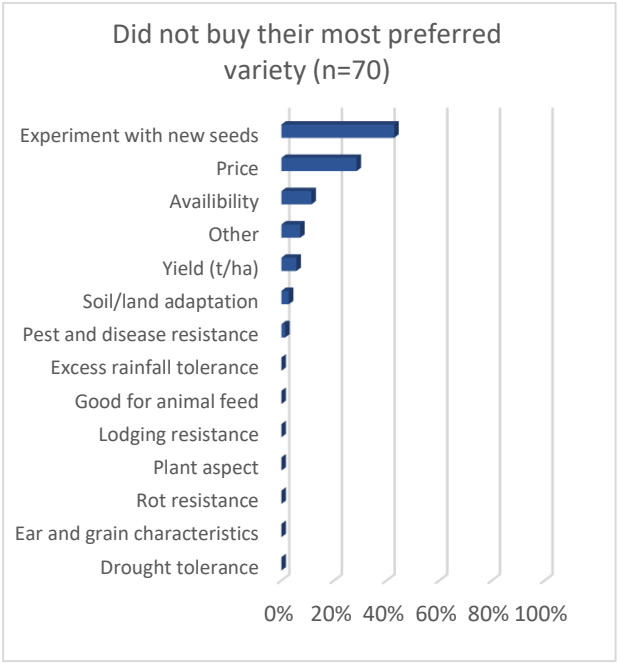


Figure 20 | Drivers of farmers' selection of alternative seed varieties at agro-dealers (N=500). Source: Post-purchase intercept interviews with farmers at agro-dealers.

The main drivers to continue using the same variety were yield and resistance to drought. The main reasons to change seeds were yield, experimenting with new seeds, drought tolerance and resistance to pests and diseases. When farmers switched seed, 28% of these decisions were made to experiment with a new maize variety, while 43% of their decisions for not to buy their most preferred variety were made for the same reason. This suggests that some buyers are open to experimenting with new seeds, and therefore they can be persuaded in-store in their decisions of what seed to buy. Finally, according to the farmers' responses, the price was a negligible reason for repurchasing the same seed and important only 15% of the time when changing variety. When buyers did not buy their most preferred seed (in about a third of 14% of transactions) only in a small number of cases was price the second most important factor under consideration.

4.6.3. Farmers' decision-making and agro-dealers' influence

Figure 21 illustrates the process of farmers' decision-making as they engaged with the agro-dealer on information exchange, evaluation of alternatives and decisions about their purchases. When arriving in the shop 92.8% of farmers were sure about the seed they wanted to buy, 90.8% of these farmers found that variety available and most of them (90.3%) bought it. Only 2% of the customers did not find the seed they looked for. For the group that did not find their seed variety, engagement with the agro-dealer was minimal as farmers barely asked and the store attendant did not try to influence customers. Another 7.2% of farmers were unsure of what seed they wanted to purchase. For this group, 40% (out of the 7.2%) received advice from the agro-dealers and all followed their recommendations. The majority of the remaining 60% left the store without receiving any advice. Overall, only 5% of farmers followed the store attendant's recommendation.

Although farmers planned their purchases outside the store, they still engaged with the agro-dealer in searching for information. Out of all farmers surveyed, around a third (34%) asked for information about other available seeds and almost four out of ten farmers (37%) asked questions about the seed they bought. Apart from asking about other seed options, the main information requested by farmers about either other available seeds in the store or the seed they bought was the price, seed treatment and yield (Figure 22). The small percentage difference between farmers requesting and receiving information about other available varieties (less than 10%) suggests that agro-dealers made little effort to promote seeds in the absence of stimulus from customers.

<table>
<tr><td rowspan="12">Was sure about what seed to buy 92.8%</td><td rowspan="6">Variety sought was available</td><td rowspan="3">Yes 90.8%</td><td rowspan="3">Purchased variety sought</td><td rowspan="2">Yes 90.3 %</td><td rowspan="2">Received advice</td><td>Yes 27.9%</td><td rowspan="2">Followed advice</td><td>Yes 2.3%</td></tr>
<tr><td>No 62.4%</td><td>No 25.6%</td></tr>
<tr><td>No 0.5 %</td><td>Received advice</td><td>Yes 0.2%</td><td rowspan="2">Followed advice</td><td>Yes 0%</td></tr>
<tr><td></td><td></td><td></td><td></td><td>No 0.2%</td></tr>
<tr><td rowspan="3">No 2.0%</td><td rowspan="3">Asked for alternative seed</td><td rowspan="2">Yes 0.8 %</td><td rowspan="2">Received advice</td><td>No 0.3%</td><td></td><td></td></tr>
<tr><td>Yes 0.3%</td><td rowspan="2">Followed advice</td><td>Yes 0%</td></tr>
<tr><td>No 0.5%</td><td></td><td>No 0.3%</td></tr>
<tr><td rowspan="2">No 1.2 %</td><td rowspan="2">Received advice</td><td>Yes 0.7%</td><td rowspan="2">Followed advice</td><td>Yes 0%</td></tr>
<tr><td>No 0.5%</td><td></td><td>No 0.7%</td></tr>
<tr><td rowspan="4">Was unsure about what seed to buy 7.2%</td><td colspan="3" rowspan="4">Asked for available seeds</td><td rowspan="2">Yes 2.9 %</td><td rowspan="2">Received advice</td><td>Yes 2.9%</td><td rowspan="2">Followed advice</td><td>Yes 2.6%</td></tr>
<tr><td>No 0%</td><td>No 0.3%</td></tr>
<tr><td rowspan="2">No 4.3 %</td><td rowspan="2">Received advice</td><td>Yes 0.5%</td><td rowspan="2">Followed advice</td><td>Yes 0.3%</td></tr>
<tr><td>No 3.8%</td><td></td><td>No 0.2%</td></tr>
</table>

Figure 21 | Farmers' seed decision-making process at agro-dealers (N=391). Source: Post-purchase intercept interviews with farmers at agro-dealers.

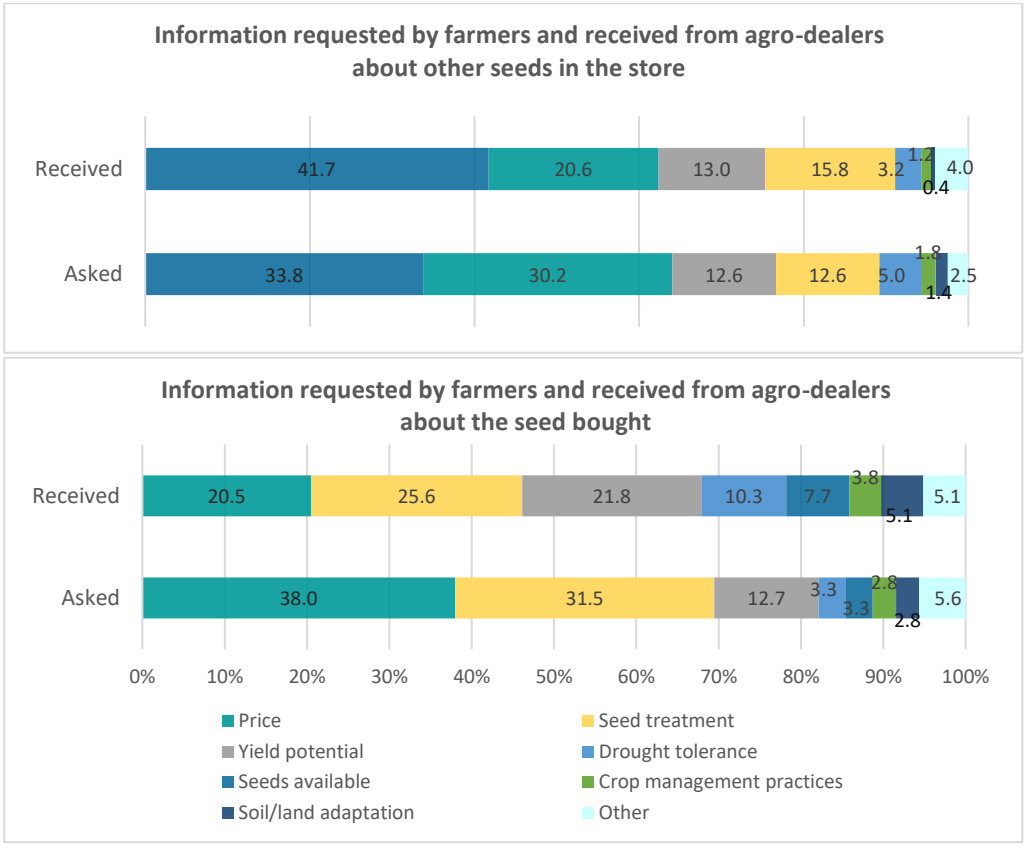


Figure 22 | Information exchange between farmers and agro-dealers (N=391). Source: Post-purchase intercept interviews with farmers at agro-dealers.

4.6.4. Interactions in the maize seed supply chain

4.6.4.1. Seed supply and distribution

Results from interviews with agro-dealers and companies' sales representatives show that seed companies used agro-dealers to distribute their seeds along with other channels, such as direct sales to farmers through sales representatives, lead farmers and independent sales agents working on a commission basis. Five out of six companies delivered their seed through agro-dealers, half made it directly to farmers and three worked through lead farmers. The sixth relied completely on direct sales to farmers through its representatives or independent sales agents. Most of the time agro-dealers dealt directly with seed companies but some depended on larger agro-dealer shops for their seed supplies. Six stores reported using wholesale agro-dealers but only about a third of their seeds were supplied through shop intermediaries.

Agro-dealers could carry on any variety from any supplier without exclusive distribution rights. Companies delivered the seed on a contract basis affording the agro-dealer either a commission for every bag of seed sold (USD$ 5.3-15.8) or a commission plus a bonus (USD$ 2.6-5.3) on every unit sold as long as the sales met or exceeded a minimum volume agreed beforehand. Most retailers received the seed on a commission and consignment basis, having the ability to return any unsold seed at the end of the planting season. Four out of eleven shops engaged in the commission plus bonus system, but the bonus benefit was provided only by Syngenta and DeKalb. Two shops paid for the seed upfront with the ability to return up to 10% of seed volume if it was not sold, and one received the seed on credit from Pioneer. Most firms offered discounts on anticipated cash purchases. Commissions offered varied from the lowest 8% per bag sold in the case of Pioneer, to the highest 17% from Syngenta and as much as 20% from national companies. When the supplier was a wholesale agro-dealer, commissions were slightly lower. Overall, domestic companies perceived the agro-dealer as a difficult channel for distribution of their seed as they considered the retail space was captured by seeds of multinational companies.

4.6.4.2. Agro-dealers' promotion of seed

Most of the activities in which agro-dealers engaged for the promotion of seed were in-store; their out-store engagement with producer companies for seed marketing was limited. All shops displayed seed packs in their store, recommended seed to farmers and provided posters or product information flyers. More than half the agro-dealers interviewed indicated that they only occasionally offered branded giveaways to clients, organized promotional events to encourage purchases, and offered discounts. Only one mentioned ensuring customer satisfaction and targeting sales by specific target markets (edaphological zones). Only three out of eleven shops engaged in organizing

demonstration plots and field days with seed companies, arguing that marketing was the responsibility of the seed supplier. Finally, two out of eleven agro-dealers advertised their seed on the radio, and only one offered workshops, free seed samples and layaway sales to farmers.

4.6.4.3. Seed companies' marketing activities

Seed marketing activities undertaken by companies were mainly developed independently of agro-dealers, outside the store and targeted towards end-users. All seed companies mentioned distributing posters or product information flyers to agro-dealers and half said they occasionally provided branded giveaways for distribution to farmers. Some organized in-store promotional events to stimulate purchases of seed and other inputs during the peak sales season. In contrast to the limited number of in-store marketing activities, companies reported a total of nine different activities to promote their seed outside the agro-dealers space. The main activities reported by all companies interviewed were demonstration plots and field days and, during these events, the provision of free seed samples to farmers. Five out of six companies organized workshops and training for farmers in municipality offices. Another four out of six mentioned monitoring seed performance in farmers' fields while half promoted their seed on the radio. The less frequent out-store activities included attending seed fairs and offering layaway plans through lead farmers. The latter led to an increase of 70% in sales by the company that implemented it.

Two more innovative but barely frequent methods were "commercial plots" and "seed challenges". The first refers to plantations emulating demonstration plots, but instead of being established by seed companies, they are managed by lead farmers who communicate their experience to other maize producers during field days. The latter is a marketing strategy used by Pioneer: it consists of selecting medium-scale farmers growing a hybrid produced by the competition, giving them free seed samples, and challenging them to compare Pioneer seeds with their current variety.

4.7. Discussion

We examined farmers' seed purchasing decisions at agro-dealer shops and described the interactions of agro-dealers, seed companies and farmers, in order to understand the influence of agro-input retailers on farmers buying decision-making and their potential for scaling the use of improved maize seeds delivered by SMEs. Our results show three main findings.

Firstly, farmers bought a diverse number of seed varieties but stuck to a small number of hybrids from multinational companies driven mainly by seed performance characteristics or intrinsic attributes such as yield, drought tolerance, and pest and disease resistance. Intercepted producers did not explicitly mention extrinsic cues as reasons for their purchases, but market shares and price

results show the similar important role of brand and price in the decision about what seed to buy as farmers selected one or two brands with the highest market prices. As a product with predominantly experience and credence attributes, hybrid maize seed cannot be evaluated in-store and farmers may have formed their judgements and purchase decision based on previous experience or through available quality cues. In fact, farmers in our sample were experienced buyers (who had spent an average of ten years using improved seeds), which suggests they formed their opinions according to previous experience based on their knowledge of seeds' intrinsic attributes. In addition, most farmers (72%) repurchased the same seed of the same brand as the previous season and showed no interest in looking for further information or evaluating other seed alternatives in the store.

The notion of extrinsic and intrinsic quality cues has been extensively used in marketing for understanding consumers' buying behaviour. Rao and Monroe (1988) investigated the use of quality cues in product evaluations and found consumers with greater prior product experience used more intrinsic attributes (physical and performance characteristics) to assess product quality. Lynch *et al*. (1988) similarly found that consumers relied upon recalled attribute information about known brands to guide their choices when information was accessible in memory. In markets with imperfect information, Rao and Bergen (1992) showed that quality-conscious buyers were more willing to pay price premiums for goods with high experience attributes. This research provides empirical evidence of how farmers decide on their purchases of hybrid maize seed based on subjective evaluation and the effect of product quality cues. Surprisingly, and despite the great potential for explaining adoption and purchase decisions, this approach has not been explored in the adoption and seed systems literature. The existing evidence of the effect of quality cues on consumers' choices appears in contexts widely remote from hybrid maize seed markets in developing regions, which makes it a fruitful area for further research.

Secondly, and consistent with previous research on the effect of agro-dealers on seed decision-making (Muindi and Adam, 2020; Rutsaert and Donovan, 2020), evidence has emerged to show that agro-dealers had little influence on farmers' decisions and their efforts to either engage with seed companies or farmers for the promotion of seeds were very limited. Farmers planned their seed purchases outside the store, but about a third still engaged with the agro-dealer in information searching, indicating the potential for optimizing the in-store agro-dealers' environment to influence purchases. When an innovation is introduced, farmers pass through several stages of a learning process before deciding to buy or adopt (Pannell *et al*., 2006; Pannell, 2007; Weersink and Fulton, 2020; Kotler and Keller, 2012). The results of this research suggest that for farmers in La Frailesca Chiapas the process of hybrid awareness, information searching, evaluation of alternatives and

buying decision-making started before going to the shop, which explains the little influence of agro-dealers and farmers' low engagement in the store.

Thirdly, seed companies used the agro-dealer as one of the main channels for the distribution of seeds along with other alternative outlets. Pioneer, for example, the sales leader company in our study region delivered up to 60% of its sales through lead farmers, while national companies sold about 30-40% of their total seed sales through agro-input stores. Besides, companies' marketing activities were mainly undertaken independently of the agro-dealer, outside the store and targeted toward end-users (farmers). This is in line with Rutsaert and Donovan (2020), who report that seed companies in Kenya bypassed retailers to engage directly with farmers and hardly used the agro-dealers to promote their seed varieties. Our review and results show that most marketing tools used in the maize seed industry are out-store prepurchase marketing tools and only a few are in-store prepurchase, in-store purchase or out-store postpurchase tools. Seed companies rely mostly on out-store marketing to communicate the value and attributes of their products and promote their seeds outside the retail space. This has been confirmed by Donovan *et al*. (2022), who found that advertising was one of the most useful activities used by a sample of twenty-two small national seed companies in Mexico for the promotion of seed. The most critical marketing tool reported was the implementation of demonstration plots, while less than 20% considered engagement at the point of sale to be useful for seed marketing.

In Kenya, Rutsaert and Donovan (2020) similarly found that marketing was principally used to create awareness through advertising (distribution of posters and leaflets, radio ads), demonstration plots and field days. According to their findings, apart from the distribution of leaflets and free samples, companies made hardly any use of the in-store environment to promote seed. The nature of marketing strategies in the maize seed industry is presumably another reason for the little influence of agro-dealers on seed variety choices. This makes it critically important to expand our knowledge of private sector marketing and its effect on farmers' adoption and buying decision-making. Technology adoption and seed systems research would benefit greatly from incorporating the effect of marketing, consumer behaviour and the in-store environment into an integrated view of the existing adoption and buying decision-making frameworks. This research has laid the foundations for the development of such a framework.

A comprehensive view of our findings suggests that other factors play a more important role than agro-dealers in the decision of what seed to buy. These results raise important questions: How can agro-dealers increase their influence and support expanded sales of improved maize seed varieties? What is or should be their role in seed marketing? How should domestic SMEs approach seed

marketing? and What are the limitations on the efforts of both to increase sales of hybrid maize through agro-dealer shops? Agro-dealers, like retailers in other sectors, e.g., food, should meet farmers' needs and demands as they enter the store, create a visually appealing space, encourage purchases and guide farmers through the whole seed buying decision-making process (Kelley, 2013). Building upon the experience of the food retailing sector, agro-dealers can improve the in-store environment by incorporating key layouts and design elements to encourage consumers to explore the entire shop (e.g., creative seed displays, advertisements on walls, ceilings and floors, TV commercials, strategic shelf positions, floor signs to motivate farmers to walk towards specific target points), providing full support to seed clients, and sometimes, in collaboration with seed companies, offering reduced prices and promotions to encourage seed purchases (Inman *et al*., 2009; Kotler and Keller, 2012; Kelley, 2013).

Agro-dealers also have a great potential for engaging in out-store awareness and demand generation activities as shown by experiences in Africa (IFDC, 2015; AGRA, 2017; AFAP, 2019). However, that requires strong coordination with seed companies and incentive capacity to strengthen push marketing, and here is where the biggest challenge faces SMEs. On the seed producers' side, a highly influential sales force and competitive sales commissions to seed retailers have, for many years, represented a major source of competitive advantage for large multinational companies in Mexico. On the retailers' side, unlike agro-dealers in other developing regions, e.g., Africa, agro-dealers in La Frailesca displayed significant financial capacity and a competitive distribution network. Their lack of interest in participation in seed promotion and the strong competition from brands of multinational companies raised more concern than infrastructure, credit, or seed demand. Many agro-dealers considered varieties of Pioneer their most profitable variety, given the volume of sales, but not necessarily by sales commission. As observed, national companies and Syngenta were among the firms providing the highest sales commissions. Syngenta and DeKalb also offered a bonus for every bag of seed sold, reflecting their attempts to increase their market shares. For many agro-dealers, the brands of multinational companies, especially Pioneer "sell themselves" without much need for sales effort. That means that financial incentive capacity constraints, the presence of well-known and well-positioned brands with prices signalling quality (price premiums), and farmers' brand preferences represent a barrier for domestic seed companies and PPPs seeking to increase their seed sales through agro-dealer shops.

4.8. Conclusion

Adoption decision-making has been traditionally studied in non-shopping situations and outside the agro-dealers space. This chapter studied seed purchase decisions in a shopping context and described the linkages between agro-dealers, suppliers and farmers in the maize seed supply chain. Drawing upon research on marketing, consumer behaviour and retailing, we proposed a conceptual framework to explain 1) the effect of hybrid maize seed quality attributes on farmers' buying behaviour and seed marketing, and 2) the seed industry's strategies and their influence on farmers' buying decision-making and the agro-dealers' role on the promotion of seed. The framework and findings are new to the field of technology adoption and seed systems literature, which have traditionally neglected the role of agro-input retailers and marketing on seed variety choices. Our review and empirical results show that agro-input dealers are well placed to influence seed purchasing decisions, but their role in highly concentrated markets is potentially undermined by product quality cues and out-store marketing stimuli. Consequently, seed sector development interventions aiming at scaling PPPs varieties through agro-input dealers need holistic approaches to seed promotion and delivery. Besides improving the in-store environment, seed companies in La Frailesca and elsewhere with similar market structures will need to focus on maintaining intrinsic product attributes while developing and controlling seed quality cues, building strong brands, and creating awareness and loyalty. This requires a pull-push marketing strategy that emphasizes seed customers (farmers) and targets the various stages of the adoption and buying decision-making process.

The results are relevant to scientists, international organizations, governments, policymakers and donors supporting seed industry development projects and PPPs globally. The findings are especially relevant for seed companies and agro-dealers as an input for the design of marketing strategies aiming at enhancing hybrid maize seed use, adoption and sales. Since the findings are representative of commercial and market-oriented farmers, it is recommended to study seed purchases in other segments and market contexts.

5. Brand loyalty and price-quality perceptions of hybrid maize seed in La Frailesca, Chiapas, Mexico

"Successful companies will need to deliver not only better products, but also greater value for money" (Smith, 2012).

5.1. Introduction

Chapter 3 analyzed the capacities of PPPs to generate competitive seed variety innovations and deliver these innovations on a large scale through SMEs. Results show that the MasAgro maize PPP was very successful in generating a large flow of agronomically competitive commercial hybrids and SMEs successfully incorporated those materials into their seed offering and into the market. However, by the end of the project in 2019, MasAgro hybrids had a modest market share whereas multinational hybrids continued to dominate the maize seed market.

Chapter 4 examined the role of agro-input dealers in influencing farmers' seed purchasing decisions and explored whether agro-dealers account for one of the possible reasons for the limited market penetration of MasAgro hybrids. Our analysis shows that farmers planned their purchases outside the store and formed their decisions according to seed's intrinsic attributes (e.g., yield, resistance to drought) and quality extrinsic cues (e.g., brand and price). Seed companies also relied on marketing activities undertaken mainly independently of the agro-dealer, outside the store and targeted towards end-users (farmers). As a result, agro-dealers had little influence on farmers' buying decision-making but about a third of sampled farmers still engaged with the store attendant on information searching. This suggests that agro-dealers may be well placed to influence seed purchasing decisions, but their role in highly concentrated markets might be rather limited on account of the dominance of product quality cues and out-store marketing stimuli.

This chapter further explores why agronomically competitive maize hybrids developed by MasAgro have failed to obtain a significant share of the market. The chapter examines whether 1) loyalty to multinational brands accounts for farmers' reluctance to buy new recently released maize hybrids, even when they are agronomically and yield-wise competitive and 2) if the current SMEs' pricing strategy – high quality-low price - and price-quality perceptions may be contributing to the lack of marketing success of MasAgro PPP varieties. The purpose of the chapter is to derive inferences for the design of marketing strategies for expanding PPP SMEs' hybrid maize seed sales in concentrated markets dominated by large national and multinational companies.

The outline of the chapter is as follows. The next section reviews the existing literature on the effect of brand loyalty and price-quality perceptions on consumer product evaluations. Section 5.3 describes the conceptual model, the study hypothesis and the research questions. Section 5.4 explains the research design, data collection methods and data analysis approach. Sections 5.5 and 5.6 respectively present the results and discuss the findings and managerial implications. Section 5.7 examines the study's limitations and explores the prospects for further research. Section 5.8 concludes.

5.2. Brand loyalty and price-quality perception effects on product evaluations

In today's global and highly concentrated maize seed markets, understanding the effect of brand loyalty and price on farmers' perceptions of quality and value is critical for SMEs seeking to expand their seed sales. Brand and price are two of the most important cues guiding consumer choices in the marketplace (Monroe and Krishnan, 1985; Lichtenstein *et al*., 1993; Monroe, 2003). Companies create brand loyalty as a strategy to secure repeat purchases, long-term market position, sustained growth and profits (Anderson and Mittal, 2000; Kim, 2012). Consumers' loyalty provides foreseeable and secure demand for a firm and creates barriers to entry for competing brands that make it difficult for other companies to enter the market (Aaker, 1996; Kotler and Keller, 2012). It leads to the belief, right or wrong, that other brands are inferior, allowing the firm to raise its prices without a significant fall in sales (Sloman, 2003). It also gives companies time to react to competitors' innovations and functions as a buffer in times of intensive price competition (Aaker, 1996). In the context of plant breeding, brand loyalty is an exclusion mechanism used by private companies to secure their returns on investments in agricultural research by guaranteeing consistent premium quality and performance (Pray and Umali-Deininger, 1998). In some countries such as Pakistan, Corteva Agriscience has been recognized to signal product quality by protecting the reputation of its well-known brand, Pioneer (Spielman and Kennedy, 2016).

Price, on the other hand, is present in all purchase situations. Its pervasive influence on purchasing decisions is explained because it represents to all consumers the amount of money that must be given up to engage in a purchase transaction (Lichtenstein *et al*., 1993). Viewed strictly from this economic perspective, prices have a negative impact on purchase intentions, since high prices negatively affect consumers' budgets. However, from a consumer behaviour perspective, price is also used as a signal of product quality, and viewed in this light, higher prices have a positive influence on purchases probabilities (Monroe and Krishnan, 1985; Lichtenstein *et al*., 1993; Bornemann and Homburg, 2011).

The notion that products with higher prices are associated with higher quality was first postulated by Scitovsky (1945) and is known as the price-perceived quality inference. Based on this premise, several conceptual models have been proposed to test the effect of price independently (Monroe and Krishnan, 1985) or in interaction with other quality signals such as brand (Dodds and Monroe, 1985), store name (Dodds *et al*., 1991; Teas and Agarwal, 2001), market share size (Hellofs and Jacobson, 1999) and advertising (Erdem *et al*., 2008) on consumers' perceptions of quality, value, sacrifice and willingness to buy. This stream of research has shown that the effect of price on perceived quality depends on its interaction with other variables. For instance, Monroe and Krishnan (1985) observed that price had a more positive effect on quality perception when brand information was available. Specifically, in the presence of a well-known (and potentially, more expensive) brand, Lichtenstein *et al*. (1993) pointed out that consumers are likely to rely on the brand as an indicator of quality rather than directly on the price. Akdeniz *et al*. (2013) similarly studied the effect of brand reputation on perceived quality and found that when a brand has a high reputation, consumers are more likely to associate higher quality with higher prices.

Prior research has evaluated the effect of brand on product evaluations, but the impact of brand loyalty in the price-perceived quality literature has not yet been studied. Grewal *et al*. (1998) and Chapman and Wahlers (1999) extended the original price-perceived quality model to include situations where buyers are exposed to a higher reference price and a lower selling price to examine the effect of price comparisons on consumers' perceptions of value and purchasing behaviour. Their results underscore two relevant strategies for enhancing consumers' perceptions of value. Overall, companies can 1) enhance the value of buying a product (i.e., acquisition value) by improving perceptions of its quality or underlining the product's benefits relative to its selling price, or 2) compare a lower selling price to a higher advertised reference price (e.g., was $250, now $210) to stress the price bargain (i.e., transaction value) and enhance value perceptions. These tactics can be used by private firms to develop value-oriented promotions and value-based pricing strategies (Grewal *et al*., 1998) to increase their seed sales.

Developing and maintaining perceived value is a major determinant for creating consumer loyalty (Yang and Peterson, 2004). Both perceived quality and perceived value are essential elements for developing brand strength (Aaker, 1996; Kim, 2012). Strong brands are one of the most intangible assets of private firms and a powerful means to secure a competitive advantage (Kotler and Keller, 2012). Despite the tremendous importance of understanding the relationship between price, brand loyalty, perceived quality and perceived value for expanding hybrid maize seed sales, there is no evidence in the adoption and seed systems literature of whether brand loyalty and price affect seed

choices, how perceived quality and price interact and how their relationship influences perceived value and willingness to buy improved seeds. To date, no empirical study has investigated the role of perceived value in variety choice and seed adoption.

In Mexico, SMEs rely on a high-quality, low-price strategy to commercialize improved maize seeds. However, the price-perceived quality relationship suggests this strategy might be counterproductive because it contains two contradictory cues: high quality and low price. When these cues are combined, they may produce confusion and cognitive dissonance, making it difficult for customers to accept one or the other. For instance, farmers drawn to the low-price cue may reject the high-quality signal, and vice versa (Shirai, 2015). Seed companies also emphasize the communication of objective quality attributes such as high yield, tolerance to drought, resistance to specific pests and diseases, etc., underplaying the role of price, brand and farmers' perceptions of quality and value. This strategy dominates, despite extensive research suggesting that adoption of innovations is based on subjective perceptions or expectations rather than factual truth (Pannell *et al*., 2006).

5.3. Conceptual model

Our conceptual model is based on Chapman and Wahlers' (1999) revised price-perceived quality model. In this model, perceived value is a mediator of willingness to buy and is a trade-off between perceived quality and perceived sacrifice. In this trade-off, the price has a dual effect. On the one hand, price has a positive effect on consumers' perception of quality, i.e., as the price increases, the perception of a product's quality will also increase, and so the product's perception of value. On the other hand, price has a positive effect on consumers' perception of sacrifice, i.e., as price increases, the perception of sacrifice – or the effort a customer needs to make to purchase a product - will also increase, and therefore the perception of the product's value will decline. In a price comparison context, if consumers are offered a discount, they create a perception of quality based on the higher (reference) price and a perception of sacrifice based on the lower (selling) price. The use of discounts can reduce the perceived sacrifice, increase the perception of a product's value and enhance a consumer's willingness to buy. This feature of the model allows us to capture the effect of both, a high and a low price, on farmers' perceptions of value.

Chapman and Wahlers' model has five constructs (unobservable factors or latent variables): perceived quality, perceived value, perceived sacrifice, redemption effort and willingness to buy. We do not, however, measure redemption effort since in our experiment we use discounts and direct price reductions in the shop do not represent any effort. A further change to Chapman and Wahlers' revised model and a contribution to the price-perceived quality literature is the addition of a brand loyalty construct to test the effect of farmers' loyalty on perceived value. Our definition of loyalty is

based on two indicators drawn from the main questionnaire survey: repurchase commitment, i.e., if the farmer had bought the same brand for at least two years; and preference, i.e., if for the actual purchase the farmer bought his most preferred variety[24]. We explain in more detail how we defined our brand loyalty construct in section 5.4.4.1. We also reduced the number of indicators (or questions or observed variables) in Chapman and Wahlers' instrument from fifteen to eight (two indicators measuring each construct) to reduce the complexity of the questionnaire and ensure the survey's completion without losing respondents' attention. The brand loyalty and price-perceived quality model used in this study is shown in Figure 23. The indicators measuring each construct appear in Appendix D (Q5.1-Q5.8). In what follows, we describe the model constructs according to the relevant existing literature.

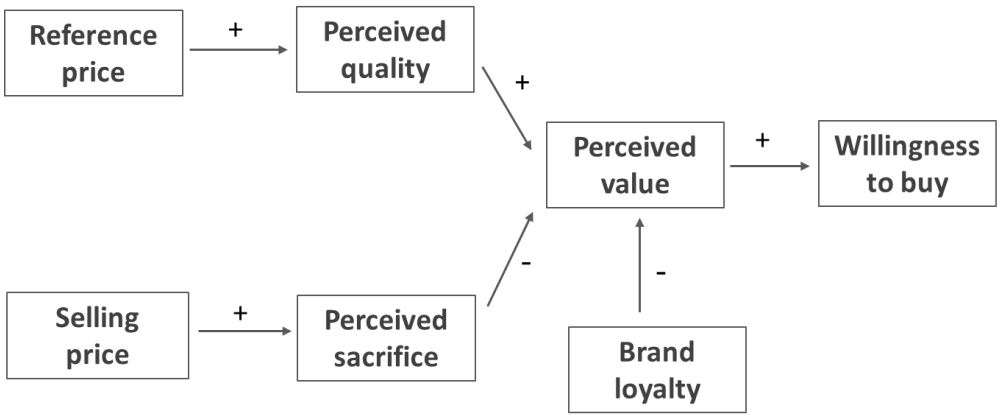


Figure 23 |Conceptual model evaluating willingness to buy hybrid maize seed based on brand loyalty and price-perceived quality. Source: Author, based on Chapman and Wahlers (1999)**.**

5.3.1. Model constructs

5.3.1.1. Perceived quality

Perceived quality is the consumers' judgement of a product's overall superiority (Zeithaml, 1988). As opposed to objective quality, which refers to the product's technical measurable excellence (e.g., yield), perceived quality refers to the consumer's subjective evaluation of a product's performance based on perceptions, feelings or beliefs (Olson, 1972; Steenkamp, 1990). The quality of a product is generally evaluated in a comparative context, i.e., among a set of alternatives, and is highly dependent on personal and situational aspects (Zeithaml, 1988; Steenkamp, 1990). Research strongly supports the positive effect of price on perceived quality evaluations (Monroe and Krishnan, 1985; Dodds and Monroe, 1985; Rao and Monroe, 1988; Chapman and Wahlers, 1999) but recognizes its effect depends on its interaction with other variables. Monroe and Krishnan (1985)

[24] Commitment and preference are binary variables of brand loyalty. For commitment the value is -1 if the seed had been purchased for less than 2 years, or 1 if the seed had been purchased for 2 years or more. It is the continuous variable of the (scale square root transformed) number of years the seed has been bought. For preference the values span from -1 to 1.

observed that quality perceptions based on the price differ when brand information is available. Specifically, in the presence of a well-known (and potentially more expensive) brand, consumers are likely to rely on the brand as an indicator of quality rather than directly on the price (Lichtenstein *et al*., 1993). In the context of comparative pricing, Chapman and Wahlers (1999) report a positive relationship between the reference price and perceived quality but Grewal *et al*. (1998) found that neither the reference price nor the selling price affected consumers' perceptions of quality.

5.3.1.2. Perceived sacrifice

Perceived sacrifice is the perception of what must be given up to buy a product (Chapman and Wahlers, 1999). Zeithaml (1988) and Holbrook (1999) suggest that perceived sacrifice consists of a monetary component (e.g., price) as well as nonmonetary resources such as time, search costs, and physical efforts. For instance, if farmers cannot find the seed in the nearest store, and need to search in different shops or travel long distances to make a purchase, a sacrifice is made. For consumers for whom the price is determinant, anything that reduces their sacrifice (e.g., coupons, discounts) will increase perceived value. For others, store proximity, prompt availability or time will be more important (Zeithaml, 1988). Buyers' perception of sacrifice depends on several different factors such as the type of product, the perceived unfairness of the price, or the perceived superiority of a brand compared to competing brands (Monroe, 2012). Overall, researchers widely agree that perceived sacrifice reduces perceived value in single (Monroe and Krishnan, 1985; Agarwal and Teas, 2001) or comparative (Chapman, 1993; Chapman and Wahlers, 1999) price situations.

5.3.1.3. Perceived value

Perceived value is an overall assessment of a product's utility based on perceptions of what is received in exchange for what is given (Zeithaml, 1988). This utility is based on a tradeoff between the perceived benefits of an offer (quality) and the perceived cost (sacrifice) (Thaler, 1985; Chapman and Wahlers, 1999; Monroe, 2003). This may include perceived quality, intrinsic and extrinsic attributes or any other benefits for the consumer such as convenience, pleasure or prestige (Zeithaml, 1988; Holbrook, 2006). Some researchers distinguish between acquisition value or the net gain obtained from a purchase, and transaction value which refers to the buyers' perceived gains or satisfaction obtained from a deal (Chapman and Wahlers, 1999; Grewal *et al*., 1998)[25]. A high perceived value is a determinant factor of consumers' purchasing decisions and a primary driver for encouraging repeat purchases and consumer loyalty (Yang and Peterson, 2004; Kim, 2012). Several

[25] Transaction value is also defined as "*the pleasure buyers get from finding and taking advantage of a price deal*" (Grewal *et al*., 1998).

studies have demonstrated the significant positive influence of perceived quality on perceived value and the negative effect of perceived sacrifice on perceived value (Monroe and Krishnan, 1985; Dodds and Monroe, 1985; Rao and Monroe, 1988; Chapman, 1993). Kim (2012) also found that perceived value has a dominant role in the creation of strong brands and is positively related to brand loyalty.

5.3.1.4. Brand loyalty

Brand loyalty is "*the biased, behavioural response expressed over time by some decision-making unit towards one or more alternative brands, and is a function of psychological decision-making, evaluative processes*" (Jacoby and Kyner, 1973 p.2). Aaker (1996, p.39) defines loyalty as "*the attachment that a customer has to a brand*" while Oliver (1999) and Kotler and Keller (2012 p.127) similarly describe it as "*a deeply held commitment to rebuy a preferred product or service consistently in the future, thereby causing repetitive same-brand or same brand-set purchasing, despite situational influences and marketing efforts having the potential to cause switching behaviour*".

Loyal customers display little sensitivity to price, reduced interest in searching for information and evaluating other alternatives and strong resistance to persuasion (Yang and Peterson, 2004; Dick and Basu, 1994). Yang and Peterson (2004) showed a positive significant influence of consumer loyalty on perceived value. Lee *et al*. (2019) found a positive significant influence of perceived (acquisition and transaction) value on consumer loyalty. We hypothesize that farmers are loyal to seeds of multinational companies and this loyalty will reduce perceived value and willingness to buy new improved hybrids. Because farmers are loyal to well-established multinational brands, it is difficult for them to evaluate a new seed choice positively. We therefore expect brand loyalty to exert a negative influence on the perceived value of new seed varieties.

5.3.1.5. Willingness to buy

Willingness to buy is the likelihood that a buyer will purchase a product (Grewal *et al*., 1998). If the perception of quality is higher than the perception of sacrifice the perceived value will be positive and the consumer will have a higher willingness to buy (Chapman and Wahlers, 1999). We hypothesize that brand loyalty will decrease perceptions of value and reduce intentions to purchase newly introduced – and therefore unknown – maize seed hybrids.

5.3.2. Hypothesis and research questions

Based on the relationships postulated in the literature and by the revised price-perceived quality model proposed by Chapman and Wahlers (1999), our hypotheses are:

H1. There is a positive relationship between the reference price of a seed and the seed's perceived quality – as seed price increases, farmers' perceptions of seed quality will also increase.

H2. There is a positive relationship between the selling seed price (after any discount) and perceived sacrifice – as the selling price decreases, perceived sacrifice will also decrease.

H3. There is a negative relationship between perceived sacrifice and the seed's perceived value – the higher the monetary sacrifice a farmer needs to make to buy the seed, the lower the seed's perceived value.

H4. There is a positive relationship between the seed's perceived quality and the seed's perceived value – as the seed's perceived quality increases, perceived value will also increase.

H5. There is a negative relationship between brand loyalty and seed's perceived value – in the presence of brand loyalty, the perceived value of newly introduced unknown hybrids will decrease.

H6. There is a positive relationship between the seed's perceived value and willingness to buy – the higher the seed's perceived value, the higher the chances a farmer will buy the seed.

Brand loyalty and a positive high-price high-quality perception will negatively influence willingness to buy low-priced hybrids, functioning as a barrier to entry for new – unknown – seeds, and hindering SMEs' capacities to expand their market shares. To test these hypotheses, we address the following research questions:

1. What are the key determinants of farmers' seed purchase decisions?
2. Is there a high price-high quality perception of hybrid maize seed?
3. How do brand loyalty and price-perceived quality affect willingness to buy new maize hybrids?

5.4. Research method

5.4.1. Study area

Data were collected in La Frailesca, Chiapas, Mexico during the 2019 spring-summer maize cropping season from intercept interviews with farmers after they purchased maize seed in agro-dealer

stores. Chiapas was chosen because it ranks first among the states of Mexico in the area planted to maize (0.69 Mha) and eighth in terms of maize production (1.25 MT). Despite the state's remarkably important place in maize farming, maize yields are very low (2.7 t/ha) and farmers' use of improved seeds is only 32%. In the state, more than 95% of the area and maize production is rainfed, where yields (1.7 t/ha) are far below the national average (4.2 t/ha). The yield gap is about 5.1 t/ha if Chiapas is compared to leading producing states such as Jalisco, the second most important maize producer, whose average rainfed maize yield is 6.8 t/ha (SIAP, 2016; SIAP, 2020a). The surprisingly low yields, the extensive area under maize cultivation and low adoption rates for improved seeds combine to represent an opportunity for seed companies to increase the use of hybrid maize specifically adapted to rainfed conditions and expand their seed sales.

The seed offer in the state is diverse and differentiated. An exploratory fieldwork trip before data collection (February-March 2019) allowed the identification of fifteen producing companies selling improved maize seed: three multinationals (Bayer-Monsanto, Corteva Agriscience and Syngenta) and twelve nationals. Bayer-Monsanto and Corteva Agriscience are large companies with annual seed sales above 5,000 t, Syngenta and three national companies are of medium size, selling over 1,000 t annually, three more national companies are small (200-1,000 t) and another six are micro-enterprises (annual sales below 200 t). Corteva Agriscience offered the most varied number of seed products, including Pioneer and its new line Brevant, Corteva's cheaper brand launched for the first time in the Mexican market during the sales year of data collection of this study. Bayer-Monsanto similarly offered a range of seed options to farmers in terms of differentiated products representing its well-known brands Dekalb, Cristiani and Asgrow. Several small national companies such as American seeds, Proase and Zarco marketed a wide but undifferentiated number of seeds while other national firms and Syngenta had only about two to four products in the market.

Seed prices in Chiapas vary according to region, seed type and colour. However, the average retail price of a hybrid maize seed bag is USD$ 91.6 (USD$ 4.6/kg). A bag produced by national firms is USD$ 69.9 (USD$ 3.7/kg) compared to USD$ 104.1 (USD$ 5.5/kg) for seed produced by multinational companies (Table 12) (SNICS, 2017a). As observed, seeds of multinational companies have a price premium of about 30% over the seeds produced by national firms.

Table 12. Average retail seed prices by seed producer in Chiapas, Mexico.

Producer	MX$		USD$	
	Per bag	Per kg	Per bag	Per kg
National	1,398	69.9	73.55	3.7
Multinational	2,082	104.1	109.60	5.5

Source: SNICS (2017).

Within Chiapas, we selected the region of La Frailesca, given its importance in the production of maize (15% of the total in the state) and the number of agro-dealers offering a diverse quantity of seed products and brands (national and international). We then concentrated in the municipalities of Villaflores, Villacorzo and La Concordia, which together account for over 90% of the area planted and maize production in the region (Figure 16 Chapter 4). La Frailesca is one of the most commercially dynamic maize seed markets in Mexico. All multinational and several domestic seed companies operate in the region. Reflecting the structure of the Mexican maize seed industry, seed sales in the region are expected to be highly concentrated. In Mexico, in 2019 two multinational companies (Bayer-Monsanto and Corteva Agriscience) accounted for over 75% of the Mexican maize seed market. One firm alone (Bayer-Monsanto) made 60% of the total maize seed sales (Figure 15, Chapter 4). These market conditions make La Frailesca Chiapas an ideal context for testing our hypothesis on brand loyalty and perceived quality perception.

5.4.2. Sampling and data collection

A list of agro-dealers (N=36) was obtained from the National Directory of Economic Units (DENUE) of the National Institute of Statistic and Geography (INEGI, 2018), the National Seed Inspection and Certification Service (SNICS, 2017b) and the MasAgro seed marketing survey (CIMMYT, 2019a). This original list was amended (N=63) during our exploratory fieldwork trip before the start of the seed sales season in February and March 2019. Only 28 stores were confirmed as selling improved maize seeds. From these, a sub-sample of nine agro-dealers was chosen for conducting a post-purchase intercept interview with maize seed customers.

The team moved to Chiapas two weeks in advance to contextualize the study. The questionnaire was tested with maize seed customers in selected shops in the region, adapted and tailored to the local context and the farmers' language. The final survey was carried out during the seed sales peak season (from 13-29th June 2019) using tablets and the Google ODK software. Seed clients were intercepted when coming out of selected agro-dealer stores (n=9) for a short 20-25 minute post-purchase intercept interview. We conveniently selected farmers who purchased or had previously purchased at least one bag of maize seed from agro-dealers. In total 391 maize farmers coming from 7 different municipalities, but mainly from our study area (97%) were interviewed (Figure 16).

The intercept interview covered four topics: 1) farmers' socioeconomic and farming characteristics; 2) maize seeds purchased, including the variety's exact name, the number and size of bags bought, the price and other characteristics; 3) reasons for continuing to buy or changing their maize variety; and 4) engagement with the agro-dealer and information exchange during the purchase (see section 4.5.2.1). A subsection of the questionnaire (Appendix D, Q5.1-Q5.8) was allocated to gather

information on farmers' price-quality perception of hybrid maize seed. This section contained eight questions, two for each construct of our conceptual model. All questions followed a seven-point Likert scale as shown in Table 13.

Table 13. Price-quality perception questions of the intercept interview survey and their measurement scales.

Construct	Question	Measurement scale
Perceived quality	Q5.1. In terms of quality, how would you qualify this seed?	1. Very poor, 2. Moderately poor, 3. Slightly poor, 4. Neither good nor poor, 5. Slightly good, 6. Moderately good, 7. Very good.
	Q5.2. Based on the information presented, do you believe this seed is reliable?	1. Very unreliable, 2. Moderately unreliable, 3. Slightly unreliable, 4. Neither reliable nor unreliable, 5. Slightly reliable, 6. Moderately reliable, 7. Very reliable.
Perceived value	Q5.3. Overall, do you believe that this seed is worth its price?	1. Strongly disagree, 2. Moderately disagree, 3. Slightly disagree, 4. Neither agree nor disagree, 5. Slightly agree, 6. Moderately agree, 7. Strongly agree.
	Q5.4. How good do you think the offer of this seed is?	1. Of very poor value, 2. Of moderately poor value, 3. Of slightly poor value, 4. Neither good nor poor value, 5. Of slightly good value, 6. Of moderately good value, 7. Of very good value.
Willingness to buy	Q5.5. Given the offer described, would you be willing to buy this seed?	1. Very unwilling, 2. Moderately unwilling, 3. Slightly unwilling, 4. Neither willing nor unwilling, 5. Slightly willing, 6. Moderately willing, 7. Very willing.
	Q5.6. How likely are you to buy it?	1. Very unlikely, 2. Moderately unlikely, 3. Slightly unlikely, 4. Neither likely nor unlikely, 5. Slightly likely, 6. Moderately likely, 7. Very likely.
Perceived sacrifice	Q5.7. Do you think this seed is expensive at this price?	1. Strongly disagree, 2. Moderately disagree, 3. Slightly disagree, 4. Neither agree nor disagree, 5. Slightly agree, 6. Moderately agree, 7. Strongly agree.
	Q5.8. Given the offer described and the amount of money you have available for the production of maize, how difficult would it be for you to buy this seed?	1. Very easy, 2. Moderately easy, 3. Slightly easy, 4. Neither difficult nor easy, 5. Slightly difficult, 6. Moderately difficult, 7. Very difficult.

Source: Author, based on Chapman and Wahlers (1999).

Farmers interviewed were mostly male and were on average 51 years old with a low level of education (Table 14). For more than 95% of farmers in all study locations, maize production was a major source of income, about 40% also depended on animal husbandry, around 30% on the production of other crops and some also worked as farm labourers. The sampled farmers had on average 13.9 ha (own+ rented) of land available for farming and planted about 4.7 ha with maize. They were experienced users of improved varieties, having been planting hybrids for an average of 10 years. Less than 7% reported that they had used improved seeds for only two years and no more than 4% planted their own-saved seed. Accordingly, they were commercial and market-oriented farmers and expected to produce about 6.1 t/ha, which is high compared to the national (2.5 t/ha) and state (1.7 t/ha) average maize production in rain-fed conditions reported by SIAP (2020a).

Table 14. Key seed customers' socioeconomic and farming characteristics.

	Mean	Villaflores	Villacorzo	La Concordia
Male respondents (%)	98.5	97.9	99.1	98.9
Age (years)	51.5	52.2	51.8	49.8
Education (%)				
No formal education	21.7	20.3	25.5	20.2
Elementary school	44.0	47.1	41.8	40.4
Secondary school	17.1	16.6	14.5	21.3
High school or technical training	10.0	10.2	9.1	10.6
University	7.2	5.9	9.1	7.4
Sources of income (%)				
Maize production	99.0	98.9	98.2	100.0
Other crops	28.3	26.7	39.1	19.1
Animal husbandry	39.5	30.5	45.5	42.6
Farm labourer	13.5	17.1	12.7	10.6
Farming characteristics				
Farming area (ha)	13.9	12.3	15.8	15.0
Area under maize (ha)	4.7	4.5	4.4	5.5
Area planted to improved seed (ha)	4.6	4.4	4.3	5.5
Average expected yield (t/ha)	6.1	6.1	6.2	6.1
Years using improved seed	9.9	9.8	10.1	10.0

Source: Post-purchase intercept interviews with farmers at agro-dealers.

5.4.3. Quality perceptions research design

5.4.3.1. Price treatments

A reasonable price range was established based on the lowest and the highest current market prices. The lowest market price of a bag of hybrid maize seed in Chiapas, according to data from the 2018 MasAgro seed marketing survey (CIMMYT, 2019a), was MX$1,050. There were lower prices in the range of MX$650-900 but these corresponded to OPVs. The most common price observed during our exploratory visit was MX$2,500 (USD$ 131.6) although some hybrids could reach up to MX$2,800 (USD$ 147.4). According to these observations, an acceptable price range for farmers of a high-quality bag of sixty thousand seeds would be between MX$1,000 (USD$ 52.6) and MX$2,800 (USD$ 147.4). Therefore, we decided to use five different price treatments between MX$1050 and MX$2,500 as shown in Table 15, of which three included high reference prices with discounts to measure the effect of perceived sacrifice.

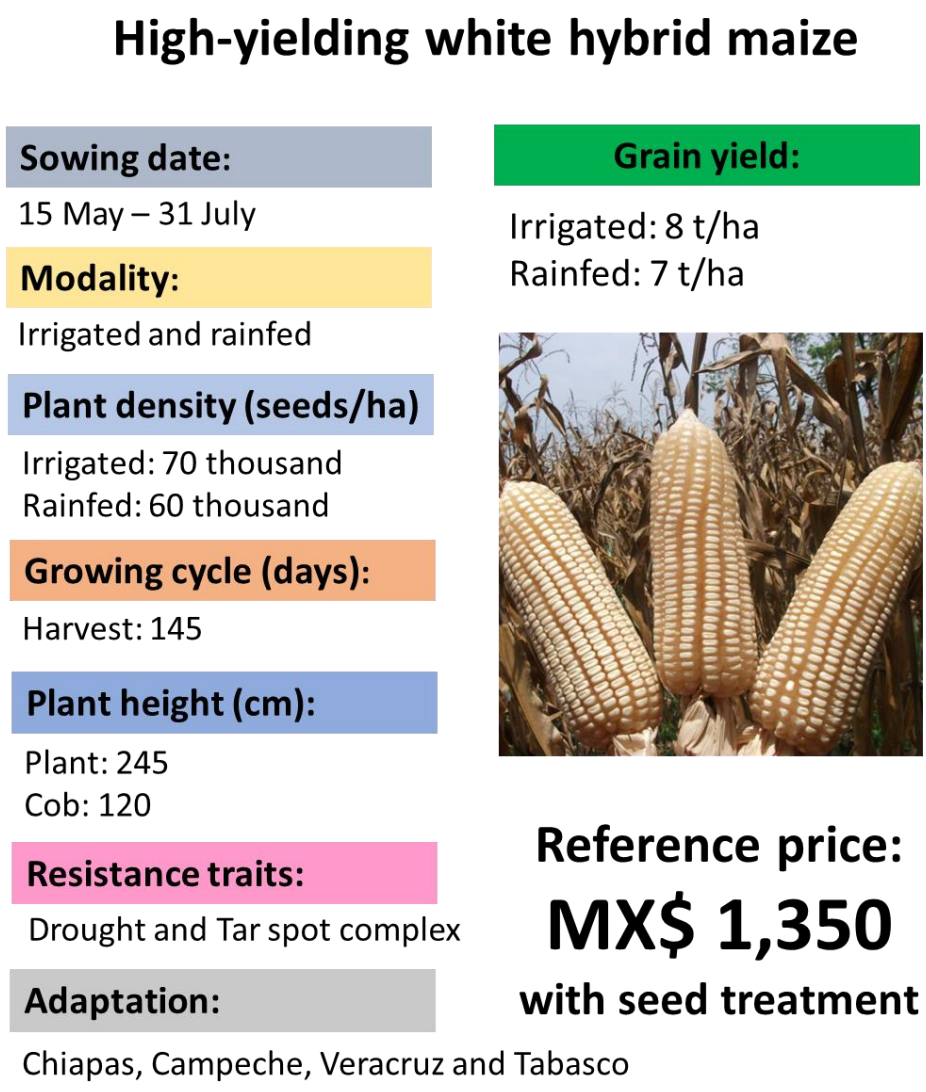
Table 15. Price-perceived quality treatments, prices in MX$.

	A	B	C	D	E
Reference price	1,050	1,350	2,500	2,500	2,500
Discount	0	0	200	350	500
Selling price	1,050	1,350	2,300	2,150	2,000

Source: Author.

5.4.3.2. Treatment allocation

Farmers were asked to pick a card at random from a pile of treatment cards and presented with a generic seed choice depending on their selection. All treatments contained the same information except for the reference price charged (i.e. $1,050, $1,350, $2,500) and the discount ($200, $350, $500 or no discount). We then used separate colourful description sheets, according to the treatment card picked, to explain the generic seed offer to farmers without reference to any brand or seed name (Figure 24).



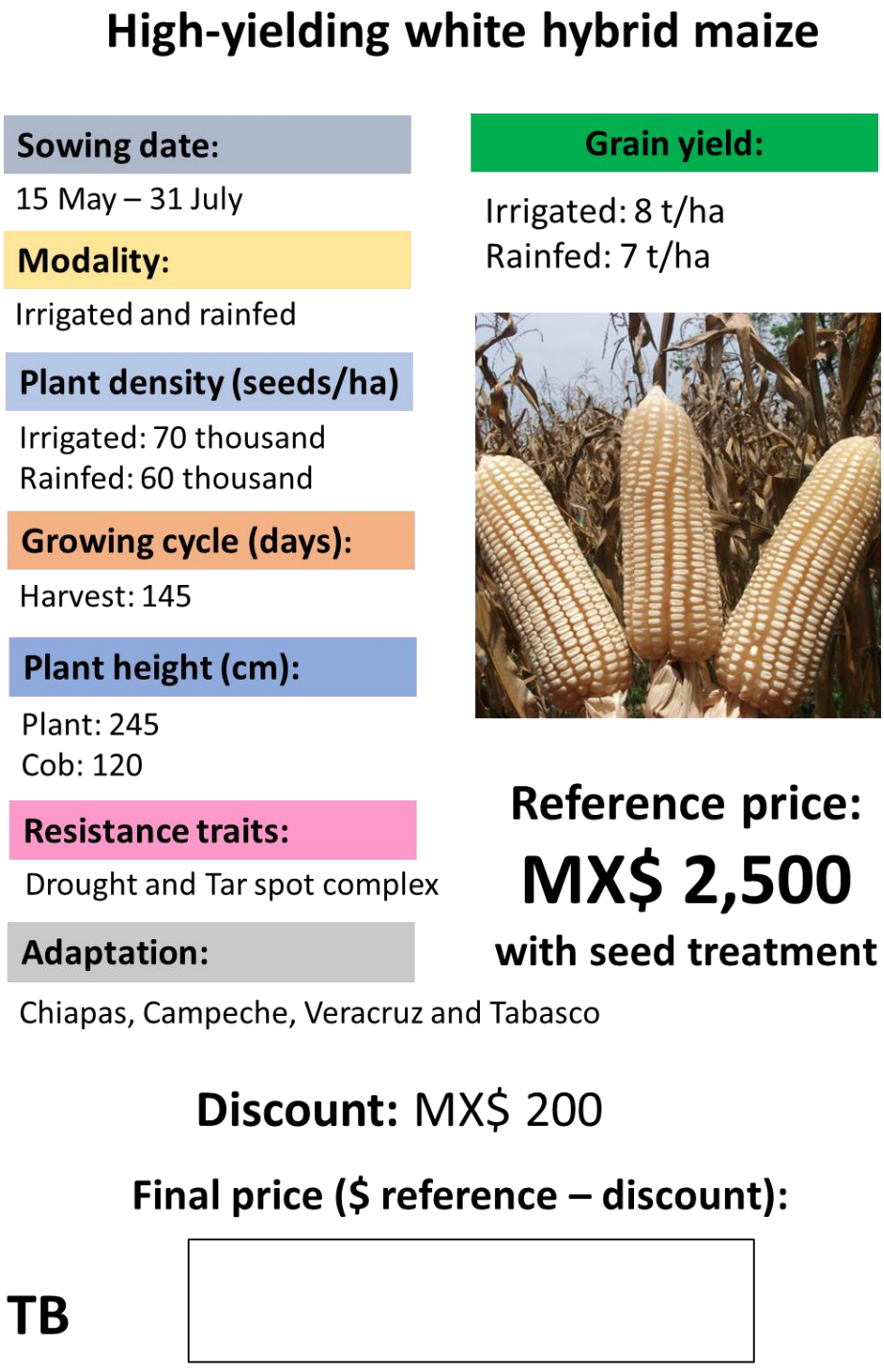


Figure 24 | Price-perceived quality description treatment cards for hybrid white maize seed. Example treatment A (TA) without discount, and treatment B (TB) with discount. Source: Author.

The hybrid description corresponded to a high yielding (8.0 t/ha in irrigated and 7.0 t/ha in rainfed conditions) white maize hybrid resistant to drought and the Tar spot complex, a common disease in the region (Figure 24)[26].

[26] The Tar spot complex (TSC) is one of the most important foliar diseases in tropical maize caused by the interaction of at least three fungal species: *Phyllachora maydis; Monographella maydis and Coniothyrium phyllachorae* (Cao *et al*., 2021).

Finally, farmers were asked to calculate the final selling price of the seed (with final reference price and discount, if any) after all the attributes of the offer were explained, and we applied the price-perceived quality subsection of the intercept interview. The exercise was assisted by visual test scales for each quality perception question to help farmers to understand the direction and magnitude of the seven-point Likert scales (Figure 25).

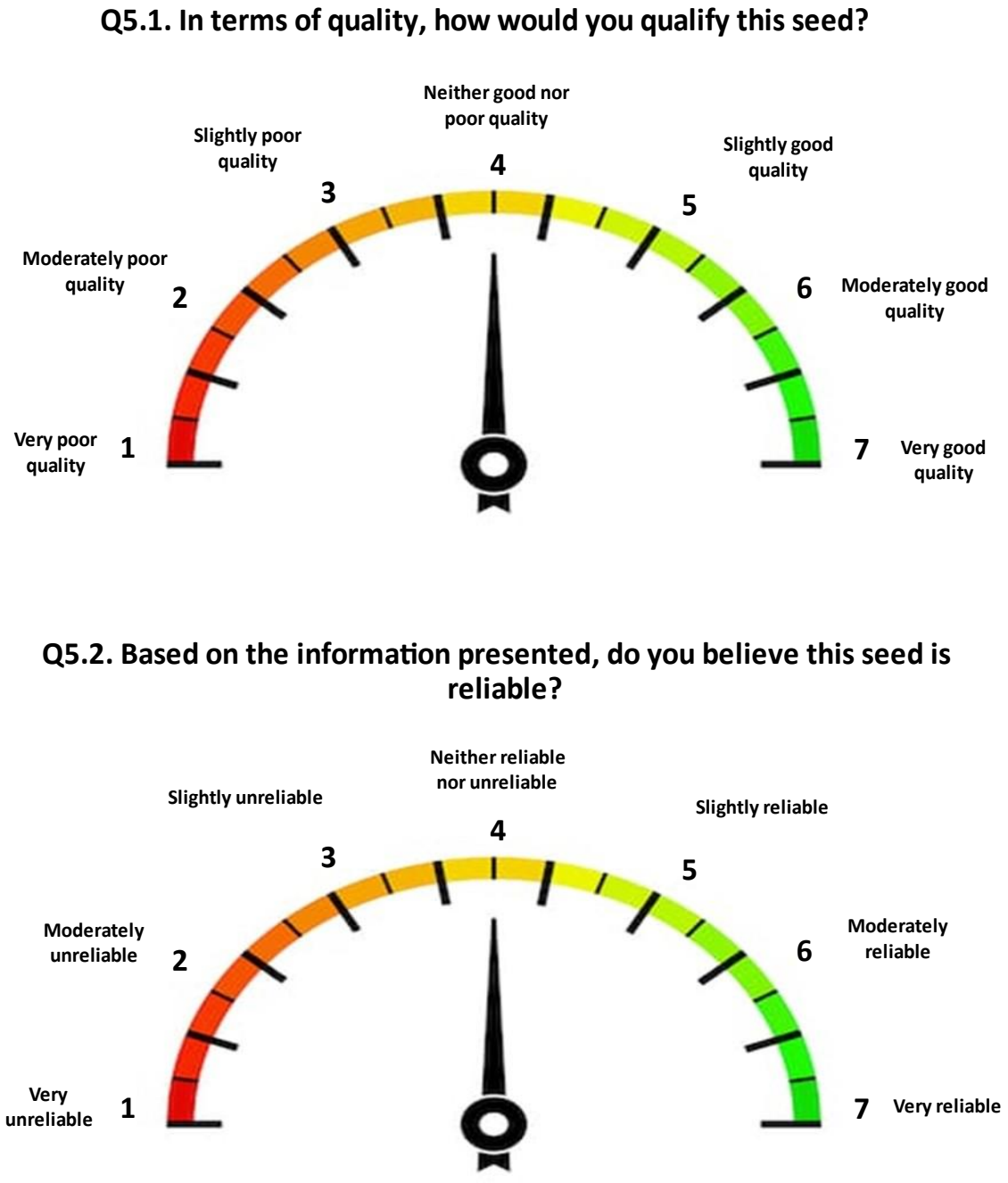


Figure 25 | Price-perceived quality visual aid test scales. Examples Q.5.1 and Q5.2 of the price-perceived quality subsection of the post-purchase intercept interview questionnaire. Source: Author.

5.4.4. Data analysis

5.4.4.1. Determinants of farmers' seed purchasing decisions

Seed purchasing decisions were analysed using descriptive statistics. Brand loyalty was assessed based on prior definitions of loyalty and selected indicators drawn from the marketing literature. Both analyses were derived from the main questionnaire survey.

Prior research has investigated brand loyalty from two main perspectives. The behavioural school considers loyalty as a behaviour and defines it in terms of repeat purchases. The limitation of this approach is that it captures only the static outcome of a dynamic process and makes no attempt to understand the factors that influence repeat purchases. For example, repeat buying may reflect situational constraints such as brands stocked by retailers or availability (Jacoby and Chestnut, 1978; Dick and Basu, 1994). The attitudinal school emphasizes the buyer's strong internal disposition to repatronize the same brand and the underlying factors behind the purchase, e.g., preferences, motivations for the consumers' choice (Mellens *et al*., 1996).

The attitudinal component of brand loyalty measures the strength of the individual's attitude that leads to repeat purchase behaviour and resistance to brand substitution despite situational changes in the environment (Dick and Basu, 1994; Amine, 2011). The use of behavioural or attitudinal measures alone has been considered insufficient to measure brand loyalty accurately, and research acknowledges that brand loyalty is better understood using both approaches together (Jacoby and Kyner, 1973; Dick and Basu, 1994; Mellens *et al*., 1996; Odin *et al*., 2001).

Jacoby and Kyner (1973) suggest six necessary requirements for defining brand loyalty: 1) a customer must systematically buy the same brand, and nothing can alter this purchase disposition; 2) an actual purchase must take place: verbal reports of bias, such as a stated preference or intention to purchase are insufficient to define brand loyalty; 3) there must be a consistent repurchase commitment to the brand for at least two different points in time; 4) the decision-maker can be the user or the purchaser of the product, or a group of individuals involved in the decision process, e.g., one or more members of a family or a household; 5) a customer must be exposed to different brands and choose one or more brands out of a set of alternatives, and; 6) several brands are compared and evaluated in a psychological process, by which the optimal brand or brands are chosen. Following these definition guidelines and as suggested by previous research, we use both approaches (behavioural and attitudinal) for assessing brand loyalty among farmers in La Frailesca, Chiapas. The indicators and the data required to operationalize our brand loyalty measurement were drawn from the questions shown in Table 16.

Table 16. Indicators of brand loyalty, measure type and questions to derive our brand loyalty measurement.

Indicator	***Measure type***	***Question***
Actual purchase (market shares)	behavioural	Which maize variety(ies) did you buy and what quantity?
Price premium	attitudinal	Which price did you pay?
Certainty	attitudinal	Before entering the shop, how sure were you about the variety/brand you wanted to buy?
Searching	attitudinal	Did you ask any questions about the maize seed you bought or any other available seed in the store?
Resistance to persuasion	attitudinal	Did the store attendant recommend an alternative variety to you? If yes, did you follow his/her advice?
Preference	attitudinal	Is this your most preferred variety?
Switching	behavioural	Are you buying this variety for the first time? If yes, which variety did you buy last year/season?
Repurchase commitment	attitudinal	If no, how many years in a row have you used this variety?
Motivations for the consumer's choice	attitudinal	If no, why did you decide to continue with the same maize variety? If yes, why did you decide to change your maize variety?

Source: Post-purchase intercept interviews with farmers at agro-dealers.

5.4.4.2. Price-quality perception

The perceived-quality relationship analysis uses the price-perceived quality relationship subsection of the survey questionnaire (Appendix D, Q5.1-Q5.8) and was made using Structural Equation Modelling (SEM).

SEM is a multivariate statistical technique for examining the relationship among variables and testing hypotheses (Bagozzi and Yi, 2012). SEM can be thought of as a form of multiple regression in which a set of p independent variables, X= {X1, X2, …, Xp} is used to predict a single dependent variable, Y, i.e., {X1, X2, …, Xp} → Y (Iacobucci, 2009). The difference from multiple regression and one major advantage of SEM is that SEMs typically include two or more equations in the model to measure the relationship among multiple variables or concepts and graphically express these relationships in path diagrams using arrows (Nachtigall *et al*., 2003; Bollen and Noble, 2011). SEM can deal with several models that are not estimable via regression. For instance, the mediation chain X→M→Y can be approximated with two sequential regressions, i.e., X→M and M→Y, but fitting both paths simultaneously in SEM {(X→M), (M→Y)} yields more precise estimates as indicated by smaller standard errors (Iacobucci, 2009).

There are two major types of variables in SEM: latent variables and observed variables. Latent variables (constructs or factors) are variables that are not directly observable or measured but are indirectly measured using tests, surveys, etc. The observed variables (measures or indicators) are

variables for which we have values and are used to define or infer the latent variable or construct (Schumacker and Lomax, 2004; Iacobucci, 2009; Bollen and Noble, 2011). For example, the questions Q5.1. How would you qualify this seed? and Q5.2. Do you believe this seed is reliable? in our questionnaire survey produced measured variables to infer the construct of perceived quality.

SEM also consists of a measurement model and a structural path model. The measurement model specifies the relations of the indicators (observed variables) to the constructs (latent variables) using Confirmatory Factor Analysis (CFA). The CFA tests whether a set of indicators define a construct and what indicator is the most closely related to the latent variable (Bollen and Noble, 2011). The structural path model uses correlation coefficients and regression analysis to specify the relationships within constructs as postulated by some underlying theory (i.e., perceived quality increases perceived value). The final model is a Structural Equation Model which essentially combines confirmatory factor models and path models that incorporate both latent and observed variables (Anderson and Gerbing, 1988; Schumacker and Lomax, 2004).

The SEM analysis involved three steps as suggested by Iacobucci (2009), Bollen and Noble (2011) and Bagozzi and Yi (2012):

1) Estimate the measurement model. In the measurement model, we first verified the validity and reliability of the questionnaire indicators and the indicators' ability to measure the construct consistently using CFA.
2) Assess how well the specified model accounts for the empirical data (model fit). We assessed the overall fit of the data to the conceptual model using the following goodness-of-fit measures: the Chi-square, the Chi-square/degrees of freedom ratio ($\chi 2$/df ratio), the Root Mean Square Error of Approximation (RMSEA), the Standardized Root Mean Square Residual (SRMR), the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI) and the Comparative Fit Index (CFI).
3) Estimate the path model. Finally, we calculated the path coefficients of the hypothesized relationships to validate or reject our hypothesis.

The use of factor analysis in the measurement model (step 1) and path analysis in the structural model (step 3) allows the separation of the measurement error from the error attributable to a model's lack of fit. This is a second major advantage of SEM over regression analysis because 1) it facilitates the diagnosis of poor measures or model misspecification, and 2) it reduces the problem of multicollinearity by discarding indicators that probably measure more than one construct (Iacobucci, 2009).

The model was estimated using Weighted Least Squares (WLS). This method is an alternative to the Maximum Likelihood (ML) estimator when variables are ordinal, such as our data in the price-perceived quality relationship subsection of the questionnaire, and when data do not follow a normal distribution (Nachtigall *et al.*, 2003). All the analysis was performed using the lavaan package in R.

5.5. Results

5.5.1. Determinants of farmers' seed purchasing decisions

5.5.1.1. Seed purchases

Figure 26 shows the market share of maize seeds purchased by intercepted farmers at selected agro-dealer stores.

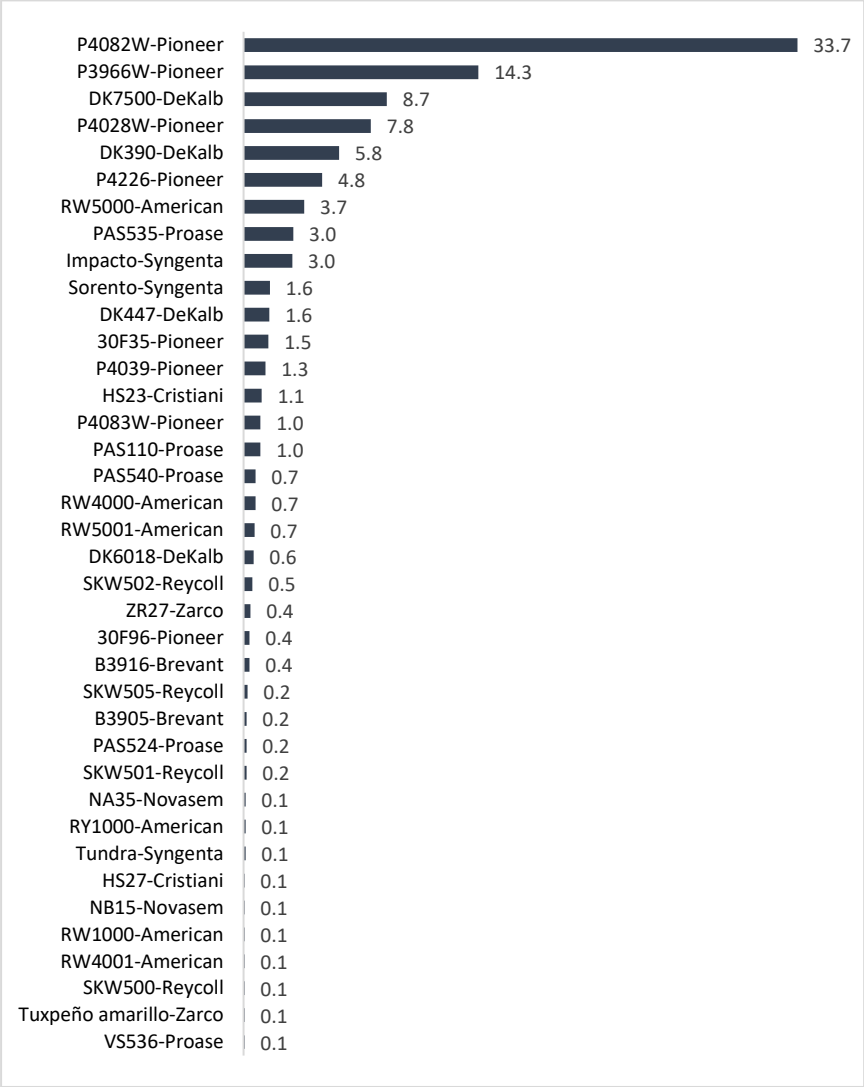


Figure 26 | Market share of maize seed varieties purchased during the 2019 spring-summer season in La Frailesca, Chiapas. Pioneer and Brevant are brands of Corteva Agriscience while Dekalb and Cristiani belong to Bayer. Proase and Reycoll seed products with the PAS and SKW acronyms are recently developed MasAgro hybrids. Source: Post-purchase intercept interviews with farmers at agro-dealers.

Farmers bought a total of 38 seed products from three multinational (Corteva, Bayer-Monsanto and Syngenta) and five national companies (Figure 26). However, a few multinational hybrids concentrated seed purchases: five varieties of Pioneer and DeKalb accounted for 70% and one single variety of Pioneer (P4082W) captured 34%. Together, purchases of hybrid maize seeds of multinational companies represented 88% while the share of recently introduced MasAgro hybrids was 6.0%. All varieties purchased were private hybrids except for Tuxpeño amarillo and VS536, both public OPVs.

A farmer bought on average 3.3 bags of seed among 10 different available brands at an average price of MX$2,296 (US$120.8) (Table 17). About 65% of customers bought Pioneer despite it was the most expensive brand, another 17% purchased DeKalb and 4.9% bought Syngenta. The leading brands of the multinational companies (Pioneer, DeKalb and Syngenta) had the highest prices and maintained an average 23% premium over the average price of a seed bag produced by national firms (Figure 27).

Table 17. Overview of maize seed brands purchased during the 2019 spring-summer season in La Frailesca, Chiapas (n=500).

Total number of different maize varieties purchased	38
Number of different brands purchased	10
Average number of bags purchased (SD)	3.3 (4.2)
Average price in MXN$ of seed varieties purchased (SD)	2,296 (344)
Average price of a seed bag from multinational companies (SD)	2,286 (220)
Average price of a seed bag from national companies (SD)	1,775 (287)

Brand	Market share (% - bags sold)	Average expected yield (t/ha)	Price (MX$)			
			Mean	Max	Min	SD
Pioneer	64.7	6.1	2,397	3,400	1,200	297
Dekalb	16.7	6.4	2,270	3,600	1,275	292
Syngenta	4.9	6.2	2,190	2,400	2,100	71
Brevant	0.5	6.5	1,863	1,950	1,700	111
Cristiani	1.2	5.3	1,450	1,500	1,400	58
American	5.3	5.6	1,950	2,500	1,400	203
Proase	5.0	6.4	1,597	2,200	620	558
Reycoll	1.0	5.7	2,033	2,500	1,700	280
Novasem	0.2	5.7	1,595	1,700	1,485	108
Zarco	0.5	n/d	1,700	1,700	1,700	n/d

Source: Post-purchase intercept interviews with farmers at agro-dealers.

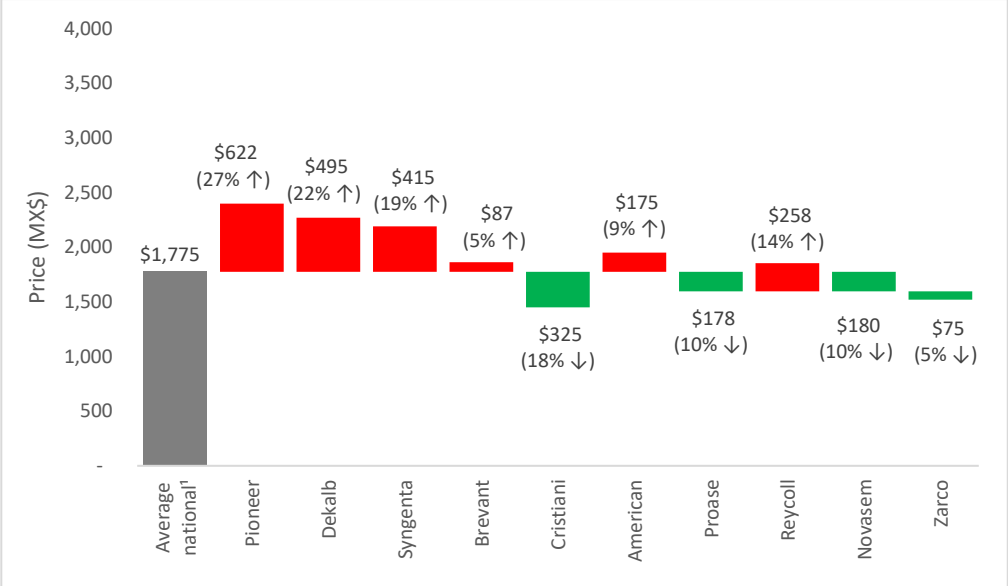


Figure 27 | Price differentials of multinational and national brands of hybrid maize seed in La Frailesca, Chiapas - MX$ (n=467). n is the number of observations for bags of sixty thousand seeds found in the survey; [1]Price differentials are based on the average seed price per bag of brands of national companies. Source: Post-purchase intercept interviews with farmers at agro-dealers.

5.5.1.2. Farmers' buying behaviour

Most intercepted buyers were single decision-makers, i.e., they decided on their purchase without consultation (Table 18). They showed a high level of certainty about the seed they wanted to buy, little interest in searching for information and strong resistance to persuasion. When entering the store, 92.8% of farmers were sure about what seed they wanted to buy, 90.8% of these farmers found that variety available and most of them (90.3%) bought it. Only around a third of seed customers engaged in seeking information: 37% of farmers asked for information about the seed they bought and 33% looked for information about other seeds available in the store. A quarter of the farmers received advice from the agro-dealer, but only 5% followed the store attendant's recommendation.

Table 18. Farmers' buying behaviour at agro-dealer stores in La Frailesca, Chiapas.

Behaviour	Mean (%)
Type of decision-making (N=391)	
Own decision (no consultation)	86.6
Shared decision (discussion with someone else)	13.4
Certainty (N=391)	
Was sure about what seed to buy	92.8
Variety sought was available	90.8
Purchased seed variety sought	90.3
Information searching (N=391)	
Asked about the seed purchased	36.9

Asked about other available seeds	33.0
Resistance to persuasion (N=391)	
Received advice from agro-dealer (seed bought or other seeds)	23.2
Followed agro-dealer's recommendation	5.0
Preference (N=500)	85.8
Switching (N=500)	
Switched variety from previous year	22.2
Switched brand from previous year	18.4
Repurchase commitment (N=500)	
≥2 years	72.0
≥3 years	48.4
≥5 years	21.8

Preference, if the farmer bought his/her most preferred variety; repurchase commitment, if the farmer had bought the same brand for at least 2,3, or 5 years. Source: Post-purchase intercept interviews with farmers at agro-dealers.

Moreover, most farmers bought their most preferred variety (86%), and only a fifth switched from one variety and from one brand to another from the previous year. The majority repurchased the same seed for at least two (72%) or three (50%) years (repurchase commitment) driven mainly by seed performance attributes (Table 19). The price was a negligible reason in the decision to repurchase the same seed. It was important only 15% of times when farmers changed variety and the second most important reason (about a third out of 14% of transactions) when buyers did not buy their most preferred seed.

Table 19. Reasons to continue buying or changing seed variety (N=500) - % of farmers per individual reason.

Motivation/reason	Continued buying the same seed (n=374)	Changed seed from previous season (n=126)	Did not buy their most preferred variety (n=70)
Yield (t/ha)	91.4	73.0	5.7
Good yield reliability	7.0	5.6	0.0
Drought tolerance	49.5	24.6	0.0
Pest and disease resistance	14.7	20.6	1.4
Ear and grain characteristics	9.9	4.8	0.0
Soil/land adaptation	6.7	2.4	2.9
Rot resistance	5.1	0.8	0.0
Price	4.3	15.1	28.6
Plant aspect (size, height, etc.)	4.0	0.8	0.0
Lodging resistance	3.2	0.8	0.0
Good for animal feed	2.9	0.0	0.0
Excess rainfall tolerance	2.7	0.0	0.0
Availability	1.3	7.1	11.4
Experiment with new seeds	0.0	28.6	42.9
Other	5.6	10.3	7.1

Each reason is a dummy variable (1 if mentioned as a reason to continue to buy, change seed or not buy their most preferred variety and 0 otherwise). Columns and rows do not sum up to 100%, n or seed transaction

observations because farmers could mention as many reasons as they could recall. Source: Post-purchase intercept interviews with farmers at agro-dealers.

So far, we have shown evidence of brand loyalty based on selected indicators drawn from the marketing literature: market shares, price premiums, certainty, searching for information, resistance to persuasion, preference, switching, repurchase commitment and motivations for the consumer's choice. The remainder of this paper presents the results of our empirical test of the effect of brand loyalty and price-quality perceptions on farmers' willingness to buy hybrid maize seed.

5.5.2. Price-quality perception

5.5.2.1. Indicators' validity and reliability

Table 20 and Figure 28 show the results of the CFA measurement model. The indicators are grouped into two per construct. The first construct, for example (perceived quality), is defined by the first two observed variables (Q5.1. Seed quality and Q5.2. Seed reliability). The arrows pointing from the constructs to the indicators in Figure 28 indicate the size of the factor loadings. This size expresses the strength of the relationship between the latent variables and the indicators and determines the quality of an indicator as the measure of a construct. In CFA, when a factor loading is not significant it means either an indicator is measuring another construct, or the indicator is a poor measure. If this is the case the indicator must be dropped from further analysis (Iacobucci, 2009). According to Bagozzi and Yi (2012), when evaluating an indicator's validity, a composite value (i.e., the average of all item factor loadings of a construct) of 0.7 or greater is satisfactory, whereas for an individual indicator a factor loading of 0.7 or higher is ideal and loadings as low as 0.5 are reasonable.

For our brand loyalty and price-perceived quality model of hybrid maize seed, the perceived quality, perceived value, perceived sacrifice and willingness to buy construct indicators are drawn from Chapman and Wahlers (1999). To select the best explanatory indicators of our brand loyalty construct we verified the validity and reliability of five brand loyalty indicators shown in Table 16. These indicators were: certainty, searching, preference, switching and commitment. Results showed a factor loading of certainty and searching below 0.5, indicating they were poor measures. The factor loadings for commitment, switching and preference were good (>0.5) but there was a high correlation between switching and commitment. Therefore, certainty, searching and switching were dropped out and we selected commitment and preference to measure the effect of brand loyalty. When running the analysis together, all the composite values and individual item factor loadings obtained from the CFA were significant and higher than 0.5 (Table 20 and Figure 28), indicating the validity and satisfactory measurement quality of all the indicators.

Table 20. Factor loadings of perceived quality, perceived value, perceived sacrifice, brand loyalty and willingness to buy hybrid maize seed.

Construct	Indicator	f.loading	std.error	p-value	ci.lower	ci.upper
Perceived quality	Q5.1. Seed quality	0.635	0.060	***0.000	0.518	0.752
	Q5.2. Seed reliability	0.640	0.061	***0.000	0.521	0.759
Perceived value	Q5.3. Seed price worthiness	0.618	0.063	***0.000	0.495	0.741
	Q5.4. Seed offer evaluation	0.742	0.048	***0.000	0.647	0.836
Perceived sacrifice	Q5.7. High price perception	0.631	0.140	***0.000	0.357	0.905
	Q5.8. Sacrifice perception	0.820	0.179	***0.000	0.470	1.171
Brand loyalty	Repurchase commitment	0.515	0.175	**0.003	0.172	0.858
	Preference	0.749	0.247	**0.002	0.265	1.232
Willingness to buy	Q5.5. Willingness to buy	0.859	0.036	***0.000	0.789	0.930
	Q5.6. Purchase likelihood	0.808	0.041	***0.000	0.726	0.889

*p < 0.05, **p < 0.01, ***p < 0.001

Source: Post-purchase intercept interviews with farmers at agro-dealers.

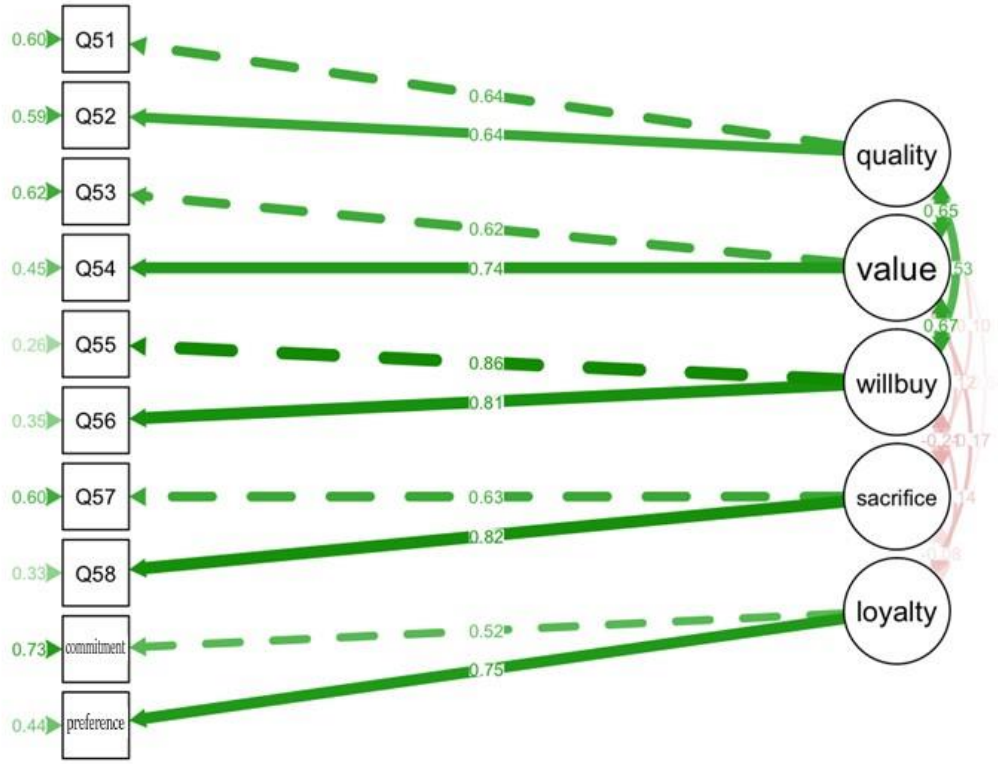


Figure 28 | Factor loadings of perceived quality, perceived value, perceived sacrifice, brand loyalty and willingness to buy. Source: Post-purchase intercept interviews with farmers at agro-dealers.

5.5.2.2. Model fit

The second step in SEM is to compare the specified model with the empirical data and assess the model fit. If the fit is acceptable, the assumed relationships and dependencies between variables are supported (Nachtigall *et al*., 2003). For a good model fit, the χ2 would not be significant (p>0.05), the χ2 adjusted by its degrees of freedom (χ2/df) would not exceed 3.0, the RMSEA would be smaller than 0.08, the SRMR would be close to 0.09 or lower, the GFI would be larger than 0.8, the AGFI

would be larger than 0.8, and the CFI would be close to 0.95 or higher (Hu and Bentler, 1999; Schermelleh-Engel *et al*., 2003; Iacobucci, 2010; Bagozzi and Yi, 2012).

Most of the time, the χ2 is significant because it is sensitive to sample size and as N increases χ2 does too. A significant χ2 could lead to erroneous rejection of a model if the assessment is based on the χ2 alone (Bollen and Long, 1993; Iacobucci, 2010; Bagozzi and Yi, 2012). For this reason, we report on several indexes as recommended by the literature, including indexes that account for sample size concerns (CFI and RMSEA), model complexity (CFI), degrees of freedom of the model (χ2/df) as well as indexes used in previous similar studies (see Chapman and Wahlers, 1999; Lee *et al*., 2019). In our model, the χ2=77.8 is significant (p=0.006) at p <0.05 but the model fits well according to six additional goodness-of-fit indexes (Table 21). The χ2/df=1.58 falls between 1 and 3 as required, the RMSEA=0.023 is smaller than 0.08 as required; the SRMR=0.048 is smaller than 0.09 as expected; the GFI=0.991 is larger than 0.8 as needed; the AGFI=0.985 is larger than 0.8 as needed; and the CFI=0.989 is larger than 0.95 as necessary.

5.5.2.3. Hypothesized relationships

Finally, the standardized estimates and corresponding standard errors and p-values for the structural price-perceived quality path models of hybrid maize seed are shown in Table 21 and Figure 29.

Table 21. Goodness of fit statistics, standardized estimate path coefficients and associated standard errors and p-values of perceived quality, perceived sacrifice, perceived value, brand loyalty and willingness to buy hybrid maize seed in a price comparison context.

From		To	Estimate	S.E.	p-value
H1 - Reference price	→	Perceived quality	0.016	0.041	n.s 0.809
H2 - Selling price	→	Perceived sacrifice	0.500	0.069	***0.000
H3 - Perceived sacrifice	→	Perceived value	-0.259	0.043	**0.002
H4 - Perceived quality	→	Perceived value	0.700	0.143	***0.000
H5 - Brand loyalty	→	Perceived value	-0.174	0.140	*0.028
H6 - Perceived value	→	Willingness to buy	0.768	0.163	***0.000
Goodness-of-Fit Index		Cutoff value	Result		
χ2		P > 0.05	77.8 (p=0.006)		
χ2/df		1 to 3	1.58		
RMSEA		<0.08	0.023		
SRMR		<0.09	0.048		
GFI		>0.8	0.991		
AGFI		>0.8	0.985		
CFI		>0.95	0.989		

χ2 = Chi-square; χ2/df ratio= Chi-square/degrees of freedom ratio; RMSEA= Root Mean Square Error of Approximation; SRMR=Standardized Root Mean Square Residual; GFI= Goodness of Fit index; AGFI= Adjusted Goodness of Fit Index; CFI= Comparative Fit Index.

*p < 0.05, **p < 0.01, ***p < 0.001

Source: Post-purchase intercept interviews with farmers at agro-dealers.

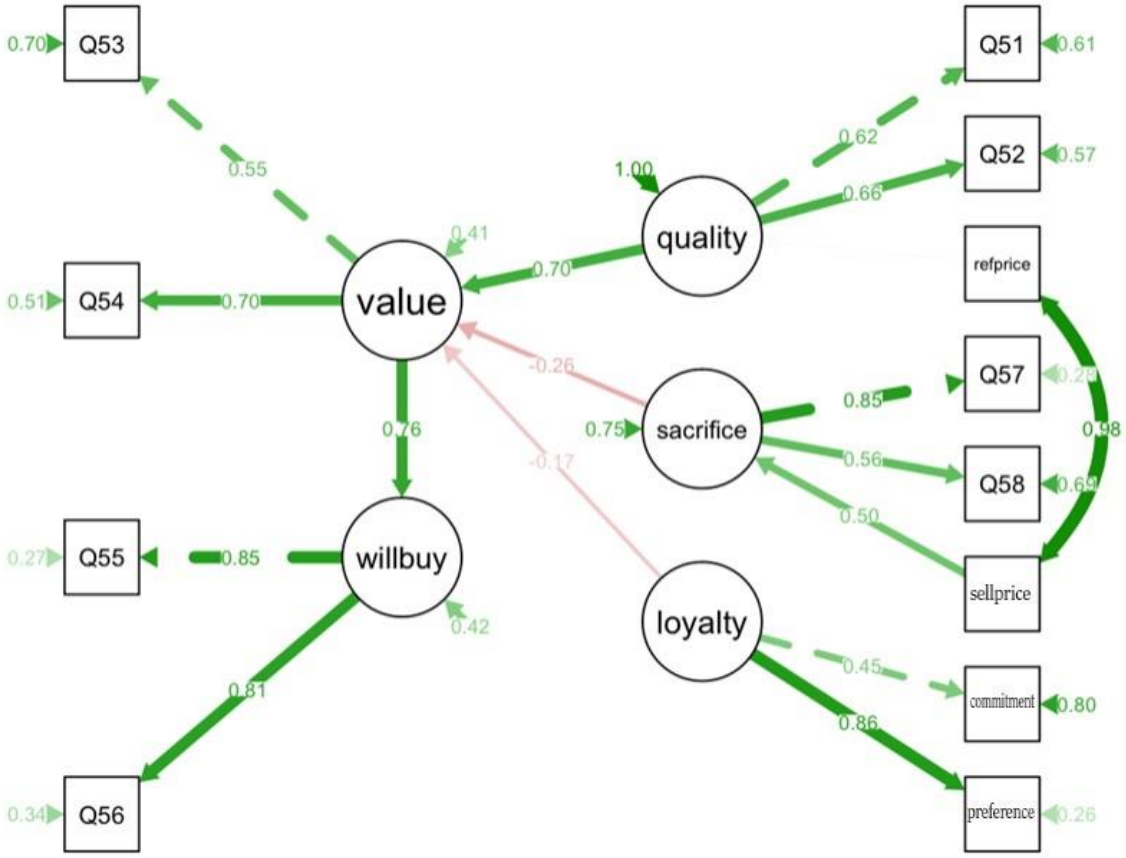


Figure 29 | Structural path model of price-perceived quality of hybrid maize seed in a price comparison context. The model constructs are depicted in circles and the indicators in boxes. Arrows rising from the constructs to the indicators and between constructs indicate their relationship according to the hypotheses (for instance, quality sacrifice and loyalty influence value). Arrows pointing to the indicators indicate the model measurement errors. Arrows pointing to the model constructs represent the error terms. No arrow points to the brand loyalty construct because no other factor in the model is thought to influence it (see hypothesized relationships in Table 18). Source: Post-purchase intercept interviews with farmers at agro-dealers.

The first hypothesis asserts there is a positive relationship between the reference price of a seed and its perceived quality. The estimate path coefficient of reference price - perceived quality is 0.016 and the p-value > 0.05, indicating that the effect of the reference price on perceived quality is not significant as we expected, and H1 is rejected. That is, farmers did not base their perception of quality of hybrid maize seed on the highest reference price.

The second hypothesis states that there is a positive relationship between the selling price (after any discount) and perceived sacrifice. The path coefficient of selling price – perceived sacrifice is 0.500 with p-value < 0.001, showing that as the selling price decreases the perceived sacrifice declines too and H2 is accepted. One problem arising from our model results might be the high correlation between the reference price and the selling price. To mitigate this concern, we regressed both

perceived quality and perceived sacrifice, only to the low selling price. The coefficient path estimate of (selling) price-perceived quality becomes negative, suggesting that a low seed price may actually affect perceptions of quality, but the effect is still not significant. All the other standardized estimate path coefficients and associated standard errors and p-value results are essentially the same as shown in Table 18 (Appendix E), which means our model is robust.

The third hypothesis assumes a negative relationship between perceived sacrifice and perceived value. The results yielded a path coefficient of perceived sacrifice - perceived value of -0.259 at a p-value < 0.01, indicating that perceived sacrifice has a negative effect on perceived value and H3 is accepted. The fourth hypothesis states that if the perceived quality of the seed increases its perceived value will also increase. The path coefficient of perceived quality – perceived value is 0.700 and p-value < 0.001, which supports the theory that perceived quality has a positive significant effect on perceived value and H4 is accepted. The fifth hypothesis suggests that brand loyalty will negatively influence perceived value of recently unknown released hybrids. The path coefficient of brand loyalty - perceived value is -0.174 at a p-value < 0.05 and therefore H5 is accepted as we expected. The last and sixth hypothesis states that if the perceived value of hybrid maize seed increases farmers' willingness to buy will also increase. The results produced a path coefficient of 0.768 at a p-value < 0.001, showing that perceived value has a positive significant effect on farmers' willingness to buy and H6 is accepted.

5.6. Discussion and managerial implications

This study examined farmers' seed purchasing decisions and empirically tested the effect of brand loyalty and price-quality perceptions on farmers' willingness to buy new recently released maize hybrids. Based on selected indicators drawn from the marketing literature, our results showed that farmers in La Frailesca, Chiapas, Mexico are loyal to the brands of multinational companies, especially Pioneer. This is the first study in the adoption and seed systems literature to assess brand loyalty in hybrid maize seed markets. Results from our price-perceived quality model indicate that while a high reference price does not significantly affect farmers' perceptions of quality (H1 rejected), a lower price created by the effect of a discount significantly reduces the perceived sacrifice involved in buying improved seeds (H2 accepted).

Under the current research design, i.e., comparative pricing where farmers evaluated a high reference price and a low selling price, we reject our hypothesis that farmers associate the high price of multinational brands with high quality, but support the idea that consumers base their perceptions of sacrifice on a reduced selling price. The positive effect of price on perceived sacrifice is widely supported by prior research (Monroe and Krishnan, 1985; Monroe and Chapman, 1987;

Chapman, 1993; Chapman and Wahlers, 1999). In a price comparison context, our results of a non-significant effect of a high reference price on perceived quality are in line with Grewal *et al*. (1998) but opposed to Chapman and Wahlers (1999) who found that buyers' quality perceptions are based on a product's high reference price. Our SEM model results based on a single low selling price (Appendix E) suggest that a positive price-quality perception may exist in single price contexts, i.e., if farmers are presented with different seed prices without discounts. Our survey results (section 5.5.1) also suggest that other factors such as brand name, market shares and objective seed quality (e.g., yield, drought tolerance) may play an important role in the creation of perceptions of the quality of hybrid maize seed. However, we did not explicitly test the relationship of any of these variables to perceived quality. The subject is worth more research to explore the effect of price on perceptions of quality in single price contexts and establish the role of brand, objective quality and other factors on quality perceptions and their effect on farmers' adoption and buying behaviour.

Perceived quality also had a positive significant effect on perceived value (H4 accepted) as previously shown by Monroe and Krishnan (1985), Dodds and Monroe (1985), Rao and Monroe (1988) and Chapman (1993). Meanwhile, brand loyalty and perceived sacrifice had a significant negative impact on perceptions of value (H5 and H3 accepted) and therefore on farmers' willingness to buy recently released new hybrids. The idea that perceived sacrifice reduces perceived value has been validated in situations where buyers are exposed to single (Monroe and Krishnan, 1985; Agarwal and Teas, 2001) and comparative pricing (Chapman, 1993; Chapman and Wahlers, 1999). The positive influence of brand as a symbol on customers' loyalty has been shown before by Lee *et al*. (2019). The results of this research further support the hypothesis that a positive perception of value increases willingness to buy (H6 accepted). Consequently, anything that seed companies do to improve value is likely to increase purchases.

Based on these results, seed companies need to maintain objective product quality while increasing the perceptions of quality and value of hybrids maize seed. As loyalty to existing seed varieties is found to negatively affect the perceived value of a new unknown variety, SMEs need to build strong brands and create consumer loyalty to increase their seed sales. Brands can be a powerful marketing tool that SMEs can use to communicate to farmers the value of their seeds, the differences from other available options, and why farmers should care about those differences. Another strategy to increase perceived value and farmers' willingness to buy, as suggested by Grewal *et al*. (1998) and Chapman and Wahlers (1999) and supported by this research, is the use of comparative pricing advertising. This strategy consists in providing a reference (high) and a selling (low) price to reduce perceived sacrifice and enhance perceptions of value (especially transaction value). Reference and

selling price cues can be provided on shelves, on the package, in advertisements or on in-store promotion materials where the price bargain (i.e., sacrifice reduction) is clearly communicated to the customer (Chapman and Wahlers, 1999). Domestic seed firms can increase their prices to a level close to those of multinational companies and offer discounts to reduce perceived sacrifice, thus enhancing value perceptions. This strategy is appropriate for the development objectives of supporting SMEs as well as increasing low-resourced income smallholders' access to better seeds at affordable prices.

Ultimately, it is necessary to understand what value truly means for farmers, i.e., what specific features besides performance attributes farmers care about (could be the distance to the shop, after sales support), the impact of that features on farmers' lives, and how much farmers are willing to pay for a bag of seed with those specific attributes. As prior research also suggests (Grewal *et al*., 1998) value will vary across markets and customer segments. Therefore, companies need to adjust their seed offering to different markets with different needs, perceptions of value and willingness to pay. Although these findings are representative only of commercial, market-oriented farmers in concentrated maize seed markets, the model can be replicable in other segments and market contexts.

5.7. Limitations and further research

This research provided a first attempt to understand the relationship between price, brand loyalty and quality perceptions of hybrid maize seed. This is useful for seed companies' managers and input retailers for the design of promotion and marketing strategies to increase their seed sales, as well as to inform domestic SMEs' pricing strategy. The findings are valid for price comparison contexts and commercial, market-oriented farmers in concentrated maize seed markets. It is therefore recommended that the generalizability of the model in other segment types and market contexts should be examined. It would be worthwhile to conduct more research on testing the validity of the brand loyalty price-perceived quality relationship in single price evaluation contexts. Our results also suggest that other factors such as brand name, market shares and objective seed quality may play a similarly important role in the creation of perceptions of quality of hybrid maize seed. Further research would benefit from including these and other important indicators and provide more insights into the determinants of farmers' variety choices. A priority for research is to find out which intrinsic and extrinsic cues farmers use as indicators of quality. It would be also useful to look more closely at farmers' individual characteristics such as mood, aversion to risk, personality, cognitive factors, etc., and explore potential differences among subjects.

This research did not capture and test the effect of acquisition value and transaction value on willingness to buy and its relationship with perceived sacrifice. We neither captured nor distinguished between the monetary and nonmonetary components of sacrifice. In the context of low-resourced income farmers and seed markets, where farmers often need to travel long distances to buy the seed, these distinctions are deemed relevant and important for the design of value-based marketing strategies.

5.8. Conclusion

This study provides empirical evidence of the effect of brand loyalty and price-quality perceptions on farmers' willingness to buy new hybrid maize seeds. Our results show that farmers in La Frailesca, Chiapas, Mexico are loyal to the brands of multinational companies, especially Pioneer. The results also indicate that in a price comparison context, a high reference price does not significantly affect farmers' perceptions of quality, but a reduced price significantly influences the perception of sacrifice. We also found that perceived value was positively influenced by perceived quality but negatively impacted by brand loyalty and perceived sacrifice. Finally, perceived value was positively and significantly related to willingness to buy. While increasing perceived quality and perceived value can stimulate seed purchases, brand loyalty and market concentration represent a barrier to entry for new - unknown – seeds. Therefore, for expanding hybrid maize seed sales, SMEs need to maintain objective quality while increasing perceptions of quality and perceptions of value, build strong brands to communicate the value of their seeds to farmers and create consumer loyalty. SMEs might need to revisit their current pricing strategy to incorporate value-oriented promotions and value-based pricing strategies.

The research makes two important contributions. First, it incorporates brand loyalty into prior price-perceived quality models to test the effect of consumer loyalty on perceived value and purchase decisions. Secondly, it empirically tests the effect of brand loyalty and price-quality perceptions on farmers' willingness to buy improved seeds. Although research on both topics spans over sixty years, neither the effect of brand loyalty nor the impact of quality perceptions has been studied in the adoption and seed systems literature, despite research suggesting that adoption is based on subjective perceptions and not on factual truth (Pannell *et al*., 2006). It is hoped that this research will lead to further investigation of the effect of brand, price, and other factors affecting quality perceptions, and its effect on farmers' adoption and buying decision-making through a consumer behaviours lens.

6. Conclusion

This research builds evidence of the contribution of PPPs to seed sector development and examines their constraints for achieving large-sale dissemination of new publicly bred hybrids delivered by SMEs in developing country contexts.

Chapter 3 assessed the capacity of PPPs to generate publicly bred variety innovations and deliver these innovations at scale through SMEs in highly concentrated maize seed markets. The chapter introduced a conceptual framework to understand crop germplasm improvement and delivery through PPPs and improve the existing knowledge of PPPs role in advancing maize seed systems. Results show that the MasAgro maize PPP was very successful in generating a large flow of agronomically competitive commercial maize hybrids during the period 2011-2019. Private domestic SMEs successfully incorporated these varieties into their seed offer and into the market. However, by the end of the project in 2019, MasAgro hybrids had a modest market share of 5.7% whereas multinational hybrids continued to occupy 77% of the maize seed market. The results on the effect of the MasAgro maize PPP on Mexico's maize seed industry contribute to understanding the relationship between industry structure, competition, innovation and growth in PPPs contexts. They show how market structure affects the development and growth of PPPs and national maize seed industries, and its influence in the dissemination of improved seed varieties. These findings contribute to the debates on innovation, competition, technology diffusion, public germplasm exchange and the role of the private sector in facilitating technology transfer. In particular, they show the role and contribution of SMEs in delivering technological innovations to low-income smallholder farmers in developing countries. The results are relevant for project leaders, policymakers, and governments for the design of policies and interventions to enhance seed production and delivery, promote competition and stimulate industry growth. Ultimately, the findings can contribute to the objectives of increasing crop production and enhancing food security. While the results are concerned with maize, they are likely to apply to other crops, and the MasAgro maize public-private approach can be replicable to other seed industries and developing countries.

Chapter 4 and Chapter 5 examined the possible reasons for the relatively limited market penetration of MasAgro PPP hybrids and their inability to capture a greater market share from multinational companies. Two possible factors were explored: the role of agro-dealers in the promotion of seed and their influence on farmers' buying decision-making; and whether brand loyalty and high prices signalling quality affected farmers' willingness to buy new recently released maize hybrids.

Chapter 4 examined the role of agro-dealers in influencing farmers' seed purchasing decisions and explored the factors hindering their potential for achieving large-scale dissemination and marketing of new hybrids developed by PPPs. The chapter draws upon research on marketing, consumer behaviour, retailing and technology adoption to propose a conceptual framework to explain 1) the intrinsic and extrinsic attributes of hybrid maize seed and their effect on farmers' buying behaviour and seed marketing, 2) the industry's strategies for marketing improved hybrids, and 3) the influence of both on farmers' buying decision-making and the role of agro-dealers in the promotion of seed. The results provide empirical evidence of 1) how farmers decide on their purchases of hybrid maize seed based upon subjective evaluation and the effect of product quality cues; and 2) the effect of agro-dealers on farmers' in-store decision-making. The findings show that agro-input retailers may be well placed to influence seed purchases, but their role in highly concentrated markets is limited by the effect of product quality cues and out-store marketing stimuli determining farmers' variety choices. The framework and findings are new to the field of technology adoption and seed systems literature which has traditionally neglected the role of agro-input retailers and marketing on seed variety choices. The results are relevant, especially for seed companies and agro-dealers to the design of in-store and out-store push-pull marketing strategies to enhance hybrid seed use, adoption and sales.

Chapter 5 studied brand loyalty and price-quality perceptions of hybrid maize and their effect on farmers' willingness to buy new recently released maize hybrids in the context of the Mexican maize seed market. The results indicate that farmers are loyal to the brands of multinational companies, especially Pioneer. Moreover, while a high reference price did not significantly affect a farmer's perceptions of quality of hybrid maize, a reduced price significantly decreased perception of sacrifice. Perceived quality also had a positive significant effect on perceived value, which in turn positively and significantly influenced willingness to buy. Finally, brand loyalty and perceived sacrifice had a significant negative impact on perceptions of value. The implication is that while increasing perceived quality and perceived value of hybrid maize can stimulate seed purchases, brand loyalty and perceived sacrifice will negatively impact perceptions of value and therefore farmers' willingness to buy new recently released - unknown – hybrids. The research in this chapter makes two important contributions to the marketing literature. First, it incorporates the brand loyalty construct into prior price-quality perception models to test the effect of consumer loyalty on perceived value and purchase decisions. Secondly, it empirically tests the effect of brand loyalty and price-quality perceptions on farmers' willingness to buy improved seeds. This is useful for seed companies' marketing managers for revisiting their current pricing strategy, enabling them to design value-oriented promotions and value-based pricing strategies.

Across the board, the findings indicate that 1) PPPs have considerable capacity and are an effective means for developing and delivering competitive crop variety innovations to smallholder farmers in low-and-middle-income countries, and 2) private domestic companies are willing and able to deliver innovations developed by international and national public sector research organizations. However, 3) product quality cues, out-store marketing stimuli, well-positioned brands with prices signalling quality (price premiums) and farmers' brand preferences in highly concentrated markets represent a barrier for domestic SMEs and PPPs to achieve large-scale dissemination of publicly bred varieties. The development of competitive high-quality high-yielding seed varieties is not enough in itself to disrupt concentrated maize seed markets, capture market shares from global market leaders and promote sufficient competition in the maize seed industry. If PPPs are to succeed in their objective of bringing affordable quality seed on a large-scale to smallholder farmers in developing countries, there is an urgent need to incorporate a marketing perspective along all steps of the plant breeding and dissemination process, to closely examine market structure and private sector marketing strategies, and to adopt a consumer behaviour lens for understanding farmers' adoption and buying decision-making.

6.1. Policy and managerial recommendations

The experience of MasAgro maize shows that PPPs working with domestic private seed companies are an effective but insufficiently exploited instrument for increasing crop production and enhancing food security in low-and-middle-income countries. To realize their full potential and achieve a greater impact on international plant breeding research, there are several factors to consider in the design of future seed sector development PPPs. We provide some recommendations drawn from this research, prior research findings, and the previous experiences of PPPs in other developing countries. We focus on four key aspects: ensure germplasm access and exchange, maintain product performance excellence through plant breeding, manage the distribution network, and enhance and communicate value to farmers. An elaboration of each guideline is given below.

6.1.1. Ensure germplasm access and exchange

The results in Chapter 3 show that domestic SMEs participating in MasAgro had the willingness and capacity for rapid introduction of new hybrids into their product portfolios and into the market. This was possible because companies were supported by 1) direct and continuous access to breeders' seed and advanced elite germplasm adapted to target environments and local markets; 2) prompt and opportune access to foundation seed; 3) training and transfer of seed production technology; and 4) support in product portfolios design and freedom to brand public CIMMYT germplasm-based hybrids. That was coupled with a consortium's targeting and segmentation strategy to orient sales

towards areas with the lowest yield and greatest immediate potential impact to encourage rapid dissemination of new hybrids.

Future PPPs in plat breeding should include these key components. Moreover, germplasm access by private companies must be guaranteed by both, the international and national public sectors, as well as the private sector. During the study period of this research, MasAgro maize partner companies shifted variety sourcing from public NARS to MasAgro hybrids, and none of the public maize varieties released by NARS appeared to have been taken up by the consortium firms. Seed companies probably switched from INIFAP to MasAgro hybrids for three main reasons: 1) foundation seed shortages, 2) marketing restrictions on branding public NARS varieties, and 3) reduction of seed production costs, given that MasAgro provided germplasm to seed companies at no cost and free of royalties. Furthermore, except for variety testing and evaluation, MasAgro maize worked independently of public institutions that historically lead breeding research and the development of the maize seed industry. While this allowed CIMMYT to make a greater impact in a relatively short period of time, it represents a risk for the sustainability of the national maize seed industry and the national agricultural research system. Public NARS must be an essential active partner of PPPs in all steps of the plant breeding and dissemination process. Their involvement should not be limited to variety testing, but include greater participation in genetic improvement, foundation seed production, and the release, promotion and dissemination of new varieties.

There is also a promising and unexploited potential in the private sector for enhancing germplasm access. The private seed sector can, independently or in collaboration with CGIAR centres or public NARS through PPPs, produce and supply high-quality foundation seed for SMEs. In recent years, several companies in Africa have been created for the production and supply of foundation seed to small seed companies. In Kenya, Zambia and South Africa, QualiBasic Seed Company (QBS) has been producing and supplying basic hybrid maize seed since 2017. The company was established with the financial support of the Bill & Melinda Gates Foundation (BMGF) (Kenya Agribusiness and Agroindustry Alliance, 2016). Premier seeds and Value seeds produce basic seed for maize hybrids in Nigeria. For other crops such as beans, soya beans, and groundnuts, MultiSeed Company (MUSECO) provides foundation seed in Malawi, while Doun Ka Fa produces basic cowpea and millet seed in Mali (Waithaka *et al*., 2021). These companies were identified and selected as foundation seed providers in 2016 during the Stress Tolerant Maize for Africa (STMA) project which was led by CIMMYT with the support of the BMGF (Badu-Apraku and Fakorede, 2017). In Asia, partner companies of the Affordable, Accessible Asian Drought Tolerant Maize Project (AAA DT Maize) maintain and produce the CIMMYT male parent seed which is licensed to seed partners royalty-free

for the production of AAA maize hybrids while Syngenta India Limited (SIL) sells the female parent every year (Syngenta Foundation, 2021b).

6.1.2. Maintain product performance excellence through plant breeding

Since the "Green Revolution", the CGIAR has been recognized for its excellence in crop genetic improvement. The on-farm agronomic advantage of CGIAR-germplasm materials over commercial privately bred cultivars has been shown by prior research (Setimela *et al*., 2017; Worku *et al.*, 2020) and is confirmed by the results in Chapter 3. In Chapter 4, results show that farmers' selection of seed is driven mainly by seed performance characteristics (intrinsic attributes or objective quality), especially grain yield, drought tolerance, and pest and disease resistance. Chapter 5 also suggests the important potential role of objective quality in the creation of perceptions of quality of hybrid maize seed. That means that maintaining objective quality in the breeding research programmes of the CGIAR, public NARS and private domestic companies is crucial for the success of PPPs.

6.1.3. Manage the seed distribution network

SMEs need to leverage their seed distribution channels and make sure the different channel intermediaries add value to their seeds. Seed companies need to help their distributors to increase their turnover so that they obtain higher returns by selling their seeds. This requires strong value chain coordination, with seed companies working with agro-dealers (or other channels) to deliver the value added in their seed, and jointly participating in the design and execution of promotion programmes and pricing strategies (Smith and Nimer, 2012). Many companies in Africa are developing innovative models to integrate agro-dealers into their supply chains. Syngenta's approach, for example, is to create awareness and understanding of their products among agro-dealers and farmers through extension and training services to create product demand, as well as to develop linkages with regional distributors and larger agro-dealers to ensure supply (AFAP, 2019). The company emphasizes marketing as a key driver for demand generation and the use of multi-channel distribution strategies to reach farmers. This approach has been used in the Nigeria Agro-Input Support (NAIS) project, where Syngenta supports agro-dealers through a retail "Store-in-Shop" campaign and further links them to lead farmers to promote their products via farm demonstrations (IFDC, 2016). Other companies such as Corteva Agriscience use a multi-channel, multi-brand strategy based on farmers' buying preferences through a segmented route-to-market approach (Corteva Agriscience, 2020). The Alliance for a Green Revolution in Africa (AGRA) uses a similar strategy to create awareness in agro-dealer shops and outside the stores through rural demonstrations, marketing campaigns and the distribution of seed samples (AGRA, 2017).

Chapter 4 touches on some strategies at the retail level with the potential to improve the agro-dealers' in-store environment and encourage seed purchases. It also emphasizes the need to pay more attention to push marketing and adopt a combined push-pull strategy to target the different stages of the adoption and buying decision-making process. For SMEs, which face fierce competition from multinational companies and usually lack the financial means for marketing their seed and consolidating their distribution networks, this represents one of the main challenges. The design of seed sector PPPs needs to consider which channels are better placed to reach a greater scale and how partner companies will guarantee their stock capacities. Maize seed sector development interventions need holistic approaches to conceptualize agro-dealers and other distribution channels as part of the larger agro-input marketing system and not in isolation.

6.1.4. Enhance and communicate value to farmers

If a new hybrid has the same proven quality as shown in Chapter 3, the main difference might be the price or the brand. In Chapter 4, results suggest that besides seed performance attributes (objective quality), product quality cues such as brand and price play a similarly important role in influencing farmers' buying behaviour. In Chapter 5, the results highlight the importance of increasing perceived value and reducing farmers' perceptions of sacrifice. The implication is that, besides communicating objective quality attributes, SMEs need to enhance and effectively communicate the value of their seeds. Our results and prior research suggest two main methods by which SMEs can enhance and communicate value to farmers: brand management and value-based pricing. On the one hand, SMEs need to build strong brands and create consumer loyalty. On the other, SMEs need to design value-based promotion and value-based pricing strategies which in turn will help to build, manage and maximize the value of their brands (see Kotler and Keller, 2012 p.240). Two different pricing strategies can be used to enhance the value of hybrid maize seed: 1) improving perceptions of quality by emphasizing the main seed attributes of value for farmers relative to its selling price, and 2) using discounts and comparative pricing advertising to stress the price bargain (see Grewal *et al*. 1998 and Chapman and Wahlers, 1999).

Seed companies can also enhance the value of the seed offer by adding complementary inputs (e.g., seed plus fertilizer), other farming equipment or even regular items that represent value for farmers (see Smith and Nimer, 2012). This is already done by some companies such as American seeds, which offer different seed packages that include the seed, fertilizer, crop protection inputs, seed purchases on credit and seed insurance in case of crop failure after sowing.

The literature discusses other marketing tools that companies can use to communicate the value of their products to customers, including product demonstrations, product samples, consumer reviews,

referrals, warranties, low-price guarantees (LPGs) and money-back guarantees (MBGs)[27]. In addition to communicating value, these tools reduce risk and uncertainty (Heiman *et al*., 2001; Boleslavsky *et al*., 2017; Heiman and Hildebrandt, 2018). Some of these tools, e.g., demonstration plots, are already widely used by seed companies, others such as seed samples are certainly underused, and the majority were not observed in this research.

Ultimately, the success of PPPs depends on the sustained investment and continuous engagement of entities in both, the public and private sectors. Governments need to provide an enabling seed production and marketing regulatory policy, including facilities for increasing foundation seed production and freedom for branding public varieties. Seed companies can contribute to funding breeding research through small membership grants or germplasm licensing agreements. Nevertheless, such arrangements must be evaluated carefully as they have been shown to restrict germplasm access (Reddy *et al*., 2001; Srinivasan, 2003; Mula *et al*., 2007). Marketing and consumer behaviour research can provide important insights into the determinants of farmers' variety choices, allowing maize breeders to integrate genetic traits of commercial interest and end-user preferences into genetic improvement, and seed companies to incorporate a demand-driven segmentation approach for seed delivery.

6.2. Further research

This research makes the first attempt to incorporate marketing and consumer behaviour into the conceptualization of seed systems in developing country contexts. It shows how market structure, private marketing and farmers' behaviour influence their development and growth and the dissemination of improved seed varieties. While it provides some pioneering insights, further research is essential to advance the development of the adoption and seed systems literature in this direction.

From this perspective, research can no longer ignore the effect of product quality cues, out-store and in-store marketing stimuli and farmers' buying behaviour on the selection of seed. More research is needed to understand private sector marketing, the different marketing tools used in the maize seed industry for the promotion of seeds, and how farmers react to their stimuli. Seed variety choices must be studied considering the different stages of the adoption and buying decision-making process in non-shopping (out-store) and shopping (in-store) contexts. Technology adoption and seed systems research would benefit greatly from developing an integrated view of the existing adoption

[27] Warranties assure consumers that the manufacturer will fix any product-related problems in a given period of time (Srivastava and Mitra, 1998). Low-price guarantees (LPGs) assure customers a refund of the price difference, within a particular time frame, if after their purchase they find a lower price for the same product at a competing retailer (Jain and Srivastava, 2000). Money-back guarantees (MBGs) assure customers a refund if after their purchase they report unsatisfactory performance (Heiman *et al*., 2002).

and buying decision-making frameworks that incorporate the effect of marketing, consumer behaviour and the in-store environment. It is also necessary to extend our understanding of agro-dealers and other distribution channels which may potentially play a similarly important role in the dissemination of improved seeds.

Lastly, the adoption of innovations is based on subjective perceptions and not on factual truth (Pannell *et al*., 2006). In the context of the current global concentrated maize seed markets, research that incorporates marketing and behavioural economic indicators into adoption frameworks is crucial for understanding the determinants of farmers' variety choices (see further research in Chapter 5). This is also critical for expanding the benefits of international plant breeding research and the development of national seed industries.

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References

Aaker, D.A. (2012). *Building strong brands*. New York, USA: Free Press.

Aaker, D.A. (1996). Measuring brand equity across products and markets. *California Management Review,* **38**(3), 102–120. https://doi.org/10.2307/41165845

Abate, T. (2016). A new generation of maize for Africa. (CIMMYT Science Week Conference paper.) https://www.academia.edu/48540159/A_new_generation_of_maize_for_Africa (accessed 8.19.22).

Access to Seeds Foundation. (2019). *Access to Seeds Index 2019: synthesis report.* Amsterdam, The Netherlands: World Benchmarking Alliance. accesstoseeds.org/app/uploads/2019/06/Access-to-Seeds-2019-Index-Synthesis-Report.pdf (accessed 8.19.22).

ACIAR. (2021). *CGIAR/ACIAR.* URL https://www.aciar.gov.au/Multilateral-Partnerships/cgiar (accessed 3.14.22).

Ackerberg, D.A. (2001). Empirically distinguishing informative and prestige effects of advertising. *The RAND Journal of Economics*, **32**(2), 316–333.

AFAP. (2019). *Assessment of sustainable agro-dealer networks: full engagement materials from studies in Tanzania and Nigeria.* https://www.afap-partnership.org/wp-content/uploads/2019/10/AFAP-Agro-dealer-Study_Full-Engagement-Materials.pdf (accessed 8.19.22).

Agarwal, S. & Teas, R.K. (2001). Perceived value: mediating role of perceived risk. *Journal of Marketing Theory and Practice*, **9**(4), 1–14.

AGRA. (2017). *Seeding an African Green Revolution: The Pass Journey*. Nairobi, Kenya: Alliance for a Green Revolution in Africa.

Ailawadi, K.L., Beauchamp, J.P., Donthu, N., Gauri, D.K. & Shankar, V. (2009). Communication and promotion decisions in retailing: a review and directions for future research. *Journal of Retailing*, **85**(1), 42–55. https://doi.org/10.1016/j.jretai.2008.11.002

Akdeniz, B., Calantone, R.J. & Voorhees, C.M. (2013). AEffectiveness of marketing cues on consumer perceptions of quality: the moderating roles of brand reputation and third-party information. *Psychology & Marketing*, **30**(1), 76–89. https://doi.org/10.1002/mar.20590

Akram, A. (2015). *Krishi Utsho: the building of an agro-input microfranchise network in rural Bangladesh.* Dhaka, Bangladesh: CARE, Innov. Br. 4. https://www.academia.edu/31730184/Krishi_Utsho-Microfranchise_Model_The_Building_of_an_Agro-Input_Microfranchise_Network_in_Rural_Bangladesh (accessed 8.20.22).

Amine, A. (2011). Consumers' true brand loyalty: the central role of commitment. *Journal of Strategic Marketing*, **6**(4), 305–319. https://doi.org/10.1080/096525498346577

Anderson, E.W. & Mittal, V. (2000). Strengthening the satisfaction-profit chain. *Journal of Service and Research*, **3**(2), 107–120.

Anderson, J.C. & Gerbing, D.W. (1988). Structural Equation Modeling in practice: a review and recommended two-step approach. *Psychological Bulletin*, **103**, 411–423.

Andorf, C., Beavis, W.D., Hufford, M., Smith, S., Suza, W.P., Wang, K., Woodhouse, M., Yu, J. & Lübberstedt, T. (2019). Technological advances in maize breeding: past, present and future.

Theoretical and Applied Genetics, **132**(3), 817-849. https://doi.org/10.1007/s00122-019-03306-3.

Angeles-Arrieta, H.H. (2000). Mejoramiento genético del maíz en México, el INIA, sus antecesores y un vistazo a su sucesor, el INIFAP. *Agricultura Técnica en México*, **26**(1), 31–48.

Atlin, G.N., Cairns, J.E. & Das, B. (2017). Rapid breeding and varietal replacement are critical to adaptation of cropping systems in the developing world to climate change. *Global Food Security*, **12**, 31–37. https://doi.org/10.1016/j.gfs.2017.01.008

Auriol, E. & Schilizzi, S.G.M. (2015). Quality signaling through certification in developing countries. *Journal of Development Economics*, **116**, 105–121. https://doi.org/10.1016/j.jdeveco.2015.03.007

Ayala-Garay, O.J., García-de los Santos, G., Ayala-Garay, A.V. & Schwentesius-Rindermann, R. (2006). Influencia de aspectos normativos en el desarrollo de la investigación, la enseñanza y la producción de semillas, el ejemplo del Colegio de Postgraduados, in: Schwentesius-Rindermann, R., Gómez-Cruz, M.A., Ayala-Garay, A.V. (eds.). *Memorias Del Foro Nacional Agenda Del Desarrollo 2006-2020. Políticas de Desarrollo Agropecuario, Forestal y Pesquero*, 20-21 Septiembre, pp. 149–163. México: CIESTAAM-Universidad Autónoma Chapingo.

Badstue, L.B., Bellon, M.R., Berthaud, J., Ramírez, A., Flores, D. & Juárez, X. (2007). The dynamics of farmers' maize seed supply practices in the Central Valleys of Oaxaca, Mexico. *World Development*, **35**(9), 1579–1593. https://doi.org/10.1016/j.worlddev.2006.05.023

Badu-Apraku, B. & Fakorede, M.A.B. (2017). *Advances in genetic enhancement of early and extra-early maize for Sub-Saharan Africa*. Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-64852-1

Bagozzi, R.P. & Yi, Y. (2012). Specification, evaluation, and interpretation of structural equation models. *Journal of the Academy of Marketing Science*, **40**(1), 8–34. https://doi.org/10.1007/s11747-011-0278-x

Baum, W.C. & Lloyd, T.E. (1985). *CGIAR - How it all began. A 1985 Annual Report Reprint.* Washington, D.C., USA: CGIAR Secretariat. https://cgspace.cgiar.org/bitstream/handle/10947/5256/how_it_all_began_warren_baum_1985.pdf?sequence=1&isAllowed=y (accessed 8.20.22).

Bawa, K. & Shoemaker, R. (2004). The effects of free sample promotions on incremental brand sales. *Marketing Science*, **23**(3), 345–363. https://doi.org/10.1287/mksc.1030.0052

Bearden, W.O. & Shimp, T.A. (1982). The use of extrinsic cues to facilitate product adoption. *Journal of Marketing Research*, **19**(2), 229–239. https://doi.org/10.2307/3151623

Bell, D.R., Corsten, D. & Knox, G. (2011). From point of purchase to path to purchase: how preshopping factors drive unplanned buying. *Journal of Marketing*, **75**(1), 31–45. https://doi.org/10.1509/jm.75.1.31

Bellon, M.R. & Morris, M.L. (2002). *Linking global and local approaches to agricultural technology development: the role of participatory plant breeding research in the CGIAR. CIMMYT Economics Working Papers 02-03*. Mexico, D.F.: CIMMYT.

Boleslavsky, R., Cotton, C.S. & Gurnani, H. (2017). Demonstrations and price competition in new product release. *Management Science*, **63**(6), 2016–2026. https://doi.org/10.1287/mnsc.2016.2449

Bollen, K.A. & Long, S.J. (1993). *Testing structural equation models*. Newbury Park, Los Angeles,

California, USA: Sage Publications.

Bollen, K.A. & Noble, M.D. (2011). Structural equation models and the quantification of behavior. *Proceedings of the National Academy of Sciences of the United States of America*, **108**(Supplement 3), 15639–15646. https://doi.org/10.1073/pnas.1010661108

Bornemann, T. & Homburg, C. (2011). Psychological distance and the dual role of price. *Journal of Consumer Research*, **38**(3), 490–504. https://doi.org/10.1086/659874

Burer, S., Jones, P.C. & Lowe, T.J. (2008). Coordinating the supply chain in the agricultural seed industry. *European Journal of Operational Research*, **185**(7), 354–377. https://doi.org/10.1016/j.ejor.2006.12.015

Byerlee, D. & Dubin, H.J. (2010). Crop improvement in the CGIAR as a global success story of open access and international collaboration. *International Journal of the Commons,* **4**(1), 452–480. https://doi.org/10.18352/ijc.147

Byerlee, D. & Fisher, K. (2002). Accessing modern science: policy and institutional options for agricultural biotechnology in developing countries. *World Development*, **30**, 931–948.

Byerlee, D., Gary, A. & Echeverría, R.G. (2002). The evolution of public research systems in developing countries: facing new challenges. In: Byerlee, D. & Echeverría, R.G. (eds.) *Agricultural research policy in an era of privatization*. Wallingford: CABI.

Byerlee, D. & Traxler, G. (1995). National and international wheat improvement research in the post-Green Revolution period: evolution and impacts. *American Journal of Agricultural Economics,* **77**(2), 268–278. https://doi.org/10.2307/1243537

Cairns, J.E. & Prasanna, B.M. (2018). Developing and deploying climate-resilient maize varieties in the developing world. *Current Opinion in Plant Biology*, **45**(Part B), 226–230. https://doi.org/10.1016/j.pbi.2018.05.004

Camacho-Villa, T.C., Almekinders, C., Hellin, J., Martinez-Cruz, T.E., Rendon-Medel, R., Guevara-Hernández, F., Beuchelt, T.D. & Govaerts, B. (2016). The evolution of the MasAgro hubs: responsiveness and serendipity as drivers of agricultural innovation in a dynamic and heterogeneous context. *The Journal of Agricultural Education and Extension*, **22**(5), 455–470. https://doi.org/10.1080/1389224X.2016.1227091

Cao, S., Song, J., Yuan, Y., Zhang, A., Ren, J., Liu, Y., Qu, J., Hu, G., Zhang, J., Wang, C., Cao, J., Olsen, M., Prasanna, B.M., San Vicente, F. & Zhang, X. (2021). Genomic prediction of resistance to Tar Spot Complex of maize in multiple populations using Genotyping-by-Sequencing SNPs. Frontiers in Plant Science, **12**, 1–12. https://doi.org/10.3389/fpls.2021.672525

Carballo-Carballo, A., Virgen, J., Castillo-Gonzalez, F., Ramires, M.E. (2014). *Guía técnica para la descripción varietal. Maíz (Zea mays L.)*. https://docplayer.es/53263731-Guia-tecnica-para-la-descripcion-varietal-maiz-zea-mays-l.html

CGIAR. (n.d.). Our assets. URL https://www.cgiar.org/ (accessed 7.2.20).

CGIAR Genebank Platform and Crop Trust. (2019). *2019 CGIAR Genebank Platform Annual Report*. https://www.genebanks.org/wp-content/uploads/2020/07/2019-Genebank-Platform-Annual-Report.pdf (accessed 8.21.22).

Chapman, J. (1993). The effect of discounts on the price-perceived quality paradigm. *Journal of Marketing Theory and Practice*, **1**(2), 1–11.

Chapman, J. & Wahlers, R. (1999). A revision and empirical test of the extended price-perceived quality model. *Journal of Marketing Theory and Practice*, **7**(3), 53–64.

https://doi.org/10.1080/10696679.1999.11501840

Chassaigne-Ricciulli, A.A., Mendoza-Onofre, L.E., Córdova-Téllez, L., Carballo-Carballo, A., San Vicente-García, F.M. & Dhliwayo, T. (2020). Development of seed production technology of CIMMYT tropical single cross maize hybrids. *Agriculture*, **10**(7), 1–12. https://doi.org/10.3390/agriculture10070259

Chinsinga, B. (2011). *Agro-dealers, subsidies and rural market development in Malawi: a political economy enquiry*. Brighton: Future Agricultures.

CIMMYT. (2019a). MasAgro seed marketing survey, 2013-2019. Texcoco, Mexico: CIMMYT, unpublished data.

CIMMYT. (2019b). MasAgro seed evaluation network, 2011-2019. Texcoco, Mexico: CIMMYT, unpublished data.

CIMMYT. (2015). MasAgro germplasm impact survey. Texcoco, Mexico: CIMMYT, unpublished data.

CIMMYT. (2012). *MasAgro maíz, solicitud de semilla*. MasAgro maize. URL https://masagro.mx/es/solicitud-de-semilla (accessed 7.24.20).

CIMMYT. (n.d.). *MasAgro*. URL https://www.cimmyt.org/projects/masagro/ (accessed 7.22.20a).

CIMMYT. (n.d.). *MasAgro Maize*. URL https://www.cimmyt.org/projects/masagro-maize/ (accessed 7.22.20b).

CNFA. (2021a). *Zimbabwe Agro-dealer Strengthening Program*. URL https://www.cnfa.org/program/agrodealer-strengthening-program-3/ (accessed 6.30.21).

CNFA. (2021b). *West African Seed Alliance*. URL https://www.cnfa.org/program/west-africa-seed-alliance/ (accessed 6.29.21).

CNFA. (2021c). *Tanzania Agrodealer Strengthening Program*. URL https://www.cnfa.org/program/agrodealer-strengthening-program-2/ (accessed 6.30.21).

CONABIO. (2020). *Razas de maíz en México*. Biodiversidad Mexicana. URL https://www.biodiversidad.gob.mx/diversidad/alimentos/maices/razas-de-maiz (accessed 11.4.20).

Córdova-Téllez, L. (2019a). Presentación en la 4ta Sesión Ordinaria 2019 (49th Sesión), Consejo Técnico del SNICS. México: SNICS, SADER y Gobierno de México.

Córdova-Téllez, L. (2019b). Presentación en la 2° Reunión del grupo de trabajo "Innovación y Desarrollo Tecnológico" SINASEM 23-05-2019. México: SNICS y SADER.

Corteva Agriscience. (2020). *Corteva announces retail route-to-market changes for 2021 sales season*. URL https://www.prnewswire.com/news-releases/corteva-announces-retail-route-to-market-changes-for-2021-sales-season-301057837.html (accessed 5.10.21).

Cucculelli, M. & Ermini, B. (2012). New product introduction and product tenure: what effects on firm growth? *Research Policy*, **41**(5), 808–821. https://doi.org/10.1016/j.respol.2012.02.001

Darby, M.R. & Karni, E. (1973). Competition and the optimal amount of fraud. *The Journal of Law and Economics*, **16**, 67–88.

Deconinck, K. (2020). Concentration in seed and biotech markets: extent, causes, and impacts. *Annual Review of Resource Economics*, **12**(1), 129-147.

Dick, A.S. & Basu, K. (1994). Customer loyalty: toward an integrated conceptual framework. *Journal*

of the Academy of Marketing Science, **22(2)**, 99–113. https://doi.org/10.1177/0092070394222001

Dodds, W.B. & Monroe, K.B. (1985). The effect of brand and price information on subjective product evaluations. *Advanced Consumer Research*, **12**, 85–90.

Dodds, W.B., Monroe, K.B. & Grewal, D. (1991). Effects of price, brand, and store information on buyers' product evaluations. *Journal of Marketing Research*, **28**, 307–319.

Donnet, M.L., Dámaris, I., Becerril, L., Black, J.R., Hellin, J. (2017a). Productivity differences and food security: a metafrontier analysis of rain-fed maize farmers in MasAgro in Mexico. *AIMS Agriculture and Food*, **2**(2), 129–148. https://doi.org/10.3934/agrfood.2017.2.129

Donnet, M.L., Molnar, T. & Silva-Hinojosa, A. (2017b). How public-private seed partnerships leverage the sector growth and diversity: The MasAgro seed consortium. Texcoco, Mexico: International Food and Agribusiness Management Review (IFAMA) Research Proposal, unpublished communication.

Donovan, J., Rutsaert, P., Domínguez, C. & Peña, M. (2022). Capacities of local maize seed enterprises in Mexico: implications for seed systems development. *Food Security,* **14***,* 509-529. https://doi.org/https://doi.org/10.1007/s12571-021-01247-8

Echeverría, R.G. (1990). *Public and private investments in maize research in Mexico and Guatemala*. CIMMYT Economics Working Paper 90/03. Mexico: CIMMYT.

Edmeades, G.O. (2013). *Progress in achieving and delivering drought tolerance in Maize - An Update*, ISAAA Brief 44. Ithaca, New York, USA: ISAAA.

Erdem, T., Keane, M.P. & Sun, B. (2008). A dynamic model of brand choice when price and advertising signal product quality. *Marketing Science*, **27**(6), 1111–1125. https://doi.org/10.1287/mksc.l080.0362

Erenstein, O. & Kassie, G.T. (2018). Seeding eastern Africa's maize revolution in the post-structural adjustment era: a review and comparative analysis of the formal maize seed sector. *International Food and Agribusiness Management Review*, **21**(1), 39–52. https://doi.org/10.22434/IFAMR2016.0086

Ert, E., Raz, O. & Heiman, A. (2016). (Poor) seeing is believing: when direct experience impairs product promotion. *International Journal of Research in Marketing*, **33**(4), 881–895. https://doi.org/10.1016/j.ijresmar.2016.04.003

Ervin, D., Lomax, T., Buccola, S., Kim, K., Minor, E., Yang, H., Glenna, L., Jaeger, E., Biscotti, D., Armbruster, W., Clancy, K., Lacy, W., Welsh, R. & Xia, Y. (2003). *University-industry relationships: framing the issues for academic research in agricultural biotechnology. Expert Workshop on Public Goods and University-Industry Relationships in Agricultural Biotechnology.* Charles Hamner Conference Center, Research Triangle Park, North Carolina, USA: Pew Initiative on Food and Agriculture and Portland State University. https://www.iprsonline.org/research/UIR.pdf (accessed 8.21.22).

Espinosa, C.A., Tadeo, R.M. & Turrent, F.A. (2010). *Concentración de la oferta de semillas mejoradas de maíz*. La Jornada. URL https://www.jornada.com.mx/2010/03/13/oferta.html (accessed 9.24.21).

Evenson, R. & Gollin, D. (eds.) (2003). *Crop variety improvement and its effect on productivity: the impact of international agricultural research*. Wallingford: CABI Publishing. https://doi.org/10.1079/9780851995496.0447

FAO. (2022). *Global maize imports and exports*. FAOSTAT. URL https://www.fao.org/faostat/en/#data (accessed 2.27.22).

FAO. (2020). *Global maize production database*. FAOSTAT. URL http://www.fao.org/faostat/en/#data%0A (accessed 11.11.20).

Feder, G., Just, R.E. & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change*, **33**(2), 255–298.

Fernandez-Cornejo, J. (2004). *The seed industry in U.S agriculture: an exploration of data and information on crop seed markets, regulation, industry structure and research and development*. Agriculture Information Bulletin Number 786. Washington, DC, USA: United States Department of Agriculture, Economics Research Service. https://ageconsearch.umn.edu/record/33671/?ln=en (accessed 8.21.22).

Ferroni, M. & Castle, P. (2011). Public-private partnerships and sustainable agricultural development. *Sustainabilit*y, **3**(7), 1064–1073. https://doi.org/10.3390/su3071064

Fuglie, K. (2016). The growing role of the private sector in agricultural research and development world-wide. *Global Food Security*, **10**(9), 29–38. https://doi.org/10.1016/j.gfs.2016.07.005

Fuglie, K.O. & Toole, A.A. (2014). The evolving institutional structure of public and private agricultural research. *American Journal of Agricultural Economics*, **96**(3), 862–883. https://doi.org/10.1093/ajae/aatl07

Galluzzi, G., Halewood, M., Noriega, I.L. & Vernooy, R. (2016). Twenty-five years of international exchanges of plant genetic resources facilitated by the CGIAR genebanks: a case study on global interdependence. *Biodiversity and Conservation*, **25**, 1421–1446. https://doi.org/10.1007/s10531-016-1109-7

Giannakas, K. & Fulton, M. (2020). On the market for "Lemons": quality provision in markets with asymmetric information. *Humanities and Social Sciences Communications*, **7**(1), 1–6. https://doi.org/10.1057/s41599-020-00658-w

Gilligan, D.O. & Karachiwalla, N. (2021). *Subsidies and product assurance: evidence from agricultural technologies*. Washington, D.C., USA: International Food Policy Research Institute (IFPRI).

Gotret, M.V. & Patiño, O.B. (2004). Twenty years of cassava innovation in Colombia: scaling up under different political, economic, and social environments. In: Pachico, D. & Fujisaka, S. (eds.) *Scaling up and out: achieving widespread impact through agricultural sesearch*. Cali, Colombia: Centro Internacional de Agricultura Tropical (CIAT).

Gowda, C.L.L., Rai, K.N. Reddy, B.V.S. & Saxena, K.B. (eds.) (2006). *Hybrid Parents Research at ICRISAT*. Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Gowda, C.L.L., Reddy, B.V.S. & Saxena, K.B. (2004). ICRISAT collaboration with the seed industry in Asia. Paper presented at the Asian Seed Congress 2004, Seoul, South Korea, September 13-17, 2004. In: *Apsa Technical Report No. 38*, Bangkok, Thailand: Asia and Pacific Seed Association.

Grewal, D., Monroe, K.B. & Krishnan, R. (1998). The effects of price-comparison advertising on buyers' perceptions of acquisition value, transaction value, and behavioral intentions. *Journal of Marketing*, **62**, 46–59. https://doi.org/10.1177/002224299806200204

GRiSP (Global Rice Science Partnership). (2013). *GRiSP: partnership in motion*. Los Baños, Philippines: International Rice Research Institute (IRRI).

Hagedoorn, J., Link, A.N. & Vonortas, N.S. (2000). Research partnerships. *Research Policy*, **29**(4-5),

567–586.

Hall, A. (2006). Public private sector partnerships in an agricultural system of innovation: concepts and challenges. *International Journal of Technology Management & Sustainable Development*, **5**(1), 3-20.

Hall, A., Bockett, G., Taylor, S., Sivamohan, M.V. & Clark, N. (2001). Why research partnerships really matter: innovation theory, institutional arrangements and implications for developing new technology for the poor. *World Development*, **29**(5), 783–797.

Hartwich, F., Gottret, M.V., Babu, S. & Tola, J. (2007a). *Building public-private partnerships for agricultural innovation in Latin America. Lessons from capacity strengthening.* IFPRI Discussion Paper 00699. Washington, D.C., USA: International Food Policy Research Institute. https://ageconsearch.umn.edu/record/42415

Hartwich, F., Tola, J., Engler, A., González, C., Ghezan, G., Vázquez-alvarado, J.M.P., Silva, J.A., Espinoza, J.de.J. & Gottret, M.V. (2007b). *Building public-private partnerships for agricultural innovation*. Food Security in Practice technical guide series. Washington, D.C., USA: International Food Policy Research Institute. https://doi.org/10.2499/9780896297715fsp4

Heiman, A., Ferguson, J. & Zilberman, D. (2020). Marketing and technology adoption and diffusion. *Applied Econonomics Perspectives and Policy*, **42**(1), 21–30. https://doi.org/10.1002/aepp.13005

Heiman, A. & Hildebrandt, L. (2018). Marketing as a risk management mechanism with applications in agriculture, resources, and food management. *Annual Review of Resource Economics,* **10**, 253–277. https://doi.org/10.1146/annurev-resource-100517-023047

Heiman, A., Mcwilliams, B., Zhao, J. & Zilberman, D. (2002). Valuation and management of money-back guarantee options. *Journal of Retailing*, **78**(3), 193–205.

Heiman, A., McWilliams, B. & Zilberman, D. (2001). Demonstrations and money-back guarantees: market mechanisms to reduce uncertainty. *Journal of Business Research*, **54**(1), 71–84. https://doi.org/10.1016/S0148-2963(00)00181-8

Hellofs, L.L. & Jacobson, R. (1999). Market share and customers' perceptions of quality: when can firms grow their way to higher versus lower quality? *Journal of Marketing*, **63**(1), 16–25.

Holbrook, M.B. (2006). Consumption experience, customer value, and subjective personal introspection: an illustrative photographic essay. *Journal of Business Research*, **59**(6), 714–725. https://doi.org/10.1016/j.jbusres.2006.01.008

Holbrook, M.B. (1999). Introduction to consumer value. In: Holbrook, M.B. (ed.), *Consumer value: a framework for analysis and research*. London and New York: Routledge, pp. 1-28. . https://doi.org/https://doi.org/10.4324/9780203010679

Howard, P.H. (2015). Intellectual property and consolidation in the seed industry. *Crop Science*, **55**(6), 2489–2495. https://doi.org/10.2135/cropsci2014.09.0669

Hoyer, W.D. (1984). An examination of consumer decision making for a common repeat purchase product. *Journal of Consumer Research*, **11**(3), 822–829.

Hu, L.T. & Bentler, P.M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, **6**(1), 1–55. https://doi.org/10.1080/10705519909540118

Hybrids SureFlex. (2021). Hybrids SureFlex. (2021). *$80/bag offer ends Nov. 30* . URL https://www.sureflexhybrids.com/80-

2/?gclid=CjwKCAjw7rWKBhAtEiwAJ3CWLAtyoBVHahu4fGzzxSFAiZnJ6fTR6Wh8eq0tldHEWbBTiYgBUHmTPRoCqE4QAvD_BwE (accessed 9.24.21).

Iacobucci, D. (2010). Structural equations modelling: fit indices, sample size, and advanced topics. *Journal of Consumer Psychology*, **20**, 90–98. https://doi.org/10.1016/j.jcps.2009.09.003

Iacobucci, D. (2009). Everything you always wanted to know about SEM (structural equations modelling) but were afraid to ask. *Journal of Consumer Psychology*, **19**, 673–680. https://doi.org/10.1016/j.jcps.2009.09.002

IFDC. (2017). An IFDC core competency: agro-dealer development. URL https://issuu.com/ifdcinfo/docs/ifdc_core_competency_agrodealerdevelopment (accessed 8.21.22)

IFDC. (2016). *IFDC 2015 Annual Report*. Muscle Shoals, Alabama, USA.

IFDC. (2013). *IFDC, 2012 Annual Report: increasing agricultural progress and sustainability through partnerships*. Muscle Shoals, Alabama, USA.

INEGI. 2018. Directorio Estadístico Nacional de Unidades Económicas (DENUE). URL https://www.inegi.org.mx/app/mapa/denue/default.aspx (accessed 1.20.2019)

Inman, J.J., Winer, R.S. & Ferraro, R. (2009). The interplay among category characteristics, customer characteristics, and customer activities on in-store decision making. *Journal of Marketing*, **73**(5), 19–29.

IPES-Food & ETC Group. (2021). *A long food movement: transforming food systems by 2045.* www.ipes-food.org/pages/LongFoodMovement

Jacoby, J. & Chestnut, R.W. (1978). *Brand loyalty: measurement and managemen*t. New York: John Wiley & Sons.

Jacoby, J. & Kyner, D.B. (1973). Brand loyalty vs repeat purchasing behavior. *Journal of Marketing Research*, **10**(1), 1–9. https://doi.org/10.2307/3149402

Jain, S. & Srivastava, J. (2000). An experimental and theoretical analysis of price-matching refund policies. *Journal of Marketing Research*, **37**(3), 351–362.

Kapur, A. (2011). IPR laws to protect innovation not restrict crop breeding - A rational approach. *Journal of Intellectual Property Rights*, **16**(2), 117–123.

Kelley, K.. (2013). *Layout and design for retail agricultural businesses*. URL https://extension.psu.edu/layout-and-design-for-retail-agricultural-businesses (accessed 5.10.21).

Kenya Agribusiness and Agroindustry Alliance. (2016). *The first foundation seed production entity for Africa*. URL https://kaaa.co.ke/the-first-foundation-seed-production-entity-for-africa/ (accessed 3.18.22).

Kim, R.B. (2012). Determinants of brand equity for credence goods: consumers' preference for country origin, perceived value and food safety. *Agricultural Economics/Zemedelska Ekonomika* (Czech Republic), **58**(7), 299–307. https://doi.org/10.17221/45/2012-agricecon

Kopp, R.J. & Greyser, S.A. (1987). Packaged goods marketing - "pull" companies look to improved "push." *Journal of Consumer Marketing*, **4**(2), 13–22.

Kotler, P. & Keller, L.K. (2012). *Marketing management*, 14th ed. New Jersey, USA: Prentice Hall.

Langyintuo, A.S., Mwangi, W., Diallo, A.O., MacRobert, J., Dixon, J. & Bänziger, M. (2010). Challenges

of the maize seed industry in eastern and southern Africa: a compelling case for private-public intervention to promote growth. *Food Polic*y, **35**(4), 323–331. https://doi.org/10.1016/j.foodpol.2010.01.005

Lee, H.N., Lee, A.S. & Liang, Y.W. (2019). An empirical analysis of brand as symbol, perceived transaction value, perceived acquisition value and customer loyalty using Structural Equation Modeling. *Sustainability,* **11**(7), 1–12. https://doi.org/10.3390/su11072116

Léger, A. (2005). Intellectual property rights in Mexico: do they play a role? *World Development*, **33**(11), 1865–1879. https://doi.org/10.1016/j.worlddev.2005.07.003

Lichtenstein, D.R., Ridgway, N.M. & Netemeyer, R.G. (1993). Price perceptions and consumer shopping behavior: a field study. *Journal of Marketing Research*, **30**(2), 234–245. https://doi.org/10.2307/3172830

Lopez-Pereira, M.A. & Morris, M.L. (1994). *Impacts of international maize breeding research in the developing world, 1966-1990*. Mexico, D.F.: CIMMYT. https://doi.org/10.1017/CBO9781107415324.004

Louwaars, N.P. & de Boef, W.S. (2012). Integrated seed sector development in Africa: a conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement*, **26**(1), 39–59. https://doi.org/10.1080/15427528.2011.611277

Luna-Mena, B.M., Rodríguez, M.A.H., Garay, O.J.A., González, F.C. & Contreras, J.A.M. (2012). Perspectivas de desarrollo de la industria semillera de maíz en México. *Revista Fitotecnia Mexicana*, **35**(1), 1–7.

Lynch, J.G., Marmorstein, H. & Weigold, M.F. (1988). Choices from sets including remembered brands: use of recalled attributes and prior overall evaluations. *Journal of Consumer Research*, **15(2)**, 169–184.

Mellens, M., Dekimpe, M.G. & Steenkamp, J.B.E.M. (1996). A review of brand loyalty measures in marketing. *Tijdschrift voor Economie en Management*, **41**(4), 507–533.

Meyers-levy, J. & Malaviya, P. (1999). Consumers' processing of persuasive advertisements, an integrative framework of persuasion theories. *Journal of Marketing*, **63**(special issue 1999), 45–60.

Monroe, K.B. (2012). Price and customers' perception of value. In: Smith, G.E. (ed.) *Visionary pricing: reflections and advances in honor of Dan Nimer*. Boston, Massachusetts, USA: Emerald Group Publishing Limited, pp. 129–152. https://doi.org/10.1108/S1069-0964(2012)0000019012

Monroe, K.B. (2003). *Pricing: making profitable decisions*, 3rd ed. Irwin, Burr Ridge, Illinois, USA: McGraw-Hill.

Monroe, K.B. & Chapman, J.I. (1987). Framing effects on buyers' subjective product evaluation. in: Wallendorf, M. & Anderson, P. (eds.), *Advances in consumer research*. Provo, Utah, USA: Association for Consumer Research, pp. 193–198.

Monroe, K.B. & Krishnan, R. (1985). The effect of price on subjective product evaluations. In: Olson, J.J. & Jerry, C. (eds.) *Perceived quality: how consumers view stores and merchandise*. Lexington, Massachusetts, US: Lexington Books, pp. 209–232.

Monsalvo-Velázquez, G., Romero-Perezgrovas, R., Govaerts, B. & Rendón-Medel, R. (2014). Innovative networks in conservation agriculture: Bajio hub case study, Mexico. In: Christy, R.D., Da Silva, C.A., Tihanyi, K. & Mabaya, E. (eds.) *Innovative institutions, public policies and private strategies for agro-enterprise development*. Rome, Italy: The Food and Agriculture Organization

of the United Nations; Singapore: World Scientific Publishing Co. Pte. Ltd., pp. 61-86. https://doi.org/10.1142/9789814596619

Morris, M.L. (1998). *Maize seed industries in developing countries*. Texcoco, Mexico: CIMMYT.

Morris, M.L. (1996). CIMMYT-Maize breeding impact survey. Texcoco, Mexico: CIMMYT, unpublished data.

Morris, M.L., Bellon, M.R. (2004). Participatory plant breeding research: opportunities and challenges for the international crop improvement system. *Euphytica* **136**, 21–35.

Muindi, P. & Adam, R.I. (2020). *Gender dynamics in the retailing behavior of agro-dealers and the purchasing behavior of farmers in Kenya: a summary brief*. Mexico: CIMMYT. https://repository.cimmyt.org/handle/10883/20928?show=full (accessed 8.21.22).

Mula, R.P., Rai, K.N., Kulkarni, V.N. & Singh, A.K. (2007). Public-private partnership and impact of ICRISAT 's pearl millet hybrid parents research. *Journal of SAT Agricultural Research*, **5**(1), 1–5. http://ejournal.icrisat.org/volume5/Sorgum_Millet/sm2.pdf

Nachtigall, C., Kroehne, U., Funke, F. & Steyer, R. (2003). (Why) Should we use SEM? Pros and cons of Structural Equation Modeling. *Methods of Psychological Research Online*, **8**(2), 1–22.

Naseem, A., Spielman, D.J. & Omamo, S.W. (2010). Private-sector investment in R&D: a review of policy options to promote its growth in developing-country agriculture. *Agribusiness*, **26**(1), 143–173. https://doi.org/10.1002/agr

Nelson, P. (1970). Information and consumer behavior. *Journal of Political Economy*, **78**, 311–329.

Niebur, B. (2009). The power of partnerships: a private-sector perspective. In: *World Food Security: Can Private Sector R&D Feed the Poor?* Presented at Conference by Crawford Fund for International Agricultural Research, Parliament House, Canberra, Australia, October 27-28, pp. 46–49. doi: 10.22004/ag.econ.125193.

Noriega, I.L., Halewood, M., Galluzzi, G., Vernooy, R., Bertacchini, E., Gauchan, D. & Welch, E. (2013). How policies affect the use of plant genetic resources: the experience of the CGIAR. *Resources,* **2**, 231-269. https://doi.org/10.3390/resources2030231

Odame, H. & Muange, E. (2011). *Can agro-dealers deliver the green revolution in Kenya?* IDS Bulletin 42, 78–89. https://doi.org/10.1111/j.1759-5436.2011.00238.x

Odin, Y., Odin, N. & Valette-Florence, P. (2001). Conceptual and operational aspects of brand loyalty: an empirical investigation. *Journal of Business Research*, **53**, 75–84.

OECD/Eurostat. (2018). *Oslo Manual 2018: Guidelines for collecting, reporting and using data on innovation*, 4th ed., *The measurement of scientific, technological and innovation activities, handbook of innovation indicators and measurement*. https://doi.org/10.1787/9789264304604-en

Oliver, R.L. (1999). Whence consumer loyalty? *Journal of Marketing*, **63**(special issue), 33–44. https://doi.org/10.2307/1252099

Olson, J.C. (1972). Cue utilization in the quality perception process, a cognitive model and empirical test. Unpublished Dissertation, Purdue University, West Lafayette, Indiana, USA; Ann Arbor, USA: University Microfilms International, 1984.

Pannell, D. (2007). *Influences on technology adoption in different phases*. Pannell Discussion #103, June. URL http://www.pannelldiscussions.net/2007/06/103-influenceson-%0Atechnology-adoption-in-different-phases/ (accessed 6.8.21).

Pannell, D.J.A., Marshall, G.R.B., Barr, N.C., Curtis, A.D., Vanclay, F.E. & Wilkinson, R.C. (2006). Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture*, **46**(11), 1407–1424.

Pardey, P.G., Alston, J.M. & Chan-kang, C. (2013.) Public agricultural R&D over the past half century: an emerging new world order. *Agricultural Economics*, **44**(s1), 1–11. https://doi.org/10.1111/agec.12055

Perales, H. & Golicher, D. (2014). Mapping the diversity of maize races in Mexico. *PLoS One* 9. https://doi.org/10.1371/journal.pone.0114657

Pingali, P.L. (2012). Green Revolution: impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences*, **109**(31), 12302–12308. https://doi.org/10.1073/pnas.0912953109

Pixley, K. V., Salinas-Garcia, G.E., Hall, A., Kropff, M., Ortiz, C., Bouvet, L.C., Suhalia, A., Vikram, P. & Singh, S. (2018). CIMMYT's Seeds of Discovery initiative: harnessing biodiversity for food security and sustainable development. *Indian Journal of Plant Genetic Resources*, **31**(1), 1–10. https://doi.org/10.5958/0976-1926.2018.00001.3

Potrykus, I. (2010). Lessons from the "Humanitarian Golden Rice" project: regulation prevents development of public good genetically engineered crop products. *New Biotechnology*, **27**(5), 466–472. https://doi.org/10.1016/j.nbt.2010.07.012

Pray, C.E. (2001). Public-private sector linkages in research and development: biotechnology and the seed industry in Brazil, China and India. *American Journal of Agricultural Economics*, **83**(3), 742–747. https://doi.org/10.1111/0002-9092.00201

Pray, C.E. & Fuglie, K. (2001). *Private investment in agricultural research and international technology transfer in Asia*. ERS Economic Report, No. 805. Washington, DC, USA: Economic Research Service, United States Department of Agriculture.

Pray, C.E. & Umali-Deininger, D. (1998). The private sector in agricultural research systems: will it fill the gap? *World Development*, **26**(6), 1127–1148.

PRWeb Newswire. (2016). *DuPont Pioneer & International Maize and Wheat Improvement Center form CRISPR-Cas public/private partnership*. URL https://go.gale.com/ps/i.do?p=ITOF&u=rdg&id=GALE%7CA464935850&v=2.1&it=r&sid=ITOF&asid=8f55b9d2 (accessed 9.28.16).

Ramaswami, B., Murugkar, M. & Shelar, M. (2009). Product proliferation in India's cotton seed market: are there too many varieties? *Journal of Agricultural and Food Industrial Organization*, **7**(1), 1–17.

Rao, A. & Monroe, K.B. (1988). The moderating effect of prior knowledge on cue utilization in product evaluations. *Journal of Consumer Research,* **15**(2), 253–264.

Rao, A.R. & Bergen, M.E. (1992). Price premium variations as a consequence of buyers' lack of information. *Journal of Consumer Research*, **19**(3), 412–423.

Reddy, B.V.S., Hall, A.J. & Rai, K.N. (2001). The long road to partnership: private support of public research on sorghum and pearl millet. In: Hall, A.J., Yoganand, B., Rasheed Sulaiman, V. &Clark, N.G. (eds.) *Sharing Perspectives on Public -Private Sector Interaction: Proceedings of a Workshop, 10 April 2001*, Patancheru, India: National Centre for Agricultural Economics and Policy Research (NCAP) and International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) p. 48.

Renkow, M. &, Byerlee, D. (2010). The impacts of CGIAR research: a review of recent evidence. *Food Policy*, **35**(5), 391–402. https://doi.org/10.1016/j.foodpol.2010.04.006

Rutsaert, P. & Donovan, J. (2020). Sticking with the old seed: input value chains and the challenges to deliver genetic gains to smallholder maize farmers. *Outlook on Agriculture,* **49**(1), 39–49. https://doi.org/10.1177/0030727019900520

San Vicente, F. (2013). Reporte final. Estrategia Internacional para Aumentar el Rendimiento de Maíz (MasAgro-Maíz), Meta 3.2: Desarrollar híbridos variedades de maíz de alto rendimiento y adaptarlos a condiciones de temporal para la región Trópico. Texcoco, Mexico: CIMMYT.

Schenkelaars, P., de Vriend, H. & Kalaitzandonakes, N. (2011). *Drivers of consolidation in the seed industry and its consequences for innovation*. Report for COGEM (Commissie Genetische Modificatie). Wageningen, The Netherlands: Schenkelaars Biotechnology Company. https://www.lisconsult.nl/files/docs/consolidation_seed_industry.pdf (accessed 8.21.22).

Schermelleh-Engel, K., Moosbrugger, H. & Müller, H. (2003). Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research Online*, **8,** 23–74.

Schumacker, R.E. & Lomax, R.G. (2004). *A beginner's guide to Structural Equation Modeling*, 2nd ed. Mahwah, New Jersey, U.S.A: Lawrence Erlbaum Associates, Inc..

Scitovsky, T. (1945). Some consequences of the habit of judging quality by price. *Review or Economic Studies*, **12**(2), 100–105.

Secretaría de Agricultura y Ganadería. (1961). *Ley sobre producción, certificación y comercio de semillas*. Diario Oficial de la Federación, Viernes 14 Abril 1961. URL http://dof.gob.mx/index_113.php?year=1961&month=04&day=14 (accessed 7.13.20).

Secretaría de Economía. (2019). *Sistema de Consulta de Información Estadística por País*. URL http://www.economia-snci.gob.mx/sic_php/pages/estadisticas/ (accessed 5.19.19).

Setimela, P.S., Magorokosho, C., Lunduka, R., Gasura, E., Makumbi, D., Tarekegne, A., Cairns, J.E., Ndhlela, T., Erenstein, O. & Mwangi, W. (2017). On-farm yield gains with stress-tolerant maize in eastern and Southern Africa. *Agronomy Journal*, **109**(2), 406–417. https://doi.org/10.2134/agronj2015.0540

Shirai, M. (2015). Impact of "high quality, low price" appeal on consumer evaluations. *Journal of Promotion Management*, **21**(6), 776–797. https://doi.org/10.1080/10496491.2015.1088922

SIAP. (2020a). *Estadística de Producción Agrícola*. Mexico: Ministry of Agriculture and Rural Development (SADER). URL http://infosiap.siap.gob.mx/gobmx/datosAbiertos.php (accessed 8.6.20).

SIAP. (2020b). *Boletin balanza disponibilidad-consumo de maíz*. Mexico: Ministry of Agriculture and Rural Development (SADER).

SIAP. (2016). Uso de tecnología y servicios en el campo. Mexico: Ministry of Agriculture and Rural Development (SADER). URL https://www.gob.mx/siap/documentos/tecnificacion (accessed 2.5.21).

Simtowe, F. (2019). Monitoring, evaluation & learning in Stress Tolerant Maize for Africa (STMA) project.

Sloman, J. (2003). *Economics*, 5th ed. Harlow, Essex: Pearson Education Limited.

Smith, G.E. & Nimer, D. (2012). One on one, pricing with Dan Nimer. In: Smith, G.E. (ed.), *Visionary*

pricing: reflections and advances in honor of Dan Nimer. Boston, Massachusetts, USA: Emerald Publishing Limited, pp. 67–85. https://doi.org/10.4324/9781315010335-12

SNICS. (2020). *Catalogo Nacional de Variedades Vegetales en linea*. Mexico: National Seeds Inspection and Certification Service. URL https://datastudio.google.com/reporting/5b7206ba-e190-48fe-9696-73523bfccf58/page/itBWB (accessed 9.7.20).

SNICS. (2019). *Producción de semilla calificada 2011-2019*. Mexico: National Seeds Inspection and Certification Service, unpublished data. Some data available at https://www.gob.mx/snics/acciones-y-programas/boletin-de-semilla-calificada (accessed 6.21.21).

SNICS. 2017. Precios y existencias de semilla de maíz. Mexico: National Seeds Inspection and Certification Service. URL https://www.gob.mx/snics/documentos/precios-y-existencias-de-semilla-2017 (accessed 6.21.21)

SNICS. 2017b. Directorio de productores, obtentores y comercializadores de semillas (DPOCS). URL https://www.gob.mx/snics/acciones-y-programas/directorio-de-productores-obtentores-y-comercializadores-de-semillas-237740 (accessed 1.20.19)

Spielman, D.J., Hartwich, F. & Grebmer, K. (2010). Public-private partnerships and developing-country agriculture: evidence from the international agricultural research system. *Public Administration and Development*, **30**, 261–276. https://doi.org/10.1002/pad.574

Spielman, D.J., Hartwich, F. & von Grebmer, K. (2007). *Sharing science, building bridges, and enhancing impact public-private partnerships in the CGIAR*, IFPRI Discussion Paper 00708. Washington, DC, USA: International Food Policy Research Institute.

Spielman, D.J., Kolady, D.E., Cavalieri, A. & Rao, N.C. (2014). The seed and agricultural biotechnology industries in India: an analysis of industry structure, competition, and policy options. *Food Policy,* **45**, 88–100. https://doi.org/10.1016/j.foodpol.2014.01.001

Srinivasan, C.S. (2003). Concentration in ownership of plant variety rights: some implications for developing countries. *Food Policy*, **28**, 519–546. https://doi.org/10.1016/j.foodpol.2003.10.003

Srinivasan, C.S., Thirtle, C. & Palladino, P. (2003). Winter wheat in England and Wales, 1923–1995: what do indices of genetic diversity reveal? *Plant Genetic Resources: Characterisation and Utilisation*, **1**(1), 43–57. https://doi.org/10.1079/pgr20031

Steenkamp, E.M. (1990). Conceptual model of the quality formation process. *Journal of Business Research*, **21**(4), 309–333.

Sun, M. (2011). Disclosing multiple product attributes. *Journal of Economics and Management . Strategy*, **20**(1), 195–224.

Syngenta Foundation for Sustainable Agriculture. (2021a). *Public-private partnerships for crop breeding*. URL https://www.syngentafoundation.org/public-private-partnerships-crop-breeding (accessed 4.5.21).

Syngenta Foundation for Sustainable Agriculture. (2021b). *Affordable, Accessible, Asian ("AAA") Drought-Tolerant Maize*. aaa_maize_overview_website_jan_21.pdf (accessed 21.8.22).

Syngenta Foundation for Sustainable Agriculture. (2018). *Public Private Partnerships*. URL https://www.syngentafoundation.org/public-private-partnerships (accessed 9.29.18).

Syngenta Foundation for Sustainable Agriculture. (2016). *Database of Public-Private Partnerships in Agriculture*. pppmap.net (accessed 8.21.22).

Teas, R.K. & Agarwal, S. (2001). The effects of extrinsic product cues on consumers' perceptions of quality, sacrifice, and value. *Journal of the Academy of Marketing Science*, **28**(2), 278–290.

Tefera, T., Mugo, S. & Beyene, Y. (2016). Developing and deploying insect resistant maize varieties to reduce pre-and post-harvest food losses in Africa. *Food Security*, **8**, 211–220. https://doi.org/10.1007/s12571-015-0537-7

Tellis, G.J. (2003). *Effective advertising: understanding when, how, and why advertising works*. Thousand Oaks, California, US: Sage.

Thaler, R.H. (1985). Mental accounting and consumer choice. *Marketing Science*, **4**(3), 199–214.

Torres-Flores, J.L., Mendoza García, B., Prasanna, B.M., Alvarado, G., San Vicente, F.M. & Crossa, J. (2017). Grain yield and stability of white early maize hybrids in the highland valleys of Mexico. *Crop Science*, **57**(6), 3002–3015. https://doi.org/10.2135/cropsci2017.03.0145

Turrent, A., Wise, T.A. & Garvey, E. (2012). *Achieving Mexico's maize potential* (GADE Working Paper 12-03). Medford Massachusetts, USA: Tufts University.

UN Environment Program. (2022). *The Cartagena Protocol on Biosafety*. Convention on Biological Diversity. URL https://bch.cbd.int/protocol/ (accessed 5.2.22).

UPOV. (2022). *Members, UPOV Convention* (1961), as revised at Geneva (1972, 1978 and 1991). Members International Union for the Protection of New Varieties of Plant. URL http://www.upov.int/members/en (accessed 3.8.22).

UPOV. (2011). *About UPOV*. URL https://www.upov.int/about/en/ (accessed 5.2.22).

USAID and IFDC. (2015). *Impact assessment of the effectiveness of agro-dealer development activities conducted by USAID-AIMS III in Mozambique. Agricultural Input Markets Strengthening (AIMS) III.* Muscle Shoals, Alabama, USA: IFDC.

van der Meer. (2002). Public-private cooperation in agricultural research: examples from the Netherlands. In: Byerlee, D. and Echeverría, R.G. (Eds.) *Agricultural Research Policy in an Era of Privatization*. Oxford: CABI, pp. 123–136.

Virgen-Vargas, J., Zepeda-Bautista, R., Avila-Perces, M.A., Espinosa-Calderón, A. & Arellano-Vázquez, J.L. (2016). Producción y calidad de semilla de maíz en Valles Altos de México. *Agronomía Mesoamericana*, **27**(1), 191–206.

Waithaka, M., Mugoya, M., Mabaya, E. & Tihanyi, K. (2021). *Decentralized seed services in Africa: an assessment of Tanzania and Uganda. ZEF Working Paper 206*. Bonn, Germany: Center for Development Research, University of Bonn. Germany: https://bonndoc.ulb.uni-bonn.de/xmlui/bitstream/handle/20.500.11811/9511/ZEF_Working_Paper_206.pdf?sequence=1&isAllowed=y (accessed 8.21.22).

Walker, T.S. & Alwang, J. (Eds.) (2015). *Crop improvement, adoption and impact of improved varieties in food crops in Sub-Saharan Africa*. Montpellier, France: CGIAR and CAB International.

Weersink, A. & Fulton, M. (2020). Limits to profit maximization as a guide to behavior change. *Applied Economic Perspectives and Policy*, **42**(1), 67-79. https://doi.org/10.1002/aepp.13004

Witcombe, J.R., Packwood, A.J., Raj, A.G.B. & Virk, D.S. (1998). The extent and rate of adoption of modern cultivars in India. In: Witcombe, J. R., Virk, D.S. & Farrington, J. (eds.) *Seeds of choice: making the most of new varieties for small farmers*. Oxford IBH, New Delhi & London: Intermediate Technology Publications, pp. 53–68.

Worku, M., De Groote, H., Munyua, B., Makumbi, D., Owino, F., Crossa, J., Beyene, Y., Mugo, S.,

Jumbo, M., Asea, G., Mutinda, C., Kwemoi, D.B., Woyengo, V., Olsen, M. & Prasanna, B.M. (2020). On-farm performance and farmers' participatory assessment of new stress-tolerant maize hybrids in Eastern Africa. *Field Crops Research*, **246**, 107693. https://doi.org/10.1016/j.fcr.2019.107693

Yang, Z. & Peterson, R.T. (2004). Customer perceived value, satisfaction, and loyalty: the role of switching costs. *Psychology & Marketing*, **21(**10), 799–822. https://doi.org/10.1002/mar.20030

Zeithaml, V.A. (1988). Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. *Journal of Marketing*, **52**(3), 2–22.

Appendix

This Appendix consists of the following parts:

Appendix A. Examples of public-private partnership (PPP) research consortiums in plant breeding.

Appendix B. Grain yield (GY) OLS linear regression results of MasAgro, public, private national and private multinational hybrids.

Appendix C. Sampled MasAgro SMEs product portfolios composition supplementary tables.

Appendix D. Post purchase intercept questionnaire survey applied to seed clients at agro-dealers.

Appendix E. Results of the brand loyalty and price-quality perception model of hybrid maize seed for single price evaluations.

Appendix F. Summary of the transcripts of the interviews with agro-dealers and seed companies' sales representatives.

Appendix A. Examples of public-private partnership (PPP) research consortiums in plant breeding.

Project name - year launched	Country/region	Crops	Major partners	Project objectives	Main results/outputs	Reference
Insect-Resistant Maize for Africa IRMA - (1999-2003).	Kenya	Maize	CIMMYT, KARI, Syngenta Foundation, Monsanto, Wakala Seeds.	Development and delivery of insect resistant (IR) - to stem borers and post-harvest pests - maize varieties.	• Development of source lines of the key Bt genes Cry1Ab and Cry1Ba. • Release of 13 stem borer resistant non-GM maize varieties (3 OPVs and 10 hybrids) and 4 storage pest-resistant hybrids in Kenya between 2006 and 2011. • Three IR hybrids (KH 414-1 SBR, 414-4 SBR) and the OPV Pamuka commercialised in Kenya by Monsanto, Wakala Seeds and KARI Seed.	Mugo et al. (2002); Mugo et al. (2005); Mabeya and Ezezika, 2012.; Tefera et al. (2016); Syngenta Foundation (2021).
The sorghum, pearl millet and pigeonpea Hybrid Parents Research Consortia (2000-2017).	India, Egypt, Indonesia and Thailand.	Sorghum, pearl millet and pigeonpea.	ICRISAT, private companies (MAHYCO, JK Agri Genetics, Proagro Seed Company/Bayer BioScience, Vikki's Agro-Tech Ltd, Ganga Kaver i Seeds, Biogene, Monsanto).	Develop sorghum, pearl millet and pigeonpea hybrid cultivars adapted and resistant to major biotic and abiotic stresses. Promote private seed sector development.	• 50 private companies members of one or more consortia by 2008. • 15 sorghum hybrids developed by affiliated companies using ICRISAT-bred materials • 103 pearl millet hybrids developed between 2000 and 2010. • 8 pigeonpea hybrids directly released by the private sector using ICRISAT parental lines. • 25 consortium companies marketed 82 pearl millet hybrids using ICRISAT-derived breeding materials by 2006.	Gowda et al. (2004), Mula et al. (2007).

Striga-Resistant Maize Project[e] - STRIGAWAY (2006-2014).	Kenya, Malawi, Uganda, Tanzania	Maize, sorghum, millet and rice.	CIMMYT, AATF, KARI, NARs of participating countries (KALRO, DARS, NARO, TARI), BASF, regional seed companies.	Introduce maize, sorghum, millet and rice varieties resistant to the StrigAway herbicide (BASF®).	• STRIGAWAY® technology developed • Insect resistant (IR) maize hybrid Ua Kayongo (Striga Killer) commercially launched in Kenya in 2006. • Over 100t of certified seed of the hyhrid Ua Kayongo (Striga killer) produced by WSC for large scale testing in 2007. • 10t of IR maize seed distributed by AATF in 2007. • 6 early OPVs, 5 late OPVs and 2 hybrids allocated to seed companies and NARS for registration as new varieties and subsequent commercialization.	Spielman et al. (2007); Odame and Muangue (2011); Fukuda-Parr and Orr (2012).
Drought-Tolerant Maize for Africa DTMA - (2006-2015) and Drought Tolerant Maize for Africa Seed Scaling - DTMASS (2015-2020).	Sub-Saharan Africa	Maize	CIMMYT, IITA, USAID, DFID, B&MGF, Howard G. Buffett Foundation, CSIR (Kenya), NARs (ARCN, KALRO, NARO, EIAR, ZARI, DRSS, etc.) small and medium seed companies.	Develop and disseminate drought-tolerant (DT) maize hybrids in 13 countries of Sub-Saharan Africa; Scaling up and out drought tolerant, stress-resilient and high-yielding maize hybrids.	• 233 varieties (including about 200 distinct DT maize varieties) released across target countries as of 2016. • African NARs providing 300t of breeder seed annually to community-based seed production schemes. • Over 33,000t (1,650,000 bags) of seeds distributed to farmers in participating SSA.	Lumpkin and Armstrong (2009); Edmeades (2013); CIMMYT (2015); Martey et al. (2020).

AGRA Program for Africa's Seed Systems - PASS (2007 to date 2017).	Africa: eventually grew to include 18 countries	Staples	USAID, The Rockefeller Foundation, B&MGF, Howard G. Buffett Foundation.	Develop and release new crop varieties; Strenghthen Africa's breeding and seed sector capacities; Build agro-dealer networks to sell improved seed and other inputs to local, smallholder farmers.	• 114 African seed companies producing over 128,000 t of certified seed annually. • Public crop breeding teams developed and released 600 new crop varieties. Over 400 of these were at some stage of commercialization. • About 25,000 agro-dealers trained and certified for operation as private input suppliers in 18 countries across Africa. • A total of 404,000 MT of seed and over 1.1 million MT of fertilizer sold to farmers through agro-dealers trained by 2018.	AGRA, 2013; AGRA, 2017. AGRA, 2020a; AGRA, 2020b. See links
Water-Efficient Maize for Africa WEMA (2008-2018).	Eastern and Southern Africa	Maize	CIMMYT, AATF, B&MGF, Howard G. Buffett Foundation, NARs of participant countries (KALRO, TARI, ARC, IIAM, NARO), Monsanto, BASF.	Development of water-efficient and insect resistant maize hybrids for its performance to drought conditions in Africa.	• Successful confined field trials for GM maize varieties in Kenya, Uganda and South Africa (2008-2013). • First WEMA non-GM drought tolerant maize hybrids scheduled to be released in 2013. • Bt insect resistance traits (MON87460 and MON810) in confined field trial testing stage in 2013 in Uganda and Kenya. • Bt IR and DT WEMA GM hybrids scheduled for release by 2016/2017.	Odame and Muangue (2011); Fukuda-Parr and Orr (2012); Edmeades (2013); Oikeh et al. (2014).

Affordable, Accessible Asian Drought Tolerant Maize Project - AAA DT Maize (2010-2016).	Southeast Asia (India), Indonesia, Philippines and Vietnam	Maize	CIMMYT, Syngenta, Syngenta Foundation, NARs of Indonesia, Philippines and Vietnam.	Develop drought-tolerant, low-cost maize hybrids for smallholder farmers in low-rainfall drought-prone areas of South Asia.	• Hybrid TA5084 first sold during the 2018 Kharif (monsoon) season and promoted by around ten Indian seed partners (either small companies or NGOs) in Madhya Pradesh, Rajasthan and Gujarat states of India. • Local seed partners sold 18 t of AAA maize in 2018, 50 t in 2019 and 120 tons in 2020. • Some 8k farmers in central India planted the seeds on about 6000 ha. • Local seed companies and NGOs sell 4kg and 1kg bags under the AAA brand.	CIMMYT, n.d. Syngenta Foundation, 2021a. Syngenta Foundation, 2021b.
International Maize Improvement Consortium IMIC-Asia - (2010-2020) and IMIC-Africa (2018 to date).	South and Southeast Asia, mainly India Africa: Ethiopia, Kenya, Zimbabwe	Maize	Asia: CIMMYT, GIZ/GMBH, local seed companies Africa: CIMMYT, NARs of participating countries (EIAR, KALRO, DRSS), private seed companies.	Develop improved early and advanced maize lines; evaluate pre-release CIMMYT-bred hybrids and hybrid combinations of partners; strengthen public and private maize breeding and seed sector capacities.	• 43 affiliated members from the public and the private sectors by 2014. • 317 CIMMYT-bred hybrids distributed to members for in-house evaluation and shortlist the best five hybrids in 2014. • Deployment of hybrids once registered was expected to be made by private companies. • IMIC-Africa launched in 2018	Sadananda et al. (2014).
Improved Maize for African Soils (IMAS) - 2010-2015.	Eastern and Southern Africa	Maize	CIMMYT, USAID, KALRO, South African ARC, KARI, B&MGF, DuPont-Pioneer.	Development of high yielding maize varieties with improved nitrogen use efficiency (NUE)	• The largest tropical N stress phenotyping network in the world, with more than 120,000 N-depleted research plots at 16 experimental stations in seven countries established. • 10 NUE lines used as donor parents in more than 600 pedigree starts, crossed with Africa adapted germplasm and being advanced through pedigree selection and doubled haploid technology.	Semagn et al. (2015).

Stress Tolerant Maize for Africa - STMA (2016-2020).	Eastern, Southern and West Africa.	Maize	CIMMYT, USAID, B&MGF, NARs of participating countries (EIAR, KALRO, TARI, NARO, DARS, ARC, ZARI, DRSS, etc.), private companies.	Develop improved maize varieties with resistance and tolerance to drought, low soil fertility, heat, maize lethal necrosis and pests affecting maize production.	• 15 varieties released in 2016, 17 in 2017 and 14 in 2018. • 36,622t of certified seed produced in 2016, 39,917t in 2017, 54,565t in 2018 and >85,000 in 2019.	Simtowe (2019); Prasana (2019).

Partners: CIMMYT- International Maize and Wheat Improvement Center; KARI - Kenyan Agricultural Research Institute; ICRISAT - International Crops Research Institute for the Arid Tropics; AATF - African Agricultural Technology Foundation; KALRO - Kenia Agricultural & Livestock Research Organization; DARS - Malawi's Department of Agricultural Re Services; NARO - Uganda's National Agricultural Research Organization; TARI - Tanzanian Institute of Agricultural Research; Agricultural Research Council of South Africa Mozambique Institute of Agricultural Research (IIAM); Agricultural Research Council of Nigeria (ARCN); EIAR - Ethiopian Institute of Agricultural Research; ZARI - Zambian Agric Research Institute; DRSS - Zimbawe's Department of Research and Specialist Services; IITA - International Institute for Tropical Agriculture; USAID - United States Age International Development; DFID - UK Department for International Development; B&MGF - Bill & Melinda Gates Foundation; GIZ/GMBH - Deutsche Gesellschaft Fuer Interna Zusammenarbeit.

Appendix B. Grain yield (GY) OLS linear regression results of MasAgro, multinational, private national and public hybrids.

Table B1. GY mean results, GY differences and p-values of MasAgro, multinational, private national and public hybrids evaluated in the Highlands (HL), Subtropical (ST) and Tropical (LT) MasAgro seed evaluation networks in Mexico, 2011-2019.

Mega-		MasAgro		Multinational		Private national		Public	
environment/colour	GY	Diff	P-value	Diff	P-value	Diff	P-value	Diff	P-value
Subtropical white									
MasAgro	8.18	--	--						
Multinational	8.74	0.56	**0.03	--	--				
Private national	8.63	0.45	*0.07	-0.11	0.62	--	--		
Public	7.83	-0.35	0.17	-0.91	***0.00	-0.80	***0.00	--	--
Subtropical yellow									
MasAgro	7.99	--	--						
Multinational	8.81	0.83	**0.01	--	--				
Private national	8.13	0.14	0.54	-0.69	0.02	--	--		
Public	7.03	-0.95	**0.02	-1.78	***0.00	-0.04	***0.00	--	--
Highlands white									
MasAgro	7.01	--	--						
Multinational	6.89	-0.12	0.73	--	--				
Private national	7.01	-0.01	0.98	0.12	0.74	--	--		
Public	6.90	-0.11	0.70	**0.01	0.98	-0.11	0.73	--	--
Highlands yellow									
MasAgro	6.62	--	--						
Multinational	6.95	0.33	0.45	--	--				
Private national	6.45	-0.17	0.70	-0.50	0.40	--	--		
Public	5.81	-0.81	***0.00	-1.14	**0.02	-0.64	0.20	--	--
Tropical white									
MasAgro	7.09	--	--						
Multinational	6.87	-0.22	0.43	--	--				
Private national	6.46	-0.63	**0.03	-0.41	0.23	--	--		
Public	6.42	-0.67	***0.00	-0.45	0.14	-0.04	0.90	--	--
Tropical yellow									
MasAgro	6.41	--	--						
Multinational	6.29	-0.11	0.58	--	--				
Private national	5.54	-0.87	***0.00	-0.76	0.00	--	--		
Public	6.08	-0.33	0.42	-0.21	0.62	0.54	0.20	--	--

Robust standard error *** p<0.01, ** p<0.05, * p<0.1, R-squared= 0.7037, Root MSE= 0.7800.

Appendix C. Sampled MasAgro SMEs product portfolios composition Supplementary Tables

Supplementary Table C1. Product portfolio composition of maize varieties and composition of maize seed sales by product type, 2011-2019 (n=31).

Product type	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Products in portfolio								
Hybrids	111	138	154	167	196	235	229	259	295
OPVs	32	34	26	24	32	30	33	32	27
Total	***143***	***172***	***180***	***191***	***228***	***265***	***262***	***291***	***322***
	Percentage of sales[1]								
Hybrids	71.6	75.0	88.3	89.9	89.9	91.3	90.3	92.8	91.9
OPVs	28.4	25.0	11.7	10.1	10.1	8.7	9.7	7.2	8.1
Total	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***
Total sales (t)	**5,019**	**6,002**	**9,953**	**12,090**	**11,832**	**12,618**	**12,090**	**12,250**	**13,589**

Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author). [1] Percentage of sales refers to each category of seed sales relative to total sales of sampled companies.
The total of products in portfolio differs from the total of products in portfolio in Table 6 because information of the product type of some varieties is missing.

Supplementary Table C2. Product portfolio composition of maize varieties and composition of maize seed sales by mega-environment, 2011-2019 (n=31).

Mega-environment	2011	2012	2013	2014	2015	2016	2017	2018	2019
	Products in portfolio								
Subtropic	77	96	103	107	115	133	131	145	158
Tropic	46	56	52	45	65	81	90	94	112
Highlands	21	22	28	42	48	53	41	53	52
Total	**144**	**174**	**183**	**194**	**228**	**267**	**262**	**292**	**322**
	Percentage of sales[1]								
Subtropic	62.1	65.2	74.8	71.4	67.7	69.2	64.7	65.7	57.6
Tropic	31.7	28.6	19.8	21.1	22.6	21.9	24.9	23.1	33.3
Highlands	6.3	6.1	5.3	7.5	9.7	8.8	10.4	11.2	9.1
Total	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***	***100***
Total sales (t)	**5,019**	**6,002**	**9,953**	**12,090**	**11,832**	**12,618**	**12,090**	**12,250**	**13,589**

Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author). [1] Percentage of sales refers to each category of seed sales relative to total sales of sampled companies.

Supplementary Table C3. Product portfolio composition of maize varieties and composition of maize seed sales by company size and seed category, 2011-2019 (n=31).

Firm's size and seed category	Products in portfolio								
	2011	2012	2013	2014	2015	2016	2017	2018	2019
Medium									
CIMMYT MasAgro	-	-	-	11	13	15	13	14	17
Public	9	9	9	4	3	5	6	3	8
Private national	29	30	29	32	35	48	42	46	48
Private MasAgro	-	-	1	2	1	4	4	7	5
Small									
CIMMYT MasAgro	-	-	-	3	20	27	29	30	45
Public	39	45	48	43	47	44	44	43	45
Private national	12	18	16	20	21	22	20	23	20
Private MasAgro	-	-	-	-	2	4	6	9	9
Micro									
CIMMYT MasAgro	-	3	8	17	20	40	39	48	59
Public	40	54	58	50	54	42	39	44	41
Private national	15	15	14	12	12	14	18	18	17
Private MasAgro	-	-	-	-	-	2	2	7	8
	Percentage of sales[1]								
Medium									
CIMMYT MasAgro	-	-	-	12.0	15.3	9.3	10.7	7.0	12.4
Public	16.7	17.6	8.8	4.9	1.6	4.8	8.8	5.2	9.1
Private national	83.3	82.4	90.6	79.0	82.6	83.1	77.1	78.2	71.8
Private MasAgro	-	-	0.5	4.0	0.5	2.9	3.4	9.6	6.7
Small									
CIMMYT MasAgro	-	-	-	0.3	6.7	8.7	13.7	10.3	28.2
Public	83.9	79.1	77.8	76.9	67.7	64.5	61.3	46.1	40.3
Private national	16.1	20.9	22.2	22.8	25.2	26.0	22.0	32.3	21.7
Private MasAgro	-	-	-	-	0.4	0.7	3.1	11.3	9.8
Micro									
CIMMYT MasAgro	-	0.3	3.0	6.2	13.4	26.7	34.9	35.7	35.0
Public	73.6	75.7	74.8	71.4	69.7	56.7	51.2	46.7	49.9
Private national	26.4	24.1	22.2	22.4	16.9	16.1	12.4	15.2	11.1
Private MasAgro	-	-	-	-	-	0.5	1.6	2.4	4.0
Total sales (t)	**5,019**	**6,002**	**9,953**	**12,090**	**11,832**	**12,618**	**12,090**	**12,250**	**13,589**

Source: MasAgro seed marketing survey, 2013-2019 (CIMMYT, 2019a); MasAgro germplasm impact survey, 2015 (CIMMYT, 2015); and Product portfolio survey, 2020 (Author). [1] Percentage of sales refers to each category of seed sales relative to total sales of sampled companies.

Appendix D. Post purchase intercept questionnaire survey administered to seed clients at agro-dealers.

Introduction:

My name is ……. and I work for the International Maize and Wheat Improvement Centre (CIMMYT) – an organization that aims to improve maize farming in Mexico and in many other countries. We are conducting a study to better understand the experiences and needs of farmers when purchasing seed. We have some questions that we'd like to ask you about the seed you bought. We are here to listen and learn from you.

Everything you say to us will be treated with the highest confidentiality and results will be reported anonymously. This study is voluntary. If you choose to participate, you may change your mind and leave the study at any time.

Do you agree to participate?

1=Yes, and proceed 2=No, and stop the interview

Screener questions:

A1. Are you a maize farmer? 1=Yes, and proceed 2=No, and stop the interview

A2. Have you already bought your maize seed for this planting season? 1=Yes, and proceed 2=No, and stop the interview

A3. Did you buy maize for you yourself or someone else in your family? 1=Yes, and proceed 2=No, and stop the interview

Identifying Variables:

I1. Name of the respondent _____

I2. Municipality of the farmer_____

I3. Town/village of the farmer_____

For this production cycle (PV June-October 2019):

SP1. What is the total farming area of your family? a) own_____ hectares b) rented_____hectares

SP2. How much of this area will you use for growing maize in this season? _____ hectares

SP3. How much of this area is a) irrigated _____hectares, and b) rainfed? _____hectares

SP4. How much of this area will you plant with a) improved varieties _____hectares, and with b) your own seed (criollo) _____hectares

SP5. How many years have you used improved maize seeds? _____

Q1. The following questions refer to the seed purchase you made for this cropping season

Q1.1. Which maize variety(ies) did you buy and what quantity?

Q1.1.1. Variety name/brand	Q1.1.2. Number of bags	Q1.1.3. Size of the bag 1. 20 kg 2. 50 thousand seeds 3. 60 thousand seeds 4. 70 thousand seeds 5. Other, specify	Q1.1.4. Price per bag	Q1.1.5. What is the yield (t/ha) you expect to obtain with this variety/brand?	Q1.1.6. Is this your most preferred variety? *1=Yes*, *2=No*	Q1.1.7. *If No*, then why didn't you buy your most preferred variety? 1. Price is high 2. It wasn't available 3. It requires more investment in complementary inputs 4. Moisture limitations 5. Decision of others in the family 6. Other, specify	Q1.1.8. *If No*, Which variety would you choose to buy today?

Q1.1.1. Variety name/brand	Q1.1.9. Did you have any funding to buy the seed? *1=Yes*, *2=No*	Q1.1.10. If yes, who is the provider? 1. Financial Ag. company 2. Private bank 3. This agro-dealership 4. Lender 5. Subsidy/government 6. Own money 7. The seed company 8. Other, specify	Q1.1.11. How important was this funding to your purchase of the seed? 1. Not important at all 2. Not important 3. Neutral 4. Important 5. Very important	Q1.1.12. What percentage did you pay from each source? 1. Financial Ag. company 2. Private bank 3. This agro-dealership 4. Lender 5. Subsidy/government 6. Own money 7. Seed company 8. Other, specify	Q1.1.13. Did you have any funding for all the other crop management practices? *1=Yes*, *2=No*	Q1.1.14. *If Yes* How important was this funding to your purchase of the seed? 1. Not important at all 2. Not important 3. Neutral 4. Important 5. Very important

Q1.1.1 Variety name/brand	Q1.1.15. Did you buy this seed as part of a technological package? *1=Yes, 2=No*	Q1.1.16. *If Yes* How important was the ability to buy the seed in a technological package for your decision to buy it? 1. Not important at all 2. Not important 3. Neutral 4. Important 5. Very important	Q1.1.17. Does the seed include technical assistance? *1=Yes, 2=No*	Q1.1.18. *If Yes* How important was the fact that the seed included technical assistance to your decision to buy it? 1. Not important at all 2. Not important 3. Neutral 4. Important 5. Very important

Q2. Who selected the maize variety you bought?

Q2.1. Variety name/brand	Q2.2. Are you buying this variety for the first time? *1=yes, 2=no*	Q2.3. ***(If No)*** How many years in a row have you used this variety/brand?	Q2.4. ***(If No)*** Who decided to continue with the same seed? - Own decision (no consultation) - Decision of someone else in the family (no consultation) - Shared decision (discussion with members of the family) Q2.5. Why did you decide to continue with the same maize variety/brand? *Please indicate the three most important reasons:* 1. Good yield (t/ha) 2. Good yield reliability (produces even in bad season) 3. Good price 4. Good drought tolerance 5. Good pest resistance	Q2.6. (**If Yes**) Which variety did you buy last year/ season?	Q.2.7. ***(If Yes)*** What is the yield (t/ha) you obtained last year/previous season with the maize variety you bought?	Q2.8. (***If Yes***) Q4.5 Who decided to change to a different seed? - Own decision (no consultation) - Decision of someone else in the family (no consultation) - Shared decision (discussion with members of the family) Q2.9. Why did you decide to change your maize variety/brand? *Please indicate the three most important reasons:* 1. Higher yield expectations (t/ha) 2. Higher yield reliability expectations (produces even in bad season) 3. Lower price 4. Better drought tolerance 5. Better pest resistance

			6. Good disease resistance 7. It is always available 8. Does not rot (good cob coverage) 9. Other, mention			6. Better disease resistance 7. It was newly available 8. Hope it does not rot (have good cob coverage) 9. Other, mention

Q3. Now, I would like to know how you selected the maize seed you bought today

Q3.1. Before coming into the shop, how sure were you about the variety/brand you wanted to buy?	1. Completely sure 2. Very sure 3. Fairly sure	Q3.2. Was that variety / brand available?	Yes	Q3.3a Did you purchase that variety/brand?	Yes	Q3.4a Did the store attendant recommend a variety/brand?	Yes	Q3.5a Did you follow his/her recommendation?	
									No
							No		
					No	Q3.4b Did the store attendant recommend a variety/brand?	Yes	Q3.5b Did you follow his/her recommendation?	Yes
									No
							No		
			No	Q3.3.b Did you ask the store attendant to recommend an alternative variety/brand?	Yes	Q3.4c Did the store attendant recommend a variety/brand?	Yes	Q3.5c Did you follow his/her recommendation?	Yes
									No
							No		
					No	Q3.4d Did the store attendant recommend a variety/brand?	Yes	Q3.5d Did you follow his/her recommendation?	Yes
									No
							No		
	4. I was not that sure 5. I had no idea			Q3.3.c Did you ask the store attendant to recommend a variety/brand?	Yes	Q3.4e Did the store attendant recommend a variety/brand?	Yes	Q3.5e Did you follow his/her recommendation?	Yes
									No
							No		
					No	Q3.4f Did the store attendant recommend a variety/brand?	Yes	Q3.5f Did you follow his/her recommendation?	Yes
									No
							No		

Q3.6a.1a Did you ask any questions about any other available maize brands in the store?		Q3.7a Did the store attendant give you any additional information about any other available maize brands in the store?		Q3.8a Did you ask any specific question about the maize seed you bought?		Q3.9a Did the store attendant give you any additional information about the maize seed you just bought?	
1	Yes	1	Yes	1	Yes	1	Yes
2	No	2	No	2	No	2	No

	Q3.6b (if yes) What did you ask about?		Q3.7b (if yes) What information did you get		Q3.8b (if yes) What did you ask about? *Don't give options*		Q3.9b (if yes) What information did you get? *Don't give options*
1	Other seeds available	1	Other seeds available	1	Other seeds available	1	Other seeds available
2	Price information	2	Price information	2	Price information	2	Price information
3	Planting date	3	Planting date	3	Planting date	3	Planting date
4	Plant spacing	4	Plant spacing	4	Plant spacing	4	Plant spacing
5	Maturity	5	Maturity	5	Maturity	5	Maturity
6	Fertilizer management	6	Fertilizer management	6	Fertilizer management	6	Fertilizer management
7	Pesticide/pests management	7	Pesticide/pests management	7	Pesticide/pests management	7	Pesticide/pests management
8	Herbicide/weeds management	8	Herbicide/weeds management	8	Herbicide/weeds management	8	Herbicide/weeds management
9	Yield potential	9	Yield potential	9	Yield potential	9	Yield potential
10	Drought tolerance	10	Drought tolerance	10	Drought tolerance	10	Drought tolerance
11	Market information	11	Market information	11	Market information	11	Market information
12	Seed treatment	12	Seed treatment	12	Seed treatment	12	Seed treatment
13	Other, mention	13	Other, mention	13	Other, mention	13	Other, mention

Q3.7c (if yes) Did you get verbal information or a leaflet or something else? *Don't give options*		Q3.9c (if yes) Did you get verbal information or a leaflet or something else? *Don't give options*	
1	Verbal explanation	1	Verbal explanation
2	Information on package	2	Information on package
3	Information leaflet	3	Information leaflet
4	SMS information	4	SMS information
5	Other, mention	5	Other, mention

Q4. Main reasons for selecting and buying the seed you bought this cropping season *(ask about the most important seed variety, i.e., the one he/she bought in higher quantity)*

Q4.1. When deciding to buy the seed you bought this cropping season, you considered the following factors important:

Aspect	*1=Yes, 2=No*
The Price of the seed	
The Brand	

Q5. Price-perceived quality subsection

Procedure

1. Present the farmer with a choice of reference price (i.e. $2,500) and a discounted price ($500, $400, $300, $200 or no discount) for the exercise.
2. Provide the farmer with a card containing information about the product, the reference price charged and the discounted price for the seed.
3. Administer the questionnaire for product evaluation (10 min).

For each of the following categories, please answer the following questions based on the seed description, reference price and discounted price you just received

On a 1-7 scale, please tell me:

Perceived Quality

Q5.1. In terms of quality, how would you qualify this seed?

1	2	3	4	5	6	7
very poor quality	moderately poor quality	slightly poor quality	neither good nor poor quality	slightly good quality	moderately good quality	very good quality

Q5.2. Based on the information presented, do you believe this seed is reliable?

1	2	3	4	5	6	7
very unreliable	moderately unreliable	slightly unreliable	neither reliable nor unreliable	slightly reliable	moderately reliable	very reliable

Perceived Value

Q5.3. Overall, do you believe that this seed is worth its price?

1	2	3	4	5	6	7
strongly disagree	moderately disagree	slightly disagree	neither agree nor disagree	slightly agree	moderately agree	strongly agree

Q5.4. How good do you think the offer of this seed is?

1	2	3	4	5	6	7
of very poor value	of moderately poor value	of slightly poor value	neither good nor poor value	of slightly good value	of moderately good value	of very good value

Willingness to Buy

Q5.5. Given the offer described, would you be willing to buy this seed?

1	2	3	4	5	6	7
very unwilling	moderately unwilling	slightly unwilling	neither willing nor unwilling	slightly willing	moderately willing	very willing

Q5.6. How likely are you to buy it?

1	2	3	4	5	6	7
very unlikely	moderately unlikely	slightly unlikely	neither likely nor unlikely	slightly likely	moderately likely	very likely

Perceived Sacrifice

Q5.7. Do you think this seed is expensive at this price?

1	2	3	4	5	6	7
strongly disagree	moderately disagree	slightly disagree	neither agree nor disagree	slightly agree	moderately agree	strongly agree

Q5.8. Given the offer described (initial price + discount) and the amount of money you have available for the production of maize, how difficult would it be for you to buy this seed?

1	2	3	4	5	6	7
very easy	moderately easy	slightly easy	neither difficult nor easy	slightly difficult	moderately difficult	very difficult

Identifying Variables:

I4. Gender: 1= Male, 2= Female

I5. Age: _____

I6. The farmer's highest education level_____ (*1=no formal education, 2=primary level, 3=secondary level, 4=high school level, 5= college/technical training, 6= university*

I7. What are the three most important sources of income for your household?

1. Maize production	
2. Other crops production	
3. Animal husbandry, cattle	
4. Own business	
5. Formal employment	
6. Remittances	
7. Farm labourer	
8. Other, mention	

I8. Enumerator _____

I9. Municipality of the agro-dealer_____

I10. Village/town of the agro-dealer_____

I11. Store name _____

I12. Date of interview (DD/MM/YYYY) _____

Thank you!

Appendix E. Results of the brand loyalty and price-quality perception model of hybrid maize seed for single price evaluations.

Table. Goodness of fit statistics, standardized estimate path coefficients and associated standard errors and p-values of perceived quality, perceived value, perceived sacrifice, brand loyalty and willingness to buy for a single price evaluation setting.

From		To	Estimate	S.E.	p-value
H1 - Selling price	→	Perceived quality	-0.015	0.043	n.s 0.832
H2 - Selling price	→	Perceived sacrifice	0.491	0.070	***0.000
H3 - Perceived sacrifice	→	Perceived value	-0.223	0.042	**0.005
H4 - Perceived quality	→	Perceived value	0.706	0.145	***0.000
H5 - Brand loyalty	→	Perceived value	-0.175	0.143	*0.028
H6 - Perceived value	→	Willingness to buy	0.751	0.168	***0.000
Goodness-of-Fit Index		Cutoff value	Result		
χ2		P > 0.05	63.2 (p=0.000)		
χ2/df		1 to 3	1.62		
RMSEA		<0.08	0.024		
SRMR		<0.09	0.047		
GFI		>0.8	0.987		
AGFI		>0.8	0.978		
CFI		>0.95	0.989		

χ2 = Chi-square; χ2/df ratio= Chi-square/degrees of freedom ratio; RMSEA= Root Mean Square Error of Approximation; SRMR=Standardized Root Mean Square Residual; GFI= Goodness of Fit index; AGFI= Adjusted Goodness of Fit Index; CFI= Comparative Fit Index.
*p < 0.05, **p < 0.01, ***p < 0.001

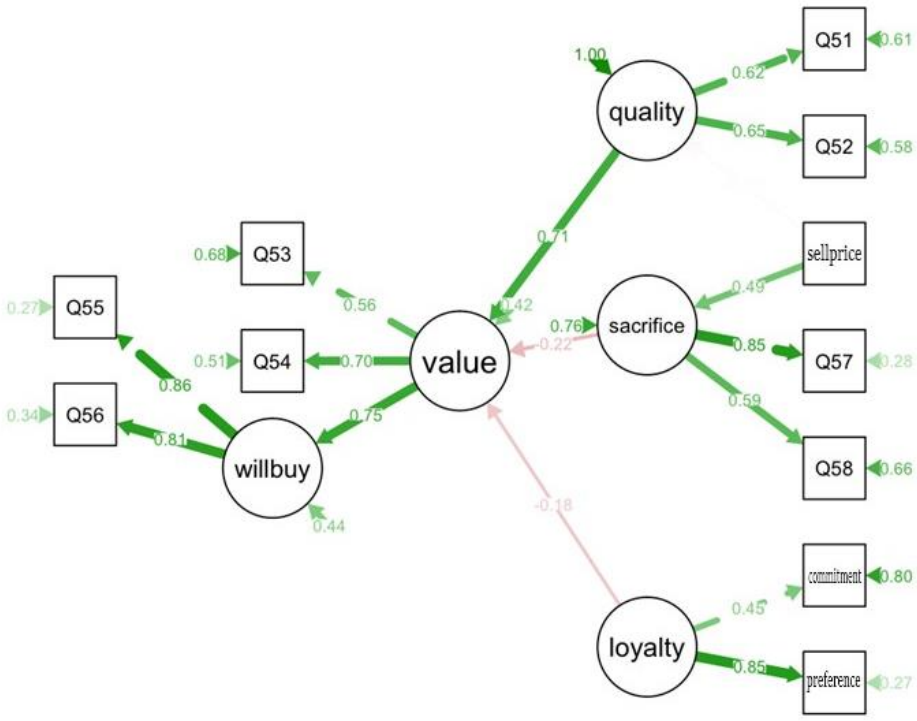

Figure. Structural path model of price-quality perception of hybrid white maize seed for a single price evaluation setting.

Appendix F. Summary of the transcripts of the interviews with agro-dealers and seed companies' sales representatives.

This appendix presents the results of the semi-structured interviews conducted with owners, store managers or employees of agro-dealer shops (n=11 out of 28 stores) and sales representatives of seed companies operating in La Frailesca and in the state of Chiapas (n=6 out of 11 seed companies).

The analysis was carried out in Excel.

Agro-dealer interviews

- A total of 11 interviews with owners, store managers or employees of agro-dealer shops were carried out (Table 1). During sampling design, a total of 63 agro-dealer shops were found in La Frailesca, of which 28 were confirmed as selling improved maize seeds. That is 39% of agro-dealers selling maize seed in the region were interviewed.
- The interviews were held by the end of the seed sales season (from the 22 of June to the 02 of July) and targeted the same shops selected for conducting the intercept interviews with farmers.
- Out of the 11 shops interviewed, 8 were in our sample for conducting the intercept interviews with farmers. We couldn't interview one of the shops.
- The number of interviewed shops by municipality was: 4 in Villaflores, 3 in Villacorzo and 4 in La Concordia.

Table 1. Location of agro-dealer stores interviewed

	Store's code	Municipality	Interview location	Survey sample
1	CHIAGVF1	Villaflores	Villaflores	No
2	CHIAGVF2	Villaflores	Villaflores	No
3	CHIAGVC3	Villacorzo	Villacorzo	Yes
4	CHIAGLC4	Independencia	La Concordia	No
5	CHIAGVC5	San Pedro Buenavista	Villacorzo	Yes
6	CHIAGVC6	Villacorzo	Villacorzo	Yes
7	CHIAGLC7	Independencia	La Concordia	Yes
8	CHIAGLC8	Independencia	La Concordia	Yes
9	CHIAGVF9	Villaflores	Villaflores	Yes
10	CHIAGLC10	Independencia	La Concordia	Yes
11	CHIAGVF11	Villaflores	Villaflores	Yes

Businesses and respondents' characteristics

- Selected stores had on average 18 years on business (Table 2). The youngest had 3 years and the oldest 50 years. More than half of the shops had more than 10 years operating.

- All shops had at least 4 different seed varieties in stock, a maximum of 21.
- All shops, except one, had at least 3 brands on offer.
- Only 3 shops had on offer MasAgro hybrids. MasAgro hybrids reported were: PAS110, PAS112, SKW502, Rio blanco, Rio amarillo.
- Out of the 11 stores interviewed, 5 were suppliers of smaller agro-dealers in the zone.
- On average, 85% of seed sales were direct to farmers and 35% to other stores.

- Stores had on average 17.7 years selling maize seeds. More than half of the shops had more than 10 years selling maize seed, almost a third had more than 20 years.
- Half of the stores were family-owned single stores. Another 36% belonged to a chain store.
- On average agro-dealers had 3.8 employees, a maximum of 9.

- Respondents had on average 43 years old and 90% were male (Table 2)
- Most respondents were well educated: 70% had a bachelor's degree in agronomy, veterinary/animal science or livestock production. An additional 10% attended college and 20% reported to only have attended high school.
- 55% of the interviewed were the owner of the shop, 27% were sales staff and 18% were the sales manager.
- On average, respondents owned or worked in the shop for at least 10 years.
- Most respondents reported being very involved in seed sales activities, including procurement, promotion, marketing and sales. They reported having high to very high knowledge of seed sales.

Table 2. Agro-dealers and respondents' characteristics (n=11).

	Mean	SD	Max	Min
Business characteristics				
Years in business (SD)	18.4	14.8	50	3
Years selling maize seed (SD)	17.7	15.1	50	3
Type of ownership (%)				
Family-owned single store	54.5			
Co-ownership	9.1			
Chain store	36.4			
Number of employees	3.8	2.3	9	2
Respondent characteristics				
Age (SD)	43.4	10.8	64	32
Male respondent (%)	90			
Education level (%)				
Lower than college/technical training	20			

College/technical training	10			
University	70			
Position (%)				
Owner	54.5			
Manager	18.2			
Sales staff	27.3			
Years working in the shop	10.5	4.7	15	4
Year owning the shop	10.8	10.4	27.0	1.0
Degree in agronomy, animal sciences or related discipline (%)	72.7			

Input stock and seed offer

- Besides maize seed, most stores had a wide range of agricultural and related activities products on offer such as crop chemicals, pharmaceutical and veterinary products, livestock/animal feed products, other crop seeds (sorghum, beans, vegetables), farm tools, fertilizers, poultry equipment, ironmongers/hardware store products, garden machinery, sprayers, fencing materials, ropes, wellington boots, cowboy products, etc. (Table 3).

Table 3. Interviewed agro-dealers in-store stock, 2019 spring-summer season (n=11).

Product	% of stores offering
Maize seeds	100
Other seeds	90.9
Fertilizers	45.5
Crop chemicals	100.0
Farm tools	90.9
Pharma/vet products	90.9
Livestock, animal feed	90.9
Irrigation tools	9.1

- The most important sources of revenue for interviewed agro-dealers were crop chemicals, pharmaceutical/veterinary products, and livestock/animal feed. Seed sales were an important source of income, but sales span for a maximum of three months during the main sales season (May-July).
- More than half of respondents (55%) believed sales of maize seeds were decreasing while the rest 45% believed they had been increasing during the last three years.
- A total of 35 different seed varieties were available in selected shops (Table 4 and 5):
  - 66% of the seeds offered were white (n=23), 44% were yellow (n=11), the colour of one of the seed varieties was unknown.
  - The average age of available seeds from their year of release was 8.4 years.

- A third of the seeds available in-store had 3 years or less of being released, another 43% had between 4 and 10 years. That means that 74% of the available seeds on offer was relatively new.
- The oldest varieties available were A7573 from Bayer (39 years of being released); the public released OPVs V526 (36 years) and VS536 (27 years); and the proprietary hybrid Tornado (24 years).
- The seed offer was predominantly made of private hybrids. Only 3 out of 35 products found in the stores were OPV's.
- All MasAgro hybrids were older than the recent seed varieties released by multinational companies, but were less available in agro-dealer shops (Table 5).
- Only 5 out of the total 35 products found were hybrids developed by MasAgro (Rio blanco, Rio Amarillo, PAS110, PAS112 and SKW502). They were offered by Proase, Zarco and Reycoll (Table 6).

Table 4. Overview of maize seed varieties available at interviewed agro-dealers during the 2019 spring-summer season in La Frailesca, Chiapas.

Variety name	Brand	Origin	Type of material	Released year	age	Colour	Average price (MX$)
9617	Novasem	Private national	Hybrid	Unregistered		Yellow	1,350
30F35	Pioneer	Private MNC	Hybrid	2010	9	Yellow	2,252
30F96	Pioneer	Private MNC	Hybrid	2006	13	White	1,775
A7573	Asgrow	Private MNC	Hybrid	1980	39	White	2,400
B2928	Brevant	Private MNC	Hybrid	2019	1	Yellow	1,700
B3905	Brevant	Private MNC	Hybrid	2019	1	White	1,700
B3916	Brevant	Private MNC	Hybrid	2019	1	White	1,900
DAS4202	Dow	Private MNC	Hybrid	Unregistered		n/d	1,900
DK390	Dekalb	Private MNC	Hybrid	2012	7	White	1,851
DK447	Dekalb	Private MNC	Hybrid	2017	2	White	2,593
DK6018	Dekalb	Private MNC	Hybrid	2018	1	White	2,660
DK7500	Dekalb	Private MNC	Hybrid	2013	6	Yellow	2,185
HS23	Cristiani	Private MNC	Hybrid	2010	9	White	1,450
HS27	Cristiani	Private MNC	Hybrid	Unregistered		White	1,405
HS55	Cristiani	Private MNC	Hybrid	2012	7	White	1,425
Impacto	Syngenta	Private MNC	Hybrid	2013	6	Yellow	2,195
NA35	Novasem	Private national	Hybrid	2012	7	Yellow	1,650
NB15	Novasem	Private national	Hybrid	2014	5	White	1,400
P3966W	Pioneer	Private MNC	Hybrid	2012	7	White	2,397
P4028W	Pioneer	Private MNC	Hybrid	2018	1	White	2,679
P4039	Pioneer	Private MNC	Hybrid	2017	2	Yellow	2,550
P4082W	Pioneer	Private MNC	Hybrid	2009	10	White	2,215
P4226	Pioneer	Private MNC	Hybrid	2012	7	Yellow	2,297
P4279W	Pioneer	Private MNC	Hybrid	2018	1	White	

PAS110	Proase	MasAgro	Hybrid	2016	3	White	1,800
PAS112	Proase	MasAgro	Hybrid	2016	3	White	1,900
Rio amarillo	Zarco	MasAgro	Hybrid	2015	4	Yellow	1,450
Rio blanco	Zarco	MasAgro	Hybrid	2015	4	White	1,700
SKW502	Reycoll	MasAgro	Hybrid	2015	4	White	1,800
Sorento	Syngenta	Private MNC	Hybrid	2013	6	White	1,632
Tornado	Ceres	Private national	Hybrid	1995	24	White	1,925
V526	Proase	Public	OPV	1983	36	White	698
VS536	Proase	Public	OPV	1992	27	White	698
ZR24	Zarco	Private national	Hybrid	Unregistered		Yellow	1,200
ZR26	Zarco	Private national	OPV	2012	7	Yellow	1,500

Table 5. Summary of maize seed varieties available at interviewed agro-dealers during the 2019 spring-summer season in La Frailesca, Chiapas (n=11).

Total number of different maize varieties on offer		35	
Average age of variety from year of release (SD)		8.4	9.8
Average price in MXN$ of available seed varieties (SD)		1830.3	499.5
Average number of maize varieties in store (SD)		10.5	4.7
Average number of maize seed brands in store (SD)		10.5	4.7
	Name	Age	% shops
Top 5 available varieties across interviewed agro-dealers	P4082W	10	90.9
	P4028W	1	72.7
	P3966W	7	63.6
	DK7500	6	63.6
	DK390	7	54.5
Top 5 available varieties across interviewed agro-dealers released in the last 5 years (2014-2019)	P4028W	1	72.7
	DK6018	1	45.5
	P4039	2	27.3
	DK447	2	27.3
	B2928	1	18.2
MasAgro seeds available across interviewed agro-dealers released in the last 5 years (2014-2019)	PAS110	3	18.2
	Rio amarillo	4	18.2
	Rio blanco	4	9.1
	PAS112	3	9.1
	SKW502	4	9.1

Table 6. MasAgro hybrids released in the last 5 years and available at interviewed agro-dealers (n=11).

Seed variety	Brand/company	MasAgro code	Released year
PAS110	Proase	CLTHW14001	2016
PAS112	Proase	CLTHW15002	2016
Rio amarillo	Zarco	CLTHY11002	2015
Rio blanco	Zarco	CLTHW11002	2015
SKW502	Reycoll	CLTHW14003	2015

- 9 out of 11 respondents considered Pioneer was their most profitable variety (P4082W, P3966 the most mentioned). Pioneer was followed by Dekalb with 6 out of 10 store respondents mentioning it as their most profitable seeds.

Seed supply

- In most cases the seed supplier of the agro-dealer was the seed company. On average, 70% of the seed varieties reported were supplied directly by seed firms, or through their sales representatives, while the rest 30% was delivered through larger agro-dealers. Six stores reported to use larger agro-dealers but only about a third of their seeds were provided through intermediary shops.
- Overall, the seed was on time in the shops at the start of the sales season. However, some respondents mentioned delays on the delivery of some products from Dekalb, Cristiani, Reycoll, Ceres and Proase.
- Two stores could not obtain seed of VS536, PAS110 and PAS112 from Proase and DK390 from Dekalb that they wanted to sell in their shops.
- Another four shops introduced seed in their shop in the last 3 years (since 2016) but stop selling them. This was the case again for some Dekalb (DK390, DK7500) and Cristiani varieties (HS23), but also from Novasem (NA35), Biogene, CCC-Cincinnati (San Cristobal, San Diego) and Proseso (Tuxpeño amarillo) (Table 7).

Table 7. Varieties introduced in in the last 3 years and retired from stock.

Variety	Brand	Year introduced	Reason to start selling	Reason to stop selling
NA35	Novasem	2017	recommended by supplier/ friendship	Low-profit margin
Dekalb	Dekalb	2017	farmers demand	DK retired all stock without reason
Biogene	Biogene	2018	recommended by supplier	low demand
HS23	Cristiani	2018		The supplier didn't deliver it this year
San Cristobal	CCC-Cincinnati	2017		The seed didn't perform well
San Diego	CCC-Cincinnati	2017		We didn't reach an agreement for sales volume
Tuxpeño amarillo	Proseso	2017		It wasn't available from the supplier
DK390	Dekalb	2017	because of its yield	The cob has rot problems, the husk opens, lack of space to stock more varieties
DK7500	Dekalb			

- Seed category varied across seed firms. All seed from Bayer (Dekalb, Cristiani, Asgrow), Syngenta and Ceres were certified. The seed from national seed companies, e.g., Zarco, Novasem and Proase was declared.

- We found Pioneer seeds produced in Mexico of unclear category, holding tags of both, declared and certified seed. Some Pioneer varieties were declared seed. According to information on the tags, some varieties were produced either in Mexico or Brazil.
- The seed from Brevant was declared and distributed by either PHI Mexico S.A of C.V or Dow Agrosciences of Mexico S.A. of C.V.
- Most of the seed was of recently production (spring 2018, winter 2018, winter 2017). We only observed some bags from Pioneer produced in spring 2014 of unclear category and production season (winter 2019 while these observations were made in July), from Syngenta produced in winter 2015 and Dekalb produced in spring 2016.
- The seed was provided by seed companies to agro-dealers on consignation agreement (six out of eleven stores reported this purchase mode). Of these, five acquired 100% of their seed through this form and one more obtained 90%. On cash purchases were reported by four out of eleven shops: two stores bought the totality of their seed through this form. Only one of the shops bought seed on credit and it was from Pioneer.

Incentives

- All agro-dealers received sales commission for stocking and sell seed. Table 8 shows some commission percentages agro-dealers received from their suppliers. Commissions are given by seed companies, otherwise specified.
  - In all cases Pioneer was the direct supplier.
  - Except for two agro-dealers, all Dekalb seed was delivered through an intermediary.
  - Sales commissions varied by agro-dealer, going from a minimum 6-8% from Pioneer to a maximum of 20% from national companies.
  - Seed companies with the highest commission were Ceres, Proase, Zarco, Novasem and Syngenta.
  - The lowest sales commission was offered by Pioneer, varying from 6 to 10%. A common percentage applied was the 4-4-2%: that is, from the final price a 4% commission is calculated, then another 4% and then another 2%.

Table 8. Sales commissions received by interviewed agro-dealers from their suppliers.

Seed company	Shop #	Commission	
		Percentage	MX$/bag
Pioneer	2	6 – 8%	approximately MX$200-250/bag.
	3	4 – 4 – 2%	around MX$110/bag based on commission of 4 – 4 – 2%.
	4	4 – 4 – 2%	
	5	4 – 4 – 2%	
	7	4% from a larger agro-dealer.	

	8	10%, 15% if > 500 bags	
Dekalb	3		around $150/bag based on commission, from a larger agro-dealer
	4		$200 to $250/bag sold, for DK6018 $250 for example, from a larger agro-dealer.
	5	8.5%	MX$100/bag based on a contract for minimum sales volume, from a larger agro-dealer.
	7		$150/bag sold, from a larger agro-dealer supplier.
Syngenta	5	17%	
	7		$150/bag sold, from a larger agro-dealer.
	9		$50-80/bag sold.
Ceres	2	20%, but purchases are on cash.	
Proase	2	20%	
	4		$100/bag sold.
Zarco	2	20%	
Novasem	3		$200/bag, from a larger agro-dealer.
	8	18%	

- Other incentives were rare (Table 9). Some agro-dealers mentioned to receive purchases on credit, mainly from Pioneer. When the seed was purchased from agro-dealers under this scheme, seed was offered to final users (farmers) with the facility to pay at the time of harvest (credit).
- Other stores received sales bonus, mainly from Dekalb and Syngenta.
- In some cases, agro-dealers received discounts for anticipated purchases and support to attend complains when the seed did not perform well.
- One agro-dealer received support for creating demand and brand promotion from Novasem.

Table 9. Other – non sales commission – incentives and support received by interviewed agro-dealers from their suppliers.

Seed company	Shop #	Incentive
Pioneer	5	Purchases on credit to pay at harvest, payment in November or January next year (after the sales season). Farmers normally engaged to pay in January next year.
	10	Discounts in anticipated purchases, seed on credit and “credit cheque” when the sales volume accorded was surpassed, at the end of the sales season. Support in case that the seed does not perform.
Dekalb	5	Bonus for minimum sales volume.
	6	Sales bonus per volume sold, from $100 to $300/bag.
	8	When sales are higher than 200 bags, $90 extra per bag sold - from a larger agro-dealer.
	10	Discounts in anticipated purchases, seed on credit and “credit cheque” when the sales volume accorded was surpassed, at the end of the sales season. Support in case the seed does not perform.
Syngenta	5	Besides commission, MX$50 per bag on credit for supermarket purchases.
	9	Sales bonus when the negotiated volume is surpassed.
Novasem	8	Besides commission, the salary of a sales representative to create demand is covered. This person also sells Novasem products (not only seed) and offer training to farmers.

Promotion activities

- All shops displayed seed packs in their store, thus representing the most common activity for promoting seed by agro-dealers (Table 10).
- Other common promotion practices were: recommend seed to farmers (91% of shops), provide posters/seed information flyers in the store (82%), offer gifts and promotional materials to clients (63%), organize promotion day events (54.5%) and offer discounts to farmers (45.5%).
- Only three out of eleven shops engaged in demonstration plots.
- Most promotion activities were the responsibility of the seed company/supplier.

Table 10. In-store and out-store promotion activities developed by agro-dealers to promote hybrid maize seed.

Promotion activity	Frequency	%
In-store		
Display packs in the store	11	100.0
Recommend seed to customers/convince clients	10	90.9
Provide posters/seed information flyers	9	81.8
Give gifts and promotional materials to customers	7	63.6
Organize promotion day events	6	54.5
Offer discount to farmers	5	45.5
Ensure customers satisfaction	1	9.1
Targeting sales where seed performs well	1	9.1
Out-store		
Demonstration plots and field days	3	27.3
Spots in radio	2	18.2
Give workshops/training to customers	1	9.1
Offer free seed samples	1	9.1
Layaway plan sales	1	9.1

Interviews with seed companies' sales representatives

Sales representatives interviewed affiliation

- Semi-structured interviews were also conducted with sales representatives of six out of eleven seed companies found to operate in the study area (La Frailesca) and in the state of Chiapas.
- Respondents were directly involved in seed distribution and sales in all the state and reported to have regular to very high knowledge of maize seed sales.
- On average, respondents had 4.7 years working in their seed company, a minimum of 2 and a maximum of 8 years.

- Seed companies, where interviewed sales representatives worked, had on average 20 years in business. Three firms were local companies – main operations are in the state, two were regional/national – main operations were in another state, but they had sales in Chiapas, and one (Corteva Agriscience) was multinational – operations were at the international level with sales in all Mexico (Table 11).

Table 11. Overview of seed companies where interviewed sales representatives worked.

Seed company	Year established	Years operating
CHISPVF1	1970	49
CHISPTG2	2018	1
CHISPVF3	1996	23
CHISPTG4	2001	18
CHISPTG5	1998	21
CHISPVF6	2011	8

- CHISPVF1 has been operating in Mexico during the last 49 years. We don't know for how long CHISPVF1 has been present in Chiapas and in La Frailesca.
- 3 out of 5 national companies interviewed had more than 15 years in operation.
- 2 out of 5 national companies interviewed were founded in the last ten years as a result of MasAgro interventions. One of them was born as a response to the demand of a group of farmers linked to MasAgro hubs and started the distribution of seeds of the brand Reycoll and Biosemillas in 2018.

Seed offer and sales

- Seed companies interviewed offered a total of 39 seed products (Table 12).
  - The seed offer was predominantly made of private hybrids. Only 3 out of 39 products were public OPV's.
  - 69% of the seeds offered (n=27) were white maize varieties, 31% were yellow (n=12).
  - The oldest products in interviewed seed companies' portfolios were the public released OPVs V535 (29 years) and VS536 (27 years).
  - Out of the 39 products offered by interviewed seed companies, 19 were commercial hybrids from MasAgro (Table 12 and Table 13).
- Five out of six sales representatives interviewed believed their companies' seed sales had increased in the last 3 years, one thought sales had been erratic.

Table 12. Overview of maize seed varieties in product portfolios of interviewed seed companies during the 2019 spring-summer season in La Frailesca, Chiapas.

Variety name	Origin	Type of material	Released year	Colour	Price (MX$)
P4082W	Private MNC	Hybrid	2009	White	2,473
P3966W	Private MNC	Hybrid	2012	White	2,570
P4028W	Private MNC	Hybrid	2018	White	2,770
P4279W	Private MNC	Hybrid	2018	White	2,770
30F96	Private MNC	Hybrid	2006	White	1,677
30F35	Private MNC	Hybrid	2010	Yellow	2,303
P4226	Private MNC	Hybrid	2012	Yellow	2,303
P4039	Private MNC	Hybrid	2017	Yellow	2,560
SKW502	MasAgro	Hybrid	2015	White	1,700
SKW505	MasAgro	Hybrid	2015	White	1,700
SKW506	MasAgro	Hybrid	2016	White	2,000
SKY303	MasAgro	Hybrid	2015	Yellow	2,000
Tuxpeño amarillo	Public	OPV	2014	Yellow	1,100
H-377	Public	Hybrid	2010	White	
B8083	MasAgro	Hybrid		White	1,800
B1020Y	MasAgro	Hybrid		Yellow	1,800
B1060Y	MasAgro	Hybrid		Yellow	1,800
B937	MasAgro	Hybrid		White	1,800
RW4000W	Private national	Hybrid	2011	White	1,700
RW4001W	Private national	Hybrid			
RW4002W	Private national	Hybrid			
RW5000	Private national	Hybrid	2015	White	1,700
RW5001	Private national	Hybrid	2015	White	1,700
RW6000	Private national	Hybrid			
RY9000	Private national	Hybrid	2015	Yellow	1,700
RY10000	Private national	Hybrid			
PAS110	MasAgro	Hybrid	2016	White	1,600
PAS112	MasAgro	Hybrid	2017	White	1,600
PAS114	MasAgro	Hybrid	2017	White	1,600
PAS540	MasAgro	Hybrid	2015	White	1,300
PAS544	MasAgro	Hybrid	2015	White	1,300
PAS535	MasAgro	Hybrid	2017	Yellow	1,300
PAS555	MasAgro	Hybrid	2015	White	1,300
SP500	MasAgro	Hybrid	2015	White	1,300
SP610W	MasAgro	Hybrid		White	1,300
SP528	MasAgro	Hybrid	2015	Yellow	1,300
24 Kilates	Private MasAgro	Hybrid	2013	Yellow	1,300
VS535	Public	OPV	1990	White	650
VS536	Public	OPV	1992	White	650

Table 13. MasAgro hybrids released in the last 5 years in product portfolios of interviewed seed companies (n=6).

Seed variety	Brand/company	MasAgro code	Released year
SP500	Proseso	CLTHW11002	2015
SKW505	Reycoll	CLTHW13001	2015
PAS540	Proase	CLTHW13002	2015
SKW506, PAS110	Reycoll, Proase	CLTHW14001	2016
SKW502, PAS544	Reycoll, Proase	CLTHW14003	2015
PAS112	Proase	CLTHW15002	2017
PAS114	Proase	CLTHW15007	2017
PAS535, SP528	Proase	CLTHY13002	2017
SKY303	Reycoll	CSTHY10001	2015
B8083	Biosemillas	n/a	n/a
B1020Y	Biosemillas	n/a	n/a
B1060Y	Biosemillas	n/a	n/a
B937	Biosemillas	n/a	n/a
PAS555	Proase	n/a	2015
SP610W	Proseso	n/a	n/a
24 Kilates	Proseso	Private MasAgro	2013

Seed distribution

- Agro-dealers were used for seed distribution by five out of six companies interviewed (Table 14).
  - For seed companies who used this channel, seed sales through agro-dealers accounted for about 30-40% of its total seed sales.
  - For one company agro-dealers was the only distribution channel. This company reported to have carefully chosen 10 shops along the years, based on its competitiveness and capacity to promote and develop its brand. The selected ago-dealers were large shops who in turn sell to other small stores.
- Direct sales to farmers were the main distribution channel for half of the companies interviewed, with more than 40% of their seed sales made through this channel.
- One company sold all of its seed directly to farmers, occasionally through independent sales agents working on a commission basis.
- Three companies used farmer leaders to distribute their seeds, with percentages of sales through this channel varying from 30 to 70%. For Pioneer, the market leader in the region, 50-60% of seed sales were made through farmer leaders.
- One of the companies reported to sell 10% of its seed in commercial plots, that is, plots of farmer leaders whose had already used their seeds and gave testimony to other farmers.

- Most interviews agreed on the fact that sales through agro-dealers was difficult because stores were captured by multinational companies.

Table 14. Distribution channels used by interviewed seed companies to commercialize their hybrid maize seed.

Company code	Direct to farmers	Agro-dealers	Farmer leaders	Other	Total
CHISPVF1		40	60		100
CHISPTG2	40	30	30		100
CHISPVF3	100				100
CHISPTG4	60	30		10	100
CHISPTG5		100			100
CHISPVF6		30	70		100

Incentives/support to agro-dealers

- All seed companies (n=6) interviewed provided sales commission to agro-dealers, thus representing the most common incentive used to encourage the sales of their seeds in agro-input stores (Table 15).
- Other frequently used support given to agro-dealers were the provision of marketing materials (83%), monitor seed performance in farmers field (83%) and offer discounts and promotions for anticipated cash purchases (67%).
- Less than half of the companies (n=2) mentioned they provided training and support for creating demand of their brands, and the same number offered sales bonus for minimum sales volume.
- One company offered regional exclusivity for their seed distribution, and another provided seed on credit.

Table 15. Incentives and support provided by interviewed seed companies to agro-dealers.

Incentive/benefit	Frequency	%
Sales commission	6	100
Sales bonus by quantity sold	2	33.3
Seed on credit	1	16.7
Discounts and promotions in anticipated and on cash purchases	4	66.7
Gifts, sales rewards	0	0.0
Training and support for creating demand	2	33.3
Monitoring seed performance in farmers field	5	83.3
Provide marketing materials	5	83.3
Exclusivity for a determined region	1	16.7

- Sales commission offered by interviewed firms are shown in Table 16. Commissions are given for the channels used and reported by interviewed companies.
- Sales commissions varied from a minimum of MX$150 to a maximum of MX$300 to agro-dealers and from MX$97 to MX$150 to farmer leaders.
- Based on the price of the seed and the commission offered by seed companies, one of the national companies provided the highest returns to agro-dealers, followed by CHISPVF1.
- Another national copany gave the highest benefits to farmer leaders.

Table 16. Sales commissions offered by interviewed companies.

Company name	Specification	price reference (MXN $)	sales commission ($MXN/bag) to agro-dealers	to farmer leader	to sales comissionists
CHISPVF1	From sales volume, 4% out of the final price of a seed bag, 8% to agro-dealers shops.	2,428	194	97	n/a
CHISPTG2	MX$150 per bag.	1,744	150	150	n/a
CHISPVF3	When there are independent sales agents surpass their sales goals, ommission of MX$300 for sales on cash and MX$200 for packages.	1,700	n/a	n/a	200-300
CHISPTG4	$MX 100 per bag. Farmers leaders/witness have better prices and we give them a commission for seed sales.	1,429		100	n/a
CHISPTG5	20% because MNC started with high commissions. Brevant gives >$150/bag in rural shops for example, they have 4 sales representatives/region. We started with a 15 % commission.	1,500	300	n/a	n/a
CHISPVF6	MXN $100 - $150 per bag; MXN $ 100-120 per bag to about 10 farmers, MX$150 per bag when sales are to agro-dealers.	1,700	150	120	n/a

[1] Reference prices are averages prices of all products reported by sales representatives

[2] CHISPVF3 sales commission is of $300 for sales on cash and $200 for seed on packages, which may include payments at harvest.

Promotion activities

- Most promotion activities developed by seed companies to promote seeds were out-store and targeted towards end users (Table 17).
- The only two activities developed to influence customers in-store were supplying product information flyers and occasionally, provide gifts and promotional materials for customers. All seed companies mentioned to distribute posters and half said to provide gifts and promotional materials for its distribution to end users. Nevertheless, interviews with agro-dealers showed that the number of promotional materials given by seed companies was limited.
- In contrast to the limited number of in-store promotions, seed companies reported a total of nine different activities to promote their seed outside the agro-dealer space (Table 17).

The main activity undertaken are demonstration plots and field days, and the provision of free seed samples to farmers, both developed by all companies interviewed.

- In demonstration plots, companies usually gather a significant number of farmers to show their new product attributes. One or two events per year are typically carried out, at crop development stage and at harvest. Farmers are given information about product performance, product characteristics and main seed attributes, in addition to promotional materials such as leaflets, caps, pens, etc.
- Seed samples provision are given directly to farmers during demonstration plots and field days. Seed companies showed skepticism regarding the provision of seed samples. Sales representatives mentioned the importance of carefully selecting the right, potential farmers so that their seed could express its real potential in farmers plots. In this sense, samples were given only to a limited number of farmers whose land conditions and crop management were known to be favorable and appropriate.
- Five out of six companies organized workshops and training to final users in ejidos and municipality offices. Four out of six mentioned to monitor seed performance in farmers field, while half promoted their seed through spots on the radio.
- Of the less frequent activities developed outside the store were attending seed forums, offer layaway plans (direct to farmers and available through farmer leaders), organize commercial plots with witness customer and seed challenges.

Table 17. Interviewed seed companies' marketing activities for the promotion of seed.

Promotion activity	**Frequency**	**%**
In-store		
Distribute posters/information leaflets	6	100.0
Provide gifts and promotional materials for customers	3	50.0
Organize desk events	2	33.3
Out-store		
Demonstration plots and field days	6	100
Offer free seed samples	6	100
Give workshops/trainings to clients	5	83.3
Monitor seed performance in farmers field	4	66.7
Spots in radio	3	50.0
Assist to seed forums	1	16.7
Layaway plan sales	1	16.7
Commercial plots and testimonies	1	16.7
Seed challenges	1	16.7

- The number of demonstration plots by seed company, when developed, varied from 8 to 50. The market leader in our study area, Pioneer, established a total of 30 demonstration plots strategically located where their seeds were unknown (Table 18).

Table 18. Number of demonstration plots established by interviewed seed companies

Seed company	demo plots	Comments
CHISPVF1	32	Shows the newest hybrid with the one with highest sales. Strategically located where the seed is unknown.
CHISPTG2	30	Field days in 1/3 of them and the rest are used for training.
CHISPVF3	30	A field day in oct-nov at harvest with about 300 farmers.
CHISPTG4	50	Also organized 10 commercial plots where farmers followed their own management.
CHISPTG5	8	Established with farmers of a middle-income status.
CHISPVF6	0	In 2017 established 12.