

Chapter 11. Conclusion: major findings and discussion

D. Stermerding^{1*}, P.C. Struik², P. Lindhout³ and P. Gildemacher⁴

¹Independent researcher biotechnology & society, Ten Oeverstraat 24, 8012 EV Zwolle, the Netherlands;

²Centre for Crop Systems Analysis, Wageningen University, Bornsesteeg 48, 6708 PE Wageningen, the

Netherlands; ³Solynta, Dreijenlaan 2, 6703 HA Wageningen, the Netherlands; ⁴KIT Royal Tropical Institute, Mauritskade 63, 1092 AD Amsterdam, the Netherlands; dirk@dirkstermerding.nl

Abstract

Hybrid breeding may revolutionise the potato world, especially in low- and middle-income countries. The major impact will be on yield in remote and challenging agro-environments. We expect that hybrid breeding will increase the turnover of varieties in those environments when new seed systems based on hybrid true potato seed have been established. With faster breeding and multiplication systems, it is possible to produce clean seed and to respond to climate change as well as rapidly changing market and societal needs. For this revolution to happen, the potato production system (of both seed and ware) needs to be radically changed and such changes are not easy to orchestrate. During the introduction of such a potentially disruptive innovative technology, many actors, stakeholders and institutions play a significant role and each of these parties has its own objectives, interests, and concerns. This concluding chapter aims to answer the question how such a radical innovation can be steered in a societally responsible manner to realise global food security and sustainability in potato production. To guide and coordinate the system innovations triggered by the potential of hybrid potato breeding, strong public-private partnerships are required in different links of the potato value chain.

Keywords: hybrid breeding, true potato seed, *Solanum tuberosum*, agro-industrial context, international development context, responsible innovation

11.1 Preamble

This book is about the promises of hybrid breeding as a radical new development in the international potato world. Most importantly, hybrid breeding can speed up potato variety development in response to diverse market and societal needs, and hybrid seed can provide a clean source of planting material that is easy to transport and store. As a result, potato breeding and cultivation may more and more follow the dynamics of the international vegetable sector, characterised by the rapid introduction of new and improved varieties, product diversification, increasing nutritional value and the introduction of resistant and stress-tolerant cultivars. However, the chapters in this book also make clear that technological innovation involves more than just the creation of new products. Indeed, as emphasised in the Chapters 2 and 3, hybrid potato breeding has to be

considered as a system innovation that may affect almost every step in the potato value chain.⁶ It may involve game-changing and disruptive transformations, shaped by a complex interplay of seed-technological, agronomic, commercial, social and political aims and developments. The future of hybrid potato will thus depend on diverse, uncertain and dynamic system conditions, and different future development pathways are possible, as explored in the interactive scenario exercise described in Chapter 3. This raises a very important question that is addressed in several chapters of this book, namely how to guide the future of hybrid potato in desirable directions, in particular with regard to the goals of global food security and sustainability?

11.2 The future of hybrid potato in the agro-industrial context

In the introductory chapter, the agro-industrial and the international development context have been distinguished as two different global system contexts in which the development of hybrid potato breeding can make a difference. Chapter 4 focuses on the agro-industrial context, with the Netherlands as a vibrant centre in the potato world, involved in every aspect of the potato value chain. In potato breeding, there is a significant number of complex traits that need to be selected for, whereby hybrid breeding will allow breeders to respond much quicker to new demands in the market, with a higher turn-over of varieties, than in conventional potato breeding. However, building a new hybrid breeding programme from scratch requires long-term efforts and high investments. Before we can expect improved hybrid potato varieties to reach the agro-industrial market, these varieties will first have to meet the current, high-level and tight-fitting retail and potato processing standards.

Another important benefit accruing from hybrid breeding is the availability of uniform and virtually disease-free true seed as starting material for potato cultivation. Farmers may now grow potatoes from hybrid potato seed, seedlings, mini-tubers or first-generation seed potato tubers. Growing potatoes directly from seed, transplants or mini-tubers will require, however, quite a different agronomy and it remains to be seen what will be the most appropriate cultivation models in different agroecological conditions. As pointed out in Chapter 4, the use of hybrid potato starting material will also imply, for each of these cultivation systems, a significant shift in the creation of added value from the conventional seed tuber grower to the breeding/seed company. Moreover, as true potato seed can reach areas that currently do not have access to high-quality seed potato tubers, hybrid seed may create opportunities for these companies to expand their export market. The emergence of hybrid potato may thus transform as well as strengthen established business models in the agro-industrial potato sector.

In this context, Chapters 3 and 4 also raise the question what this development might mean for the leading position of the Netherlands as the world's biggest exporter of seed potato tubers. According

⁶ In a report by the High-Level Panel of Experts on Food Security and Nutrition of the 'Committee on World Food Security', innovation is likewise defined in comprehensive terms as 'changes in the design, production or recycling of goods and services, ... including changes in practices, norms, markets and institutional arrangements, which may foster new networks of food production, processing, distribution and consumption' (quoted by Haug *et al.*, 2021).

to one of the scenarios discussed in Chapter 3, hybrid potato breeding may lead to further monopolisation in the sector, in line with the current agro-industrial trend towards increasing scale and intensification. In this scenario, two large multinationals control the entire potato value chain and have monopolised breeding know-how and genetic resources. In a radically different alternative scenario, hybrid potato breeding is globally supported by the public availability of parental lines, enabling breeders all over the world to develop a broad range of hybrid potato varieties suited to local conditions. In both these scenarios the Dutch potato sector may lose its dominant position. However, as argued in Chapters 3 and 4, thanks to its strong breeding knowledge infrastructure, the Netherlands might still be the place to invest for seed companies, and the sector could maintain a leading position with a shift of focus to the international marketing of know-how.

The scenario discussion in Chapter 3 also shows an important and interesting tension between the plausibility and desirability of the potato futures discussed. While further monopolisation in the potato seed sector was generally considered as a most realistic prospect (see also Chapter 9 about the changing playing field), public support for local breeding and market diversification was seen by several discussants as a more desirable future, in which hybrid breeding could really benefit both the productivity, sustainability and diversity of potato production systems. This tension between the plausibility and desirability of possible futures underlines the need to better understand the complex interplay of the societal conditions and goals shaping these futures, which may help stakeholders, civil society organisations and policymakers to guide hybrid breeding in the right direction.

An important policy issue, discussed in Chapter 5, is the need for adjustment of global regulatory frameworks to the use and trade of hybrid true potato seed. The official protocol for testing distinctness, uniformity and stability of tuber-based potato varieties has to be adapted to seed-based hybrid varieties. Examination of the value for cultivation and use of hybrid potato varieties also requires a different approach, as well as seed quality control and certification. Although a shift towards export of true potato seed could reduce the need for phytosanitary measures, many countries have not yet opened their borders for the import of hybrid seed. Another widespread concern in the potato sector is the length of the variety registration process, mentioned in Chapter 6. An important issue to consider in this context is the impact of strict and formal seed regulations on the availability and use of hybrid potato seed in the informal seed sector, which remains of overwhelming importance to smallholders in large parts of the world. Indeed, with a view to global food security, there is much to be gained by lowering regulatory thresholds for smallholders and making the formal system more inclusive (De Winter and Lammers, 2022a).

11.3 The future of hybrid potato in the international development context

When we shift the focus from the agro-industrial to the international development context, the dominance of informal seed systems is a crucial difference to take into account in discussions about seed innovation. Globally, 90-95% of seed potato tubers are farm-saved, exchanged within farmers' communities or marketed locally, thus sustaining the livelihood of millions of resource-

poor smallholder farmers. There is a clear difference and distance between this informal seed system and the formal, agro-industrial system. In the international development context, therefore, switching from local farmers' varieties to commercial hybrid varieties represents a major shift. As potato productivity in Sub-Saharan Africa remains well below its potential, it is generally agreed that hybrid potato has great potential to contribute to global food security, but not as an innovation standing on its own. The promises of hybrid potato breeding may indeed fuel necessary changes of the seed, farm and market system. However, as argued in Chapter 8, the magnitude of the systemic changes required also indicates the persistence and complexity of the challenges involved, and hence the chances of success.

The system-level challenges associated with the introduction of hybrid potato in the international development context, also have implications for innovation strategies and business development. In various tones, the chapters in this book emphasise the need for partnerships and collaboration between a variety of stakeholders, as neither the private, nor the public sector can fully harness the potential of hybrid breeding alone. For a more detailed discussion of these issues, we will focus in the following on the two main topics that were mentioned in Chapter 1 as an agenda for debate: (1) hybrid potato variety development and selection; and (2) the organisation of hybrid potato seed and value chains.

11.3.1 Hybrid potato variety development and selection

A major promise of hybrid potato breeding is that it will boost variety development and selection. In the wording of Chapter 2, breeding companies will develop new hybrid cultivars that are tested in target markets over the globe, where local users can participate in selecting the best adapted cultivars. In the international development context of Sub-Saharan Africa, hybrid breeding may thus target potato traits that are especially relevant for attaining food and nutrient security, including the development of cultivars that are adapted to cultivation in the lowland tropics. However, as emphasised in Chapter 7, to tailor varieties to the specifics of farmer demand, a solid understanding is required of the wide diversity of farmers and farming systems, in terms of resource endowments and the local agroecological, socioeconomic and cultural conditions in which farmers operate. While, according to formal, agro-industrial sector standards, quality seed is high-yielding, uniform, genetically pure, healthy, and in the proper physiological stage, this may not fully match with the needs and meanings that compose quality in the eyes of smallholder farmers (Kilwinger, 2022). This raises the question how to accommodate, with the development of hybrid potato varieties, the heterogeneity among farmers in Sub-Saharan Africa. In answer to this question, Chapter 7 recommends to closely involve farmers and other stakeholders in the design and evaluation of new varieties, in order to enhance the likelihood of a good fit between hybrid breeding and farmers' multiple realities.

As food security policies are mostly centred around commercialisation of agriculture and 'market-led technology adoption' (De Winter and Lammers, 2022b), there is a crucial role to play for breeding companies in targeting variety development to smallholders' needs. In Chapter 6, it is observed that, without a substantial market demand, we cannot expect that traits that are

specifically interesting for smallholder farmers will receive much attention within commercial breeding programmes. International potato breeding companies are currently mostly offering best-bet varieties from their available portfolios to selected African countries. With a faster and more targeted approach, a hybrid potato breeding programme offers new and promising opportunities, but its development is a highly time-consuming and costly undertaking. When hybrid seed reaches the African market as a commercial, formal seed source, it may possibly only be suitable and affordable for market-oriented better-off farmers. As noted in Chapter 6, a dedicated hybrid potato breeding programme for Sub-Saharan Africa will therefore require joint public-private efforts, an issue that we will return to below in a discussion on responsible innovation strategies.

11.3.2 Hybrid potato seed and value chains

The starting material for hybrid potato is clean true seed that can be multiplied quickly and is easy to transport and store. When growing potatoes, farmers may thus start with seed, but they could also use seedlings transplanted from a greenhouse or nursery into the field, or use first generation (seedling) seed potato tubers. Since direct sowing or using seedlings both are quite demanding and risky procedures, we can expect that smallholder potato farmers will generally prefer to continue using tubers as they are familiar with this vigorous starting material. Moreover, accustomed to informal seed systems, farmers may keep reproducing and exchanging these tubers as high-quality planting material within their communities. Yet, with the need to regularly refresh this material, especially under conditions of high pressure of pests and diseases, farmers will depend on a continual supply of first-generation hybrid potato seed tubers. These tubers might be made available through a decentralised intermediary infrastructure, with growers specialised in raising vulnerable seedlings from tiny potato seeds, and in harvesting and selling seedling tubers for potato cultivation. A formal commercial hybrid seed system may thus function as a continuous input source that can provide disease-free tubers to the informal system (Stemerding *et al.*, 2020). However, as Chapters 7 and 8 make clear, in the (African) international development context, such a system transformation is to be regarded as one of the major bottlenecks for an introduction of hybrid potato to the benefit of smallholder farmers.

Hybrid potato seed can be produced on a large scale by international breeding companies at a few highly specialised locations. The abundant availability of true potato seed may put an end to the lack of clean and high-quality planting material, which is generally seen as a very important barrier to improving smallholder potato production and food security. But it will require an enabling institutional and policy environment in the main potato production regions. An intermediary infrastructure with growers who can supply farmers with suitable planting material is one crucial precondition. Another precondition is (inter)national regulation which enables trade and marketing of hybrid potato seed. In practice, as noted in Chapter 6, all levels of regulation – seed importation, variety registration and seed certification – place severe restrictions on the availability of new (potato) planting material. An additional hurdle for the introduction of hybrid potato is the necessary adjustment, as described in Chapter 5, of the extant rules for seed potato tubers to true potato seed.

When hybrid potato varieties do become commercially available in the (African) international development context, it is not yet obvious that smallholder farmers will have full access to these varieties. For the many resource-poor and risk-averse smallholders the price of certified planting material will be crucially important, and it remains to be seen how much hybrid potato seed or planting material will cost. As we noted above, this planting material may be attractive and affordable only for more well-to-do farmers. However, a possible scenario that is mentioned in Chapter 9 (and suggested in other chapters as well) is that hybrid potato ‘trickles down’ through informal networks, in which tubers produced by better-off and market-oriented potato farmers are locally circulated or traded to smallholders. Thus, hybrid potato might create a much-needed bridge between the formal and informal seed sectors (Stermerding *et al.*, 2020). Another way to create such a bridge between the formal and informal systems, suggested in Chapter 6, is to commercialise hybrid potato varieties under ‘truthful labelling’ instead of formal certification.

Further down the seed value chain, issues arise with regard to the cultivation and marketing of hybrid potato varieties. Chapters 6 and 7 both emphasise the great diversity in farm households and agroecological and socioeconomic farming conditions in Sub-Saharan Africa. Most potato farmers are smallholders, working under rainfed and low-input conditions. They typically use home-saved seed tubers with a short dormancy, allowing planting in multiple rainy seasons within one calendar year, but which are also subject to seed degeneration, with seed-borne diseases being a major yield-limiting factor. Hybrid breeding has the potential to more efficiently and effectively target potato breeding to high-yielding varieties, with short seed tuber dormancy, disease and pest resistance, and heat and drought tolerance as especially desirable traits for African potato farmers. Hybrid breeding may also respond to new and more diverse market incentives, resulting from growing potato consumption and increased processing in Africa, although access to these markets will remain a key challenge for the many smallholder farmers.

11.3.3 Disruption or integration?

In the various chapters of this book, we find two different perspectives on the kind of changes and improvements that hybrid breeding could or should bring in this international development context. On the one hand, hybrid potato breeding is discussed as a game changer that may cause disruptive change, with hybrid potato as a driver of potato sector transformation in Sub-Saharan Africa, aiming at the creation of commercial hybrid seed value chains. From this perspective, regionally prevailing farming habits, culture and traditions are perceived as barriers that have to be surmounted. On the other hand, we find pleas, in particular in Chapter 7, for an approach in which breeding innovations and system adaptations are tailored towards the needs and capabilities of different farm household types. Starting points, from this perspective, are the agroecological and socioeconomic farming conditions to which hybrid varieties and seed value chains should be attuned.

As noted in Chapter 8, the introduction of hybrid potato seed will require either transformation of existing seed, farm and market systems, or integration in these systems. The more radical the transformation – with hybrid seed based on an agro-industrial variety portfolio, requiring labour- and capital-intensive crop management – the more obstacles will be created to the adoption of this

seed by smallholder farmers. The more radical the integration – with hybrid varieties tailored to the practices, preferences and needs of smallholder farmers – the less likely that companies will see a business model for dedicated seed development and production. The tension between these two scenarios, raises the question, posed in Chapter 8, how to find a balance between disruption and integration. Indeed, how to navigate between these two scenarios in hybrid potato breeding with the aim to serve global food security in sustainable ways?

11.4 Responsible innovation strategies

Responsible innovation has been introduced in Chapter 3 as an approach that takes into account the complexities and uncertainties of innovation, while seeking ways in which innovation can respond to major societal challenges like food security and sustainability. The chapter describes how a broad variety of stakeholders has been involved in a process of mutual learning, to find out how a desirable future for hybrid potato breeding would look like. What do stakeholders see as important challenges and goals to which hybrid potato breeding should respond, and how to create optimal conditions for a successful development of this innovation from this point of view? In addressing these questions, the chapter also seeks to understand the complex interplay of societal conditions and goals that shape the future of hybrid potato, whereby this future finally will depend on the economic, social, and policy decisions that are adopted by the different parties involved.

Chapters 9 and 10 are both highly relevant for this discussion. Chapter 9 examines how Dutch breeding companies see their own role and responsibility with regard to hybrid potato breeding in the international development context, in particular with a view on Sustainable Development Goals (SDGs). It considers corporate social responsibility (CSR) as a frame that may stimulate companies to embrace SDGs in their innovation strategies, even though companies, for economic reasons, might prefer to focus on more secure agro-industrial markets. From interviews with representatives of the main Dutch potato breeding companies, the chapter concludes that most companies see hybrid breeding as an important innovation that can make a significant contribution to SDGs, especially with regard to food security and sustainability. Moreover, variety development and global seed trade are seen by these companies as core activities that give substance to their CSR efforts. Resource-poor smallholder farmers may benefit in this view from improved, commercially produced seed through a ‘trickle down’ process, as mentioned above, from the formal sector to informal community networks. By contrast, the authors of Chapter 9 emphasise the complexity of seed interventions that, without a more in-depth understanding of farmers’ diverse conditions and needs, are usually doomed to fail. In their view, there is a need for more inclusive breeding strategies targeting smallholder farmers. These strategies should make available hybrid potato breeding knowledge and technology also as a ‘common good’, through collective action, involving both private and public stakeholders, including farmer communities.

In line with this discussion, Chapter 10 explores how the powerful new approach of hybrid potato breeding can be harnessed for smallholder farmers through public-private collaboration. Starting point in this chapter is the observation that hybrid breeding activities in public sector institutions are currently modest, while it cannot be taken for granted that traits that are specifically interesting for smallholder farmers, but hold little commercial value otherwise, will be targeted by the private

sector. As neither the public sector nor the private sector can fully harness the potential of hybrid potato breeding, public-private collaboration will be needed to facilitate the development and dissemination of varieties that are suited to the specific contexts and needs of smallholder farmers. This chapter uses the perspective of the commons to explore the strengths and weaknesses of different partnership models, and to assess the potential of each model to enable hybrid breeding for smallholder farmers, in response to the challenges of poverty, food security and climate change. Like the preceding chapter, this chapter suggests collective action with the aim to create optimal conditions for public-private collaboration. Both chapters thus seek to find fertile ground for responsible innovation strategies, in search of a balance between system disruption and integration.

11.5 Final considerations

In this book hybrid potato futures are discussed, with food security as an all-important consideration. As the food provision in large parts of the world is highly dependent on smallholder farming, a thorough understanding of the interplay between food system dynamics and smallholder diversity is critical. It makes clear that seed interventions require a delicate balancing act: introducing viable and scalable innovations while meeting a wide variety of smallholder needs and requirements (De Winter and Lammers, 2022b). In the foregoing it was concluded that, in order to enable such a balancing act, collective action is needed, in particular aiming at public-private partnerships. Chapter 10 contains a highly valuable discussion of different models upon which such partnerships can be based (see also De Winter and Lammers, 2022c). However, a number of important questions remain to be answered. Who could take the lead in establishing such partnerships in the case of hybrid potato breeding? How to reconcile different and conflicting interests in a playing field with, on the one hand, public breeding and extension services in decline and, on the other hand, globally operating agro-industrial companies, reluctant to share information and materials? Would there be a need for 'brokerage' in the potato sector at the national and international level (Klerkx *et al.*, 2009), with organisations acting as intermediaries, supporting 'commons-based' institutional change? And again, who could take up this responsibility for a more collaborative and inclusive social ordering?

In addition to these challenging questions, there is another more fundamental issue to consider in debates about possible hybrid potato futures. Public-private partnerships may indeed support smallholder farmers with more dedicated products of hybrid seed innovation, but still will principally remain dependent on knowledge and technologies emerging from the international agro-industrial innovation system. As described in Chapters 4 and 9, the Dutch potato sector is keen to maintain a leading role in seed innovation and seed companies position themselves as key players in achieving food security, thus reframing global societal challenges as market opportunities and catalysts for commercial innovation. In response to this dominant innovation discourse, we also see a counter movement in food systems debates, emphasising the aim of food sovereignty, based on less corporate and technology-driven and more agroecological and diversity oriented self-sufficient practices of farming (Montenegro de Wit *et al.*, 2021). This opposition also manifests itself in the existence of the Alliance for Food Sovereignty in Africa (AFSA) alongside the Alliance for a Green Revolution in Africa (AGRA), which raises an important question

that is not confronted directly in this book. Do we consider potato sectors in the international development context first of all as growth markets for new products of agro-industrial breeding, or as sectors that urgently need to strengthen their own breeding and seed production capacity? In other words, should the agenda for debate only consider issues of seed quality, or issues of seed sovereignty as well?

References

- De Winter, D. and Lammers, E., 2022a. The public sector's role in achieving food system change. Synthesis paper for the NL-CGIAR Research Programme. NWO, Den Haag, the Netherlands.
- De Winter, D. and Lammers, E., 2022b. The diversity of smallholders and agri-food value chains. Synthesis paper for the NL-CGIAR Research Programme. NWO, Den Haag, the Netherlands.
- De Winter, D. and Lammers, E., 2022c. Public-private partnerships in international agricultural research. Insights from the NL-CGIAR Research Programme. NWO, Den Haag, the Netherlands.
- Haug, R., Nchimbi-Msolla, S., Murage, A., Moeletsi, M., Magalasi, M., Muitmura, M., Hundessa, F., Cacchiarelli, L. and Westengen, O., 2021. From policy promises to result through innovation in African agriculture? *World 2*: 253-266. <https://doi.org/10.3390/world2020016>
- Kilwinger, F.B.M., 2022. Method matters: exploration and reflection on the study of farmers' demand for vegetatively propagated seed. Wageningen University, Wageningen, the Netherlands. <https://doi.org/10.18174/569974>
- Klerkx, L., Hall, A. and Leeuwis, C., 2009. Strengthening agricultural innovation capacity: are innovation brokers the answer? *International Journal of Agricultural Resources, Governance and Ecology* 8(5-6): 409-438. <https://doi.org/10.1504/IJARGE.2009.032643>
- Montenegro de Wit, M., Canfield, M., Iles, A., Anderson, M., McKeon, N., Guttal, S., Gemmill-Herren, B., Duncan, J., Van der Ploeg, J.D. and Prato, S., 2021. Editorial: resetting power in global food governance: the UN Food Systems Summit. *Development* 64: 153-161. <https://doi.org/10.1057/s41301-021-00316-x>
- Stemerding, D., Swart, J.A.A., Lindhout, P. and Jacobs, J.M., 2021. Potato futures: impact of hybrid varieties. Report of an online conference held in Doorn, the Netherlands, on November 30, 2020. Available at: https://www.nlfoodpartnership.com/documents/154/Conference_report_final.pdf.