Economic and agronomic analysis of the seed potato supply chain in Ethiopia

Adane Hirpa Tufa

Thesis committee

Promotors
Prof. Dr *ir*. A.G.J.M. Oude Lansink
Professor of Business Economics
Wageningen University

Prof. Dr *ir*. P.C. Struik
Professor of Crop Physiology
Wageningen University

Co-promotors
Dr *ir*. M.P.M. Meuwissen
Associate professor, Business Economics Group
Wageningen University

Dr *ir*. W.J.M. Lommen
Assistant professor, Centre for Crop Systems Analysis
Wageningen University

Other members
Prof. Dr *ir*. M.K. van Ittersum
Wageningen University

Prof. Dr O. van Kooten
Wageningen University

Dr W.J.J. Bijman
Wageningen University

Dr N.I. Valeeva
Agricultural Economics Research Institute (LEI)
Wageningen UR

This research was conducted under the auspices of the Wageningen School of Social Sciences (WASS)

Economic and agronomic analysis of the seed potato supply chain in Ethiopia

Adane Hirpa Tufa

Thesis

submitted in fulfilment of the requirement for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Wednesday 12 June 2013
at 4 p.m. in the Aula.

Adane Hirpa Tufa

Economic and agronomic analysis of the seed potato supply chain in Ethiopia,

182 pages.

Thesis, Wageningen University, Wageningen, NL (2013)

With references, with summaries in English and Dutch

ISBN: 978-94-6173-543-0

Abstract

In Ethiopia, potato (*Solanum tuberosum* L.) can significantly contribute to food security improvement by increasing food availability and cash income of smallholder farmers. Currently, production and productivity of potato in Ethiopia are very low because of poor quality seed tubers and unavailability of seed tubers of improved varieties. The overall objective of this thesis was to study the economic and agronomic aspects that affect quality and availability of seed potatoes in Ethiopia. To accomplish this objective, first, seed potato systems currently operating in Ethiopia, i.e. informal, alternative and formal ones, were analysed for their strengths and weaknesses. The result of the analysis showed that all existing seed systems have problems in performing their function and need to improve. To enhance overall supply of seed tubers co-existence and linkage of the three seed systems were found to be very important. Second, a conjoint analysis (a technique used to measure relative contribution of product attributes) was conducted to elicit farmers' opinions on management attributes that they believed to affect yield and quality of potato. The results showed that management attributes, such as storage method, hoeing combined with hill size, fertilizer rate and fungicide application frequency had more effect on seed yield and quality than seed source, seed size, sprouting method, tillage frequency, and planting date. Third, a study was conducted to develop cost-effective seed potato production plans for farmers in Ethiopia using perceived contributions of production and postharvest management and costs. Several plans were developed from which farmers could choose an affordable plan that will enable them to produce seed potato with reasonable yield and quality levels. The fourth study was conducted to describe existing and potential seed potato supply chains, and to evaluate the performance of these chains. The findings showed that seed potato supply chains vary in their performance with respect to cost, seed quality, flexibility and responsiveness. Actors in the chains also varied with respect to their importance to improve seed potato supply chain performance sub-indicators. The results of this thesis indicate that seed quality and availability can be improved by improving economic and agronomic aspects of the seed systems in general and seed supply chains in particular.

Key words: Potato, seed quality, seed tuber, seed system, quality improvement, expert elicitation, *Solanum tuberosum*, seed potato, supply chain, performance, Ethiopia

Preface

Sometime in 2008, Wageningen University announced three PhD research positions on potato in Ethiopia for its new research programme entitled Co-innovation for Quality in African Food Chains (CoQA). I was interested in one of the positions with profiles somehow related to my academic background. I submitted an application even though the research topic was not that much close to what I had in mind. At the end of May 2008, Prof. Paul Struik came to Hawassa University, Ethiopia, to make a short list and conduct interviews. Fortunately, I was selected for the PhD (that started October 2008) about which I am writing this preface. I would like to thank Professor Paul Struik for his interest and confidence in my application and for giving me an opportunity as well as a challenge I never considered before. I would also like to thank the CoQA team for developing and implementing such an interesting programme.

This thesis was co-funded by the Interdisciplinary Research and Education Fund (INREF) of Wageningen University and the Netherlands Organization for International Cooperation in Higher Education (NUFFIC), and I would like to thank both organizations. I also want to acknowledge Hawassa University for providing transport for field research at the beginning of this thesis work and Dr JA Zwartz Foundation for covering part of the printing costs of this thesis.

I would like to express my heart felt gratitude to my supervisors Professor Dr *ir.* Paul Struik and Professor Dr *ir.* Alfons Oude Lansink and co-supervisors Dr i*r.* Miranda Meuwissen and Dr *ir.* Willemien Lommen. Without their involvement, the completion of this thesis would have been impossible. Paul, Alfons, Miranda and Willemien, thank you very much for your diligent guidance and support from the beginning to the end of the entire thesis work. You had always time to respond to my concerns, even during weekends and holidays. I will never forget those extraordinary fast responses. I have benefited a lot from the discussions we had during the several regular supervision group and individual meetings. Paul, thank you very much for coming with me to the field observation trip to the Shahsamane area. Thank you also for being considerate about the differences between the Dutch and the Ethiopian ways of communicating with people and for the efforts you made to bridge the gaps. Alfons, thank you very much for allowing me to work in Business Economics Group. Miranda, thank you very much for your friendship, in addition to your supervision. Thank you a lot for the cares and treats to me and my family. I also want to thank

your husband Stef and your children Thomas and Manon for their warm welcome during the dinner invitation at your home, your birthday party and the 2012 fest of ‘Sint Maarten’ (the light and pancakes). Willemien, thank you very much for welcoming me for additional discussions on the research issues that needed special attention. I would like to thank Ivo van der Lans for his advice on one of the papers in this thesis. Dr Adamasu, thank you for coordinating this thesis research in Ethiopia.

Prof. Haverkort, Dr Wiersema, Dr Gildemacher and Mr Abdulwhab, thank you very much for the discussions we had on potato in general and on my research topic in particular during the early stages of this thesis research, and also for filling out the questionnaires. Dr Berga, Dr Bekele and Mr Gebremedhin, thank you for providing me literatures that were not available from others sources. Dr Bijman and Prof. Leeuwis, thank you for commenting on the first paper of this thesis. I would like to thank all survey participants for their cooperation.

Business Economic Group PhD students, Tamara, Geralda, Daphne, Koenraad, Victor, Niels, Mahesh, Hugo, Daniel, Luis, João, Eva, Farahnaz, Xuezhen, Wudu, Ewaldus, Tsion, Christina, Jaap, Felix Ngoc, Frazen, Eliana and Norhariani; and staff, Anne, Dr Grigorios, Dr Monique, Dr Annet, Mr Gerard, Dr Erno, Prof. Spiro, Dr Henk, Dr Helmut and Dr Wilma, thank you very much for making my stay in the corridor a very pleasant one. Thanks to Argyris and Grigorios for welcoming me to the Netherlands and taking me to the Bungalowpark at Hoenderloo. Argyris, thanks for your jacket; it saved me from the cold shock I experienced for the first time in my life. During my stay in the BEC I shared office with former and current PhD students, Huria, Natash, Niels, Victor, Mahesh, Tamara, Geralda, Wudu, Daniel, Tsion and Hugo, thank you for creating a nice working atmosphere. Tamara and Daniel, thank you very much for willing to be my paranymphs. Tamara, thanks for assisting me in designing the cover of this thesis. Anne, thank you for all your help regarding administrative, financial and housing issues. Thank you also for the Easter eggs, the Sinterklaas chocolates and the barbecues. Ilona, Jeanette and Leonie, thank you for all your help.

Thanks to the CoQA PhD students, Gumataw, Temesgen, Engida, Djalal, Nicodème and Menouwesso; and the Post-docs, Meike, Annie and Verena for the great times we had together in the CoQA programme. Special thanks to Annie for the welcoming visit of my family at Wageningen.

Thank you to my former colleagues and friends, Dr Moti, Dr Guush, Dr Getawu, Kebebe, Thomas, Dr Dambala, Dr Michele Nori, Dr Berhanu Gebremdhin, Mohammed, and Dr Waktole for the moral support. Dr Berhanu, I learned from you how to write a scientific report. Thank you very much for that. I would like to thank my relatives and friends who gave me a hand in accomplishing some activities I left behind because of my study. Bedaso, Mesfin, Assefa, thanks for the help and moral support. Abnet and Frew, thank you a lot for driving long distances during field work and for the friendship.

I met several new friends at Wageningen University. Frederike, Desalegn, Abiy, Mahdere, Mahlet, Solomie, Dhuguma, Marga, Dawit, Shemelis, Yenenesh, Lebeyesus, Ayalew, Solomon, Zenebe, Waga, Mequanint, and Tewodros, thank you a lot for the times we spent together and drinks and traditional meals we had together.

I am thankful to Marion Zaaijer for facilitating the Netherlands entry visa for my son, Margreet van Beek for facilitating day-care for my son; and AnneMeike and other Kievitsnest day-care workers for taking care of my son.

Very special thanks to my wife Habtamnesh Girma Habtemariam and my son Japheth for their love, care, moral support and patience. Habtamnesh (Mama), thank you very much, again. Without your support and love, my PhD study would have been very difficult. You made life easier for me. I am proud of you. Japheth (Japhi), you also contributed a lot to the success of this thesis. You travelled with us this long journey. I used part of your time and your comfort to work on the thesis. You have contributed even more; your sweet smile had a great power that always refilled me with new energy after a long tiring day.

I never forget the continuous moral support, blessing and love of my mother, who passed away on 18 June 2012. It would not be possible for me to be at this stage without her care and encouragement during my childhood.

Adane Hirpa Tufa

Wageningen, June 2013

Contents

Chapter 1

General introduction

1.1. General background

Ethiopia has a total surface area of 110.43 million ha, out of which 0.7% is water surface, and 15.7 million ha is cultivated (FAO, 2013). The country can be roughly divided into highland and lowland. The highland (> 1500 m above sea level (asl)) comprises about 40% land mass, 90% of human population, and 80% of livestock population (Pasture Network for Eastern and Southern Africa, 1988). According to 2011 estimate about 84.7 million people live in Ethiopia. Agriculture is the main source of income and accounts for 45% of GDP, and 80% of employment. Teff (*Eragrostis tef* (Zucc.) Trotter, corn (*Zea mays* L.), wheat (*Triticum* L.), barley (*Hordeum vulgare* L.), sorghum (*Sorghum bicolor* L.), and millet (*Pennisetum glaucum (L) R.Br)* are the major cereal crops grown in Ethiopia (Figure 1.1). Ethiopia also grows other crops and rears livestock.

In Ethiopia, food security is an important issue, mainly because of low domestic production and productivity. Several socio-economic indicators are unfavourable in the country (African Development Bank Group, 2011). Examples are daily calorie supply per capita (1980 versus 2462 for Africa), population growth rate (2.6% for Ethiopia, and 2.3% for Africa), dependency ratio (86.5% for Ethiopia, and 77.6% for Africa), and gross national income per capita (USD 330 for Ethiopia, and USD 1550 for Africa).

Low acreage and low level of input use such as inorganic fertilizers are among the main causes of low production and productivity of Ethiopian agriculture. Currently, only about 50% of the total potentially cultivable land is under cultivation (Awulachew, 2010), and the average size of a landholding is about 1 ha (IFAD, 2010; Spielman et al., 2010; Spielman et al., 2011; USAID, 2011). Of the total area cropped with five major crops (teff, corn, wheat, barley, and sorghum) that comprised 72.4% of the total cultivated land, inorganic fertilizer is applied only to 39% (Taffesse et al., 2011). Other inputs, such as improved seed, and irrigation are hardly used. As a result, the average yields of the five major crops are low: 1.3 Mg/ha for barley, 1.9 Mg/ha for maize, 1.7 Mg/ha for sorghum, 1.2 Mg/ha for teff and 1.6 Mg/ha for wheat (Taffesse et al., 2011). These yields are lower than the average yields for all cereals in least developed countries (1.93 Mg/ha) (World Bank, 2012).

Nonetheless, agriculture is an important economic sector because it is the source of livelihood for about 80% of the population (Spielman et al., 2010). Thus, the agricultural sector needs to be improved in order to realize food security. Food supply from crops can be increased in two ways: increase in area of production and increase in productivity per area of land.

In Ethiopia, under current socio-economic setup, increasing crop food supply through an increase of productivity of crops in the highland is more feasible than through an increase of the area of arable land (Taffesse et al., 2011; Tilahun et al., 2011). Productivity of the land can be increased through the use of improved seeds, improved cultural practices, irrigation, chemicals for control of diseases and pests, and growing high-yielding crops. Potato (*Solanum tuberosum* L.) is among the high yielding crops that can be grown in the highlands of Ethiopia.

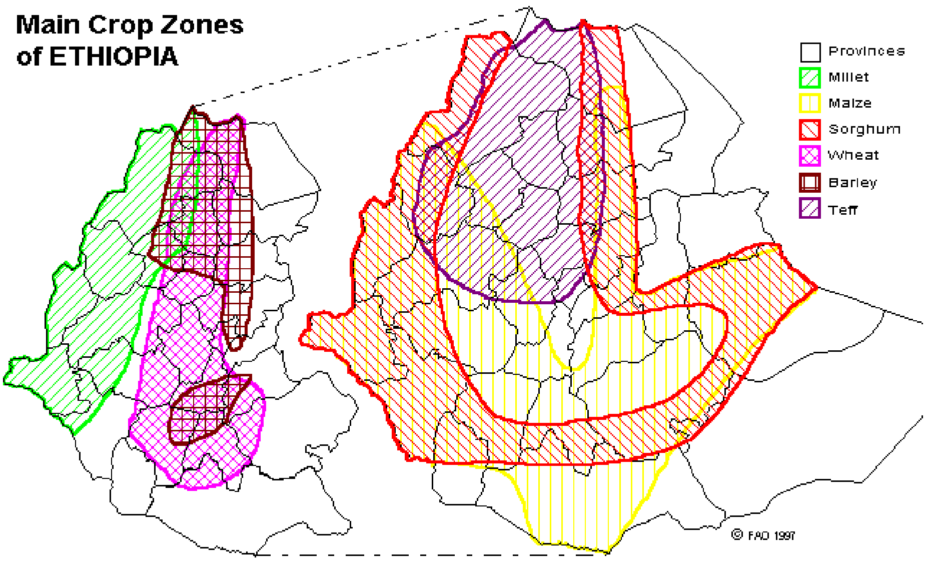


Figure 1.1. Main crop zones of Ethiopia. Source: Production Estimates and Crop Assessment Division Foreign Agricultural Service.
http://www.fas.usda.gov/pecad2/highlights/2002/10/ethiopia/baseline/Eth_Crop_Production.htm

1.2. Potato in Ethiopia

In Ethiopia, potato can potentially play a great role in improving food security because of its high yielding ability, availability of suitable agro-ecological zones within the country, and the availability of labour for its production on large areas of land (FAO, 2008). Potato gives the highest amount of energy per unit of land per day among the major arable crops like wheat, rice and maize (International Year of the Potato, 2008). Moreover, potato tubers are rich in vitamin C, a good source of vitamins B1, B2 and B6 and minerals such as potassium, phosphorous and magnesium, and a good source of high quality protein rich in S (Scott et al., 2000; International Year of the Potato, 2008). Potato can grow on 70% of the total arable land located in highland areas (from above 1500 to 3200 m asl with annual precipitation of 600 - 1200 mm, where about 90% of the Ethiopian population lives (FAO, 2008). However, potato has also disadvantages. First, it is a bulky product and therefore costly to transport. Second, it has a low dry matter concentration and it is therefore not easy to store potato tubers (under uncontrolled storage conditions it loses water, respires and produces sprouts). Third, it is very sensitive to many pests and diseases, requiring inputs like costly chemicals. Fourth, it is a labour-intensive crop and it has a low multiplication rate thus requiring large quantities of seed (Struik and Wiersema, 1999).

In Ethiopia, demand for potato is increasing because of increase in urbanization and change in consumption patterns of the urban population towards processed products like chips (Tesfaye et al., 2010). In Ethiopia, the urban population grows by 4.4% per year (African Development Bank Group, 2011) and the per capita income is also increasing steadily. According to World Bank (2012), per capita income grew from USD 160 in 2005 to USD 370 in 2011. This increase in per capita income could induce a rise in consumption of potato (Scott et al., 2000).

In Ethiopia, potato is among the major root and tuber crops. It is grown on about 0.164 million ha (CSA, 2002) by about 1.3 million smallholder farmers (CSA, 2012). Data over the period 2006-2010 from the Central Statistical Agency (CSA) show that potato covers about 30% of the total area allocated to root and tuber crops and accounts for 28% of total production. It is grown mainly in two seasons: *meher* – long rain season – June to October, and *belg* – short rain season – February to May. Potato is also grown in off-season (October to January). The *meher* and the *belg* seasons vary in the level of disease pressure. There is more diseases pressure in *meher* than in *belg* and the area of production and total yield of potato are larger in *belg* than in *meher*. According to CSA (2002), of the total land cultivated under potato, about 77% is cultivated in *belg.* Two types of potato varieties are grown in Ethiopia: local and improved. The majority of potato growers grow local potato varieties. The local varieties are mostly grown in the *belg* because of low level of disease incidence in this season and improved varieties are more often grown in the *meher* because of their high level of disease resistance (Lemaga, 2010).

In Ethiopia, several improved potato varieties were released to farmers with improved management practices. These varieties often mature within about 124 days and are characterized by high yields and biotic and abiotic stress tolerances. However, the uptake of these potato varieties and their recommended management attributes by smallholder farmers are very low. According to Gildemacher et al. (2009), seed potatoes of improved varieties comprised only 1.3% of the total supply of seed potatoes in Ethiopia.

1.3. Problem statement

The area of land under potato is only 2.3% of the total area potentially suitable for potato production. The productivity of potato is very low at about 10 Mg ha^{-1} (CSA, 2012). In Ethiopia, potato growers allotted only about 10% of their total cultivated land (CSA, 2002) to potato. Moreover, many farmers in the potato growing areas do not grow potatoes at all. Therefore, an increase in the area under potato production can be achieved by:

i) increasing the proportion of area allotted to potato by existing potato farmers,

ii) expanding potato production to new farmers within potato growing areas, and

iii) introducing potatoes to new areas.

However, increases in production and productivity are constrained by many factors among which poor quality of seed is the main one (Lemaga et al., 1994; Gildemacher et al., 2009; International Potato Center, 2011). In Ethiopia, the majority of farmers use seed tubers of local varieties that are saved from the previous harvest. These seed tubers are known for high disease burden and poor genetic quality, and thus give low yield. Improved potato varieties are less infected by diseases and are genetically superior to local varieties in terms of disease resistance and yielding ability. However, the seed tubers of these varieties are available only in a very small amount and to a small number of farmers mostly residing near agricultural research institutions. Therefore, poor quality of seed potatoes of local varieties and unavailability of seed tubers of improved varieties are major factors causing low production and productivity of potatoes in Ethiopia (Gildemacher et al., 2009; International Potato Center, 2011). These factors have both institutional and technical roots. For example there is no formal institution that multiplies and distributes seed potatoes of improved varieties except one Dutch PLC, Solagrow PLC (Solagrow PLC, 2011). Farmers also lack knowledge on improved practices of potato production (Mulatu et al., 2005; Gildemacher et al., 2009). To understand the constraints and to propose improvements in seed potato production and productivity, a better knowledge of the seed potato system is needed. Seed systems are ways in which farmers produce, select, save and acquire seeds (Sthapit et al., 2008). Some studies have been undertaken on seed potato production in different parts of

Ethiopia (e.g., Mulatu et al., 2005; Guenthner, 2006; Gildemacher et al., 2009). These studies, however, were limited in scope and did not provide a complete picture of the current state of seed potato systems in Ethiopia.

Different local environmental conditions require different production methods to achieve the “optimum” yield and quality of a product in a given situation (Mamo et al., 2003; Reece and Sumberg, 2003; Jack, 2011; Yu et al., 2011). The cause for the low uptake of improved potato varieties could be incompatibility of the recommended production method with the local environmental conditions that vary in agro-ecology, soil type, managerial capability, objectives of potato production (e.g. market or own use), and availability and access to inputs and product markets. To increase the uptake of the released potato varieties, it is important to identify alternative seed potato production methods that suit the local conditions of farmers, especially their financial capacity to purchase inputs. Reluctance in the uptake of new technologies can be more serious in a situation like in Ethiopia where markets for credit and insurance are missing (Croppentedt et al., 2003; Yesuf and Bluffstone, 2007). To identify alternative seed potato production methods, quantification of the costs and of contributions of seed potato production and postharvest management attributes (e.g., storage method, fungicide application frequency) to yield and quality is needed.

In Ethiopia, different potato varieties are grown in different seasons for diverse types of end users. Many farmers grow local potato varieties for multiple purposes, i.e. for home use as ware and seed, for sale as ware and seed. Other farmers grow local varieties in a large amount to sell as ware. Improved potato varieties are mostly grown to be sold as seed, although some farmers grow improved potato varieties for multiple purposes (for own consumption, own seed, sale). Potatoes are grown in different seasons and production conditions (under rainfed and irrigation or combination of rainfed and irrigation). Demand for different varieties also varies among the end users. Smallholder subsistence farmers demand improved varieties because these varieties are high yielding and disease tolerant and enable the farmers to produce potatoes that can be used for home consumption and sale at local markets. Commercial oriented farmers demand local varieties because local varieties have a long shelf life and good cooking quality, attributes required by potato markets in the cities. Therefore, many different chains are required to satisfy the demands for seed potatoes of the various end users. In Ethiopia, seed potato supply chains are underdeveloped and participants along the chain are not well-coordinated (Abebe et al., 2012). In order to compare existing

Ethiopian seed potato supply chains and suggest options for improvement, knowledge on management and performance of existing supply chains is essential. Also, it is essential to be able to evaluate the impact of supply chain improvements on the supply chain performance. At the onset of this research, knowledge on management and performance of existing Ethiopian seed potato supply chains and the impact of improvement options on performance was lacking.

1.4. Objectives

This thesis is part of the research programme "Co-Innovation for Quality in African Food Chains" (CoQA), which is a collaboration of Wageningen University with Hawassa University and Addis Ababa University (Ethiopia), University of Abomey-Calavi (Benin) and the University of Fort Hare (South Africa). The CoQA programme uses an interdisciplinary perspective in studying quality improvement options in three African food chains: pineapple in Benin, deciduous fruit in South Africa and potato in Ethiopia. The main objective is to analyse and design co-innovations for quality improvement in order to support smallholder producers in tailoring the quality of their products to the demands of their national and international supply chain customers, thus strengthening smallholder market access and competitiveness. The CoQA programme has been funded by the INREF fund of Wageningen UR. For further information, see www.coqa.nl. The overall objective of this thesis was to study the economic and agronomic aspects that affect quality and availability of seed tubers in Ethiopia. The specific objectives were:

1. to describe and analyse the status and performance of currently operating seed potato systems, and to identify and prioritize improvement options;
2. to elicit farmers' perceptions on the effect of seed potato management attributes on potato seed yield and quality;
3. to investigate the cost-effectiveness of alternative seed potato production methods;
4. to describe existing and design potential seed potato supply chains, and to evaluate the performance of selected chains.

1.5. Research approach

Figure 1.2 shows the research steps followed in this thesis. Different approaches were used to realize the specific objectives mentioned above.

Objective 1 had two sub-objectives. The first sub-objective was to describe seed potato systems. To attain this sub-objective, a literature review, a rapid appraisal and formal surveys, and expert elicitation were carried out and combined with field observations and local knowledge. The second sub-objective was to analyse the performance of the seed potato systems. To achieve this sub-objective a modified conceptual framework as suggested by Weltzien and vom Brocke (2001) was used. The conceptual framework had components such as seed production and storage, seed tuber quality, seed availability and distribution, and information flow.

Objective 2 aims at eliciting farmers' opinions on the importance of seed potato management attributes with respect to their perceived effect on potato seed yield and quality, and at quantifying these effects. To achieve this objective, first, a Delphi study was conducted to identify and prioritize seed potato production and postharvest management attributes for their importance to seed yield and quality. The Delphi study was conducted among experts and farmers. Second, two surveys were performed (i) conducting face-to-face interviews among farmers to collect specific demographic and management data, and (ii) using a conjoint task to elicit farmers' perceptions of the effects of selected management attributes on seed yield and quality.

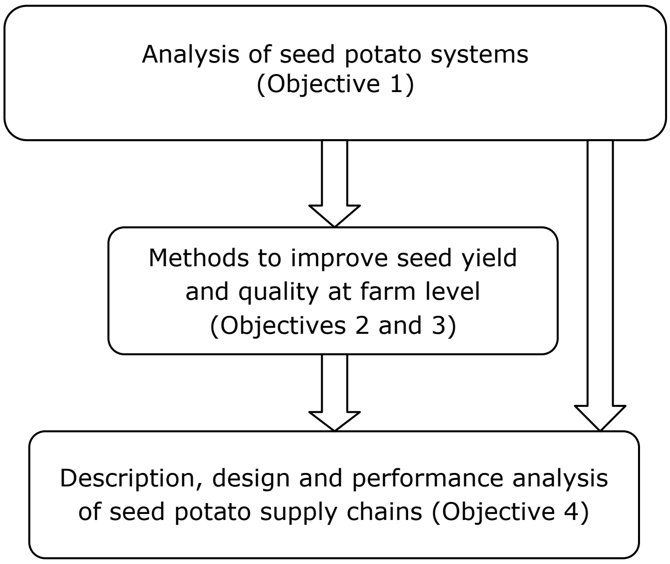


Figure 1.2. Steps followed in the thesis research knowledge flow.

Objective 3 aims at investigating cost-effectiveness of alternative seed potato production methods. This objective explores cost-effective seed potato production plans for smallholder seed potato farmers using integer linear programming techniques. The method combined costs and perceived contributions of seed potato management attribute levels to seed potato yield and quality.

Objective 4 aims at describing existing, and designing potential seed potato supply chains, and at evaluating the performance of selected chains. To fulfil this objective, three steps were followed. First, six existing and three potential seed potato supply chains were described in terms of network structure, chain management, chain business processes, and chain resources. Then, four supply chains were selected for further analysis of their performances. The selection was based on ranks allotted to them by potato experts with respect to their perceived performance, and dissimilarity among them. Finally, the selected chains were evaluated in detail for their performance using costs, flexibility, responsiveness and quality as main performance indicators and respective sub-indicators by using estimates obtained from potato experts.

1.6. Outline

This thesis contains six chapters including this general introduction. Chapters 2 to 5 address the objectives stated in section 1.4 in their order. Chapter 2 describes current seed potato systems in Ethiopia, discusses main areas of improvement and the main steps to be taken in the roadmap towards these improvements. Chapter 3 investigates contributions of seed potato management attributes to yield and quality as perceived by farmers. Chapter 4 examines alternative seed potato production plans that entail low costs and are robust to increasing input prices. Chapter 5 describes existing seed potato supply chains and designs potential ones. It also evaluates a selection of the existing and potential seed potato supply chains in terms of supply chain performance indicators such as costs, flexibility, responsiveness and quality. Chapter 6 provides a synthesis of results and discusses implications for future research, business and policy makers. The discussion in Chapter 6 included the outcome of the CoQA stakeholder workshop held in Addis Ababa on February 5, 2013 in which the results of Chapters 2 to 5 were presented to stakeholders that comprised seed potato growers, potato traders, representatives of consumer organizations, value chain analysts, seed potato experts and Ethiopian potato development partners.

References

Abebe, G.K., Bijman, J., Pascucci, S., Omta, O., Admasu T., 2012. Analysis of the causes of low adoption in less developed agri-food chains: the case of potato supply chain in the Upper Rift Valley region of Ethiopia. 10th Wageningen International Conference on Chain and Network Management (WICaNeM), 23-25 May 2012, Wageningen, The Netherlands.

African Development Bank Group, 2011. Federal democratic republic of Ethiopia country strategy paper 2011-2015. Accessed 16 January 2013 and available at http://www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/Ethiopia-2011-2015%20CSP%20ENG1.pdf

Awulachew, S.B., 2010. Irrigation potential in Ethiopia: Constraints and opportunities for enhancing the system. Accessed 17 January 2013 and available at http://ethiopianagriculture.files.wordpress.com/2010/11/ethiopia-irrigation-diagnostic-july-20101.pdf

CSA (Central Statistical Agency of Ethiopia), 2002. Ethiopia-agricultural sample enumeration. Accessed 8 January 2013 and available at http://catalog.ihsn.org/index.php/catalog/1438.

CSA (Central Statistical Agency of Ethiopia), 2012. Agricultural sample survey: Report on area and production of crops, Addis Ababa, Ethiopia, p 128

Croppenstedt, A., Demeke, M., Meschi, M.M., 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Review of Development Economics 7(1), 58-70.

Gildemacher, P., Demo, P., Barker, I., Kaguongo, W., Gebremedhin, W., Wagoire, W.W., Wakahiu, M., Leeuwis, C., Struik, P.C., 2009. A description of seed potato systems in Kenya, Uganda and Ethiopia. American Journal of Potato Research 86: 373–382.

Guenthner, J.F., 2006. Development of on-farm potato seed tuber production and marketing scheme. Agricultural economics extension series no. 06-01, July 2006. University of Idaho, Moscow.

FAO, 2008. Potato World: Africa-International Year of the Potato 2008. Accessed 7 January 2013 and available at http://www.potato2008.org/en/world/africa.html.

FAO, 2013. Ethiopia: Country fact sheet. Accessed 25 February 2013 and available at http://www.fao.org/nr/water/aquastat/data/factsheets/aquastat_fact_sheet_eth_en.pdf.

IFAD, 2010. Rural poverty report 2011: New realities, new challenges: new opportunities for tomorrow's generation. Fund for Agricultural Development, Rome.

International Year of the Potato, 2008. Potatoes, nutrients and diets. Accessed 4 January 2013 and available at http://www.potato2008.org/en/potato/factsheets.html

International Potato Center (CIP), 2011. Roadmap for investment in the seed potato value chain in eastern Africa. Lima, Peru. 27 p.

Jack, B.K., 2011. Constraints on the adoption of agricultural technologies in developing countries. White paper, Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA. Univ. of California, Berkeley.

Lemaga, B., Hailemariam, G., Gebremedhin, W. 1994. Prospects of seed potato production in Ethiopia. In Proceedings of the Second National Horticultural Workshop of Ethiopia, eds E. Hareth and D. Lemma, 254–275. Addis Ababa, Ethiopia: Institute of Agricultural Research and FAO.

Lemaga, B., 2010. The potato value chain in sub-Saharan Africa with case study on Eastern Africa. In: Strengthening potato value chains: Technical and policy options for developing countries. The Food and Agriculture Organization of the United Nations and the Common Fund for Commodities, pp. 43-54, Rome, Italy.

Mamo, M., Malzer, G.L., Mulla, D.J., Huggins, D.R., Strock. J., 2003. Spatial and temporal variation in economically optimum nitrogen rate for corn. Agronomy Journal 95:958–964.

Mulatu, E., Osman, E.I., Etenesh, B., 2005. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. Journal of New Seeds 7(3): 31–56.

Pasture Network for Eastern and Southern Africa (PANESA). 1988. African forage plant genetic resources, evaluation of forage germplasm and extensive livestock production Systems. Proceedings of the Third Workshop held at the International Conference Centre, Arusha, Tanzania, 27-30 April 1987. ILCA, Addis Ababa.

Reece, J.D., Sumberg, J., 2003. More clients, less resources: Toward a new conceptual framework for agricultural research in marginal areas. Technovation 23:409–421.

Scott, G.J., Rosegrant, M.W., Ringler, C., 2000. Global projections for roots and tuber crops in the year 2020. Food Policy 25, 561-597.

Spielman, D.J., Byerlee, D., Alemu, D., Kelemwork, D., 2010. Policies to promote cereal intensification in Ethiopia: The search for appropriate public and private roles. Food Policy 35, 185-194.

Spielman, D.J., Kelemwork, D., Alemu, D., 2011. Seed, fertilizer, and agricultural extension in Ethiopia. Accessed 4 January 2013 and available at http://www.ifpri.org/sites/default/files/publications/esspwp20.pdf.

Sthapit, B., Ram, R., Pashupati, C., Bimal, B., Pratap, S., 2008. Informal seed systems and on-farm conservation of local varieties. In Farmers, seeds and varieties: supporting informal seed supply in Ethiopia, ed. M.H. Thijssen, Z. Bishaw, A. Beshir, and W.S. de Boef, 133–137. Wageningen: Wageningen International.

Struik, P.C., Wiersema, S.G., 1999. Seed potato technology. Wageningen: Wageningen University Press, 383 p.

Taffesse, A.S., Dorosh, P., Asrat, S., 2011. Crop production in Ethiopia: regional patterns and trends. International Food Policy Research Institute (IFPRI), Addis Ababa, Ethiopia. Accessed 4 January 2013 and available at http://www.ifpri.org/sites/default/files/publications/esspwp16.pdf

Tesfaye, A., Lemaga, B., Mwakasendo, J. A., Nzohabonayoz, Z., Mutware, J., Wanda, K.Y., Kinyae, P. M., Ortiz, O., Crissman, C., Thiele, G., 2010. Markets for fresh and frozen potato chips in the ASARECA region and the potential for regional trade: Ethiopia, Tanzania, Rwanda, Kenya, Burundi and Uganda. International Potato Center (CIP), Lima, Peru. Working Paper 2010-1. 44p.

Tilahun, H., Teklu, E., Michael, M., Fitsum, H., Awulachew, S.B., 2011. Comparative Performance of Irrigated and Rainfed Agriculture in Ethiopia. World Applied Sciences Journal 14 (2): 235-244.

USAID, 2011. Feed the future: Ethiopia multi-year strategy (2011-2015). Accessed 4 January 2013 and available at http://ethiopia.usaid.gov/sites/default/files/images/USAID_FtF_MYS.pdf

Weltzien, E., vom Brocke, K., 2001. Seed systems and their potential for innovation: Conceptual framework for analysis. In: Sperling, L., Targeted seed aid and seed system interventions: Strengthening small farmer seed systems in East and Central Africa. Proceedings of a workshop held in Kampala, Uganda, 21–24 June 2000, pp. 9-13, Kampala.

World Bank, 2012.Working for a world free of poverty. Accessed 18 January 2013 and available at http://data.worldbank.org/indicator/NY.GNP.PCAP.CD/countries/ET-ZF-XM?display=graph.

Yesuf, M., Bluffstone, R., 2007. Risk aversion in low-income countries: Experimental evidence from Ethiopia. International Food Policy Research Institute (IFPRI) discussion paper No. 715, Washington D.C., 36 p.

Yu, B., Nin-Pratt, A., Funes, J., Gemessa, S.A., 2011. Cereal production and technology adoption in Ethiopia. International Food Policy Research Institute (IFPRI).Working paper 31. Accessed 8 February 2012 and available at http://www.ifpri.org/publication/cereal-production-and-technology-adoption-ethiopia-0.

Chapter 2

Analysis of seed potato systems in Ethiopia

Adane Hirpa[1,2,3], Miranda P.M. Meuwissen[1], Agajie Tesfaye[4], Willemien J.M. Lommen[2], Alfons Oude Lansink[1], Admasu Tsegaye[3] and Paul C. Struik[2]

[1]Business Economics, Wageningen University, The Netherlands.

[2]Centre for Crop Systems Analysis, Wageningen University.

[3]Hawassa University College of Agriculture, Hawassa, Ethiopia.

[4]Holetta Agricultural Research Centre, Holetta, Ethiopia.

Published in: American Journal of Potato Research (2010) 87:537–552

Abstract

This study aimed to analyse the seed potato systems in Ethiopia, identify constraints and prioritize improvement options, combining desk research, rapid appraisal and formal surveys, expert elicitation, field observations and local knowledge. In Ethiopia, informal, alternative and formal seed systems co-exist. The informal system, with low quality seed, is dominant. The formal system is too small to contribute significantly to improve that situation. The informal seed system should prioritize improving seed quality, by increasing awareness and skills of farmers, improving seed tuber quality of early generations and market access. The alternative and formal seed systems should prioritize improving the production capacity of quality seed by availing new varieties, designing quality control methods and improving farmer's awareness. To improve overall seed potato supply in Ethiopia, experts postulated co-existence and linkage of the three seed systems and development of self-regulation and self-certification in the informal, alternative and formal cooperative seed potato systems.

Key words: Potato, seed quality, seed tuber, seed system, quality improvement, expert elicitation, *Solanum tuberosum*

2.1. Introduction

Potato (*Solanum tuberosum* L.) is one of the tuber crops grown in Ethiopia. It is grown by approximately 1 million farmers (CSA, 2009). Potato is regarded a high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle (mostly < 120 days) than major cereal crops like maize. Recently the price of cereals strongly increased worldwide and in Ethiopia, the price subsequently stabilized at a high level, whereas the price of roots and tubers remained relatively low during the entire food crisis. This shows that there is room for added value in the chain of tuber crops. Potato can potentially be grown on about 70% of the 10 Mha of arable land in the country (FAO, 2008). There are improved varieties that yield 19-38 Mg ha^{-1} on farmers' fields (Gebremedhin et al., 2008). However, the current area cropped with potato (about 0.16 Mha) is small and the average yield (less than 10 Mg ha^{-1}) is far below the potential. The low acreage and yield are attributed to many factors, but lack of high-quality seed potatoes is a major factor (Lemaga et al., 1994; Endale et al. 2008a; Gildemacher et al., 2009a). Ethiopia is a land-locked, poor country with a negative trade balance, which makes expensive imports of high-quality seed tubers from Europe or elsewhere unaffordable.

Increase in potato acreage and yield calls for improvement of the quality of seed potatoes supplied to the ware potato production systems[1]. This requires the improvement of the seed potato systems operating in the country. To suggest options for improvement, knowledge on the current status and performance of seed potato systems is essential. Some studies have been undertaken on seed potato production in different parts of Ethiopia (e.g., Mulatu et al., 2005a; Guenthner, 2006; Gildemacher et al., 2009b). These studies, however, were limited in scope and did not provide a complete picture of the current state of seed potato systems in the country. The objectives of this paper are (i) to describe and analyze the status and performance of currently operating seed potato systems; and (ii) to identify and prioritize improvement options.

[1] Potato production system comprises all processes and activities (land preparation through harvesting) undertaken to produce ware or seed potatoes.

2.2. Major potato growing areas and types of seed systems

Major potato growing areas

In Ethiopia, potato is grown in four major areas: the central, the eastern, the northwestern and the southern (Figure 2.1). Together, they cover approximately 83% of the potato farmers (CSA, 2009). A brief description of each area follows:

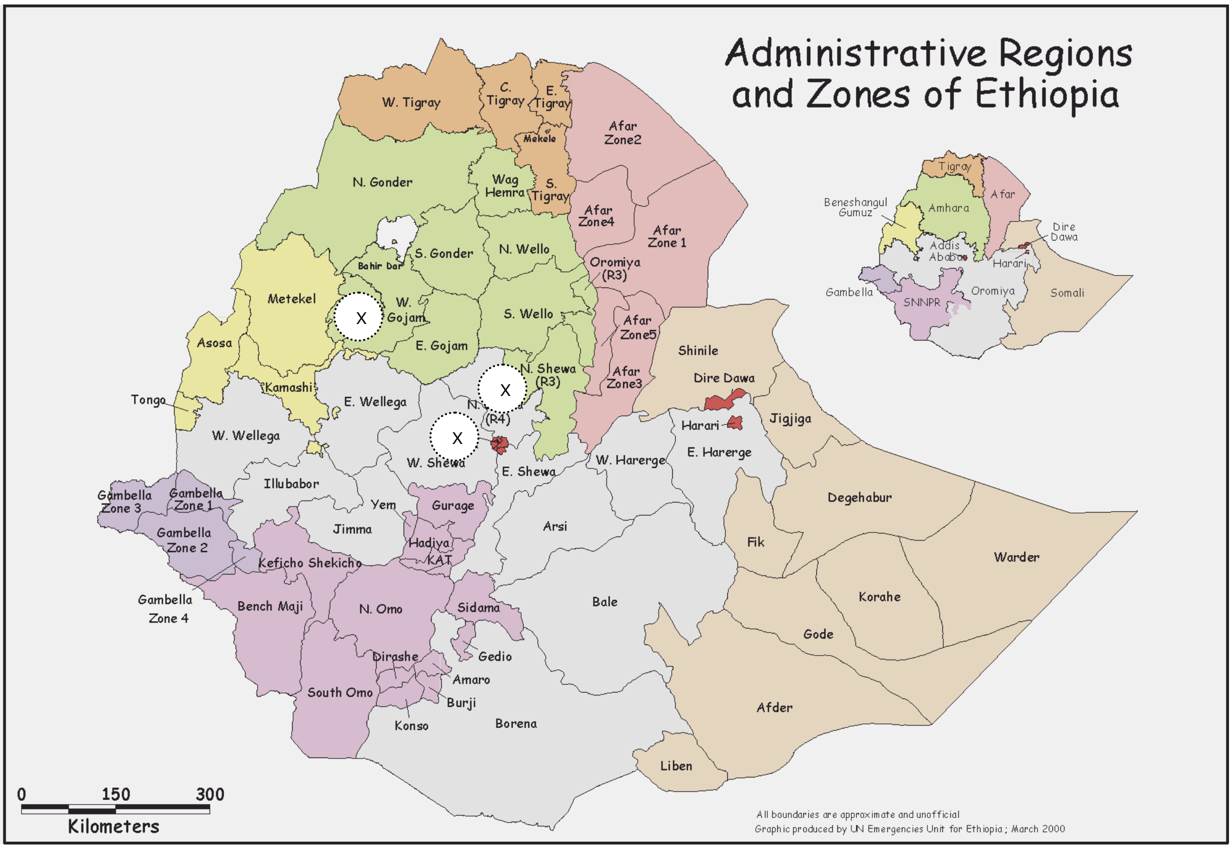


Figure 2.1. Administrative regions and zones of Ethiopia. Source: UN Emergencies Unit for Ethiopia. Note: × represents location of districts in which the survey was carried out.

In the *central area*, potato production includes the highland areas surrounding the capital, i.e. Addis Abeba, within a 100 to 150 km radius (Figure 2.2). In this area the major potato growing zones are West Shewa and North Shewa (Figure 2.1). About 10% of the potato farmers are located in this area (CSA, 2009). Average productivity of a potato crop ranges from 8 to10 Mg ha^{-1} which is higher than the productivity in the northwestern and southern areas. This higher productivity might be due to the use of improved varieties and practices obtained from Holetta Agricultural Research Centre in the central area. In the central area potato is produced mainly in the *belg* (short rain season - February to May) and meher (long rain season - June to October) periods. Potato is also grown off-season under irrigation

(October to January). Because of the cool climate and access to improved varieties, farmers in this area of the country also produce seed potatoes which are sold to other farmers in the vicinity or to NGOs and agricultural bureaus to be disseminated to distant farmers. In the central area, farmers grow about seven local varieties, eight improved varieties and six clones (i.e. genetic material which is not officially released).

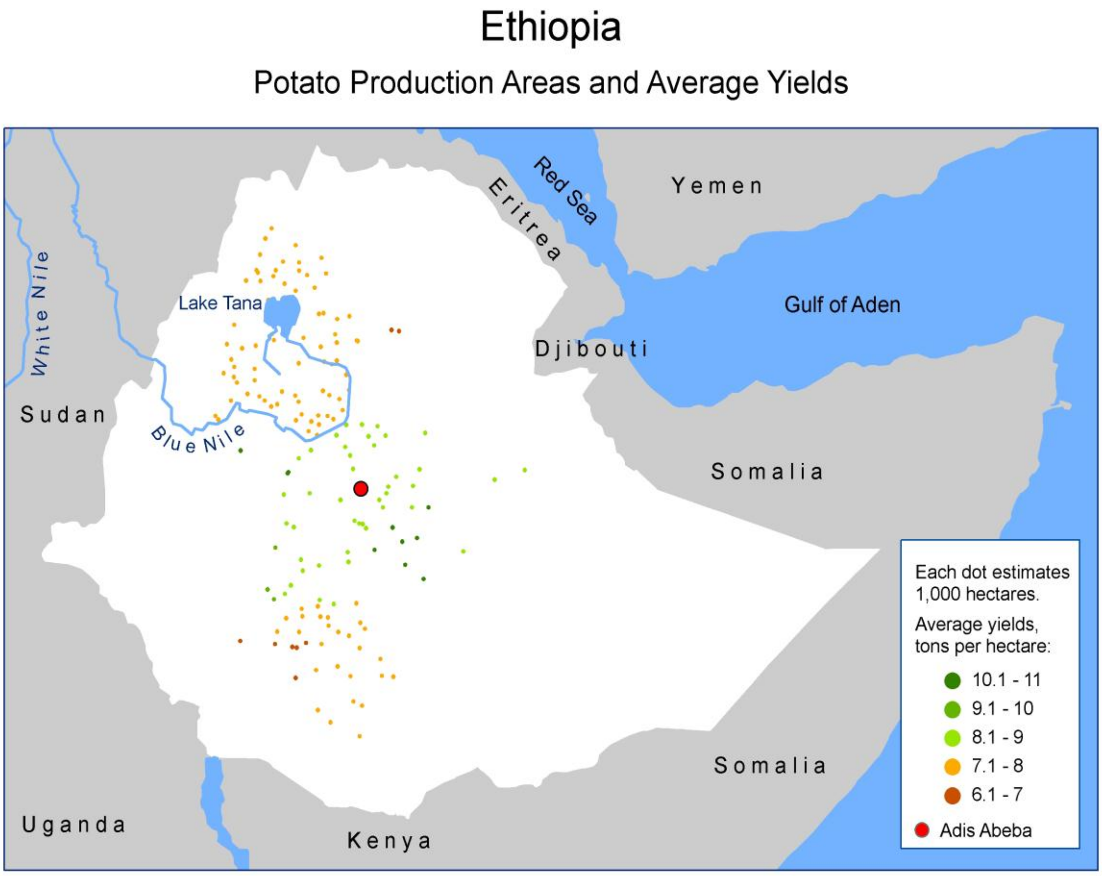


Figure 2.2. Potato production areas and average yields in Ethiopia.
Source: http://research.cip.cgiar.org/confluence/display/wpa/Ethiopia. Reproduced with kind permission from the International Potato Center, Lima, Peru.

The *eastern area* of potato production mainly covers the eastern highlands of Ethiopia, especially the East Harerge zone (Figures 2.1 and 2.2). Only about 3% of the total number of potato growers is situated in this area (CSA, 2009), but the area is identified specifically because the majority of the potato farmers in this area produce for the market and there is also some export to Djibouti and Somalia. Potato is mainly grown under irrigation in the dry season (December to April). This season is characterized by low disease pressure and relatively high prices (Mulatu et al., 2005b). Potato is also produced in the *belg* (February to

May) and the *meher* (June to October) seasons. Most farmers grow local potato varieties. However, some farmers in the vicinity of Haramaya University in the eastern area and farmers who are targeted by NGO seed programmes have access to improved varieties (Mulatu et al., 2005a). Despite the use of local varieties, the productivity of potato in this area is equivalent to the productivity in the central area. This might be due to good farm management practices triggered by the farmers' market orientation.

The *northwestern area* of potato production is situated in the Amhara region (Figures 2.1 and 2.2). It is the major potato growing area in the country, counting about 40% of the potato farmers (CSA, 2009). South Gonder, North Gonder, East Gojam, West Gojam and Agew Awi are the major potato production zones. Farmers mainly grow local varieties. Productivity ranges from 7 to 8 Mg ha^{-1}. In this area, the largest volume of potato is produced in the *belg* season followed by irrigated potato produced off-season. Potato is also produced in the *meher* season. Data on genotype use in the Awi district show that there were 21 potato genotypes grown, of which 67% were local varieties. Ninety per cent of the farmers grew these local varieties.

The *southern area* of Ethiopia in which potato is grown, is mainly located in the Southern Nations', Nationalities' and Peoples' Regional State (SNNPRs) and partly in the Oromiya region. The major potato producing zones in this area are Gurage, Gamo Goffa, Hadiya, Wolyta, Kambata, Siltie and Sidama in the SNNPRS and West Arsi zone in Oromiya. More than 30% of the total number of potato farmers is located in this area (CSA, 2009). Potato tubers are produced under rainfed conditions and under irrigation. Productivity usually ranges from 7 to 8 Mg ha^{-1}, whereas in some places potato productivity is even below 7 Mg ha^{-1}. About six varieties are grown, of which four are local and two are improved (Endale et al., 2008a).

Types of seed potato systems in Ethiopia

Seed systems can be defined as the ways in which farmers produce, select, save and acquire seeds (Sthapit et al., 2008). Different authors classify seed systems into different types. Struik and Wiersema (1999) and Endale et al., (2008a) classify seed systems into informal and formal, while others classify them into local and formal (World Bank et al., 2009), or farmers' and formal (Almekinders and Louwaars, 1999). The farmers', informal or local seed systems cover methods of local seed selection, production and distribution (Louwaars, 2007). The formal seed systems cover seed production and supply mechanisms operated by public or private sector specialists in different aspects of the seed system, ruled by well-defined methodologies, with controlled multiplication, and in most cases, regulated by national legislation and international standardization methodologies (Louwaars, 2007). In Ethiopia, we identified three seed potato systems, namely informal, alternative and formal. Each of the systems is briefly explained below.

The *informal seed potato system* is a seed potato system in which tubers to be used for planting are produced and distributed by farmers without any regulation. This seed system exists in all potato growing areas of Ethiopia. It is the major seed potato system. According to Gildemacher et al. (2009a), it supplies 98.7% of the seed tubers required in Ethiopia. The seed tubers supplied by this system have poor sanitary, physiological, physical and genetic qualities (Lemaga et al., 1994; Mulatu et al., 2005a; Endale et al., 2008a; Gildemacher et al., 2009a).

The *alternative seed potato system* is a seed potato system that supplies seed tubers produced by local farmers under financial and technical support from NGOs and breeding centres. In Ethiopia there are community-based seed supply systems which are undertaken by the community with technical and financial assistance of NGOs and breeding centres. Self-help development international (SHDI) and the FAO seed security project, both in the eastern area of Ethiopia (Getachew and Mela, 2000; Mulatu et al., 2005a) can be mentioned as good examples. These NGOs formed cooperative, community-based seed enterprises (CCBSEs) which produce seed tubers of improved varieties and sell those to other farmers or back to the NGOs for further dissemination. The roles of NGOs have been to provide the financial assistance to CCBSEs and to link the CCBSEs to the breeding centre (Haramaya University in the eastern area) for technical assistance. There are also farmers' research groups (FRG) and farmers' field schools (FFS) in the central and northwestern areas of Ethiopia which are involved in seed potato production (Bekele et al., 2002). They are formed by the Ethiopian Institute of Agricultural Research (EIAR). Some members of FRG and FFS in the central area of Ethiopia became specialized seed potato growers (Gildemacher et al., 2009b). These "specialized" commercial seed potato producers are local smallholder farmers. These farmers are producing better quality seed tubers than other farmers but these may still not be of standard quality. From 2002-2003, also some efforts were made in the southern area of Ethiopia to multiply seed potatoes by individual farmers with technical and financial assistance from breeding centres and NGOs. The alternative seed potato system supplies about 1.3% of the total supply (Gildemacher et al., 2009b).

In the *formal seed potato system* seed tubers are produced by licensed private sector specialists and cooperatives. There is no public formal seed potato supply system in Ethiopia. The contribution of the formal seed potato system to the overall seed tuber use in Ethiopia is very meagre as both the private sector and the cooperatives are at the incipient stage. Very recently, two seed potato producer cooperatives were established and two more are under the process in the central area of Ethiopia. The Ethiopian Seed Enterprise (ESE) is not involved in seed potato production and supply because of its limited capacity. There is only one modern seed potato company in Ethiopia, i.e. the SolaGrow PLC. It is established in 2006 by a group of Dutch investors in collaboration with the Dutch potato breeding company HZPC Holland B.V. with the aim of strengthening the Ethiopian agricultural sector by producing seed potatoes. From 2006 - 2008, the PLC has already a signed agreement with HZPC Holland B.V., established central and local demonstration farms and produced 150 Mg of seed potatoes (EVD, 2009).

2.3. Materials and methods

Literature review, rapid appraisal and formal surveys, expert elicitation and field observations were carried out to analyse the current status of the seed potato systems in Ethiopia. Moreover, local knowledge was used. In the analysis the four major potato growing areas and three seed potato systems identified above were taken into account.

Framework for the literature review, rapid appraisal and formal surveys, and analysis of the performance of the seed systems

To describe the present status of the seed systems in Ethiopia, a literature review, a rapid appraisal survey and a formal survey were carried out and were combined with field observations and local knowledge. To analyze the performance of the present seed systems, a modified conceptual framework as suggested by Weltzien and vom Brocke (2001) was used. According to these authors a seed system can be analyzed from different perspectives and with different objectives. They suggested using the farmers’ perspective to analyze seed systems for identification of specific strengths and weaknesses. According to Weltzien and vom Brocke (2001) five functions (seed quality, appropriateness of variety, timeliness of seed availability, conditions under which the seed is available, and capacity to innovate) should be performed by a seed system to avail high-quality seed of varieties preferred by farmers in sufficient amount at the right time and for a reasonable price. These functions can be analysed based on four process-oriented components of a seed system that overlap and interact. The four seed system components suggested by the authors are germplasm base, seed production and quality, seed availability and distribution, and information flow. For our specific analysis we slightly modified the seed system components to make the components suit our analysis. These components were (i) seed production and storage, (ii) seed tuber quality, (iii) seed availability and distribution, and (iv) information flow. We ignored the component germplasm base, for it was partly addressed in the related component seed quality. The original component seed production and quality, was divided into two components, seed production and storage, and seed quality, to give due emphasis to both components. Descriptions of (i), (iii) and (iv) are largely adopted from Weltzien and vom Brocke (2001); for (ii), i.e. seed tuber quality, we used Struik and Wiersema (1999) as their description better suited seed potatoes described in this paper. Brief descriptions of these seed system components follow:

The first component, seed production and storage, refers to all activities leading to the production of seed at the time of sowing; it includes all operations of production and storage. Specific issues to address are how seed potatoes are produced, pre-treated and stored, and whether selection is practiced to identify individual plants that will be used to collect seed tubers for the next season’s crop.

The second component, i.e. seed tuber quality, can be defined as the ability of a seed tuber to produce a healthy, vigorous plant that produces a high yield of good quality within the time limits set by the growing season into which the seed is going to be used. Seed tuber quality is affected by seed health, physiological age and status, seed size, seed purity and genetic quality. The appropriateness of the variety or genetic quality of the seed is the adaptability to specific growing conditions and biotic or abiotic stresses and its food and processing quality characteristics.

The third component, seed availability and distribution, concerns the access of all farmers to appropriate seed at the appropriate time. Timeliness is crucial for obtaining the expected yield. Delays in planting usually result in yield losses and can seriously affect the development of diseases or insect populations, which in turn can affect yield and quality at harvest. Relevant questions relating to this component are: What is the actual origin of seed that farmers are planting? Is it their own production or do they get it from other sources? What role does the market play?

The fourth component, i.e. information flow, covers issues such as: What information is available about new varieties and new seed sources? Where and from whom do farmers search for new information? How is information regarding new varieties of potato and new practices exchanged among farmers? What type of information are farmers searching for? These aspects are especially relevant in the context of change and innovation.

Rapid appraisal and formal survey

In 2007, a survey was undertaken in three major potato growing districts of Ethiopia, namely Juldu and Degem districts in the central part and Banja district in the northwestern part of Ethiopia, to gather data on the status of the use of improved potato technologies, including new varieties and improved cultural practices. Jeldu district is located in the West Shewa zone of the Oromia region at 128 km from Addis Ababa going west; Degem district is located in the North Shewa zone at 125 km from Addis Ababa going northwest; Banja district is located in the Agew Awi zone of the Amhara region at 434 km from Addis Ababa going northwest (Figure 2.1). Data collection was undertaken in three successive stages. First, secondary data was collected from relevant published and unpublished sources. Second, based on the information obtained from secondary data a checklist was prepared to conduct a rapid appraisal survey that helped to collect qualitative information and gain insight in the use of potato technologies by potato producers. Third, a formal survey was conducted using a structured questionnaire to collect quantitative data on the use of improved varieties and practices. This formal survey was conducted among two categories of farmers. One category consisted of farmers who hosted demonstration, verification and scaling-up trials on the use of cultural practices of improved potato varieties, undertaken by agricultural research institutions. The second category comprised potato producing farmers who did not directly host any kind of potato demonstration, verification or scaling-up trials. A total of 127 farmers in the first category (61 from Jeldu, 50 from Degem and 16 Banj districts) and 209 farmers in the second category (76 from Jeldu, 54 from Degem and 79 from Banja districts) were selected randomly. Descriptive statistics, mean and percentage, were employed to analyse the data.

Expert elicitation

A workshop was organized to elicit national and international seed potato experts' opinions on seed potato system improvements in Ethiopia. The half-day workshop took place in Spring 2009. In total 13 experts attended, five of them were Wageningen University professors, four were Netherlands-based research and development project managers working in developing countries, two were International Potato Centre (CIP) researchers and another two were Ethiopian PhD students doing research on potato. The meeting was set up in three blocks. During the first block we presented the main findings from literature and posed the question whether important elements were missing. In the second block, experts evaluated the informal, alternative and formal systems. Evaluations were differentiated according to regions (for the informal system we distinguished between the central, eastern, northwestern and southern regions; for the alternative system between the central, eastern and northwestern regions) or organizational form (for the formal system these were cooperatives versus Private Limited Company (PLCs). For each system, region or organizational form the same three assignments were to be carried out, i.e. (i) prioritize general improvement options in the seed system by dividing 100 points; (ii) prioritize items of improving seed quality by dividing 100 points; and (iii) indicate top-3 steps for the roadmap towards improvement. Assignments (i) and (ii) were closed-type questions as we already indicated the improvement items, while assignment (iii) was an open question. General improvement items included production methods, storage methods, seed quality, seed availability and distribution, information flow, spread of new varieties, and cost-benefit ratio, from which the latter two were added by experts during the first block of the workshop. Quality improvement items were purity, genetic quality, seed health, seed size, physical damage, and physiological age. For the roadmap, experts were free to list the steps to be taken to improve each of the four seed potato systems (informal, alternative, formal cooperative and formal private). In the third block of the workshop we discussed the feasibility of "one overall seed potato system for Ethiopia".

2.4. Current status of seed potato systems

The main characteristics describing the current status and performance of seed potato systems in Ethiopia are summarized in Table 2.1.

Seed potato production and storage

Seed potato production methods

Generally, in all areas of Ethiopia, there is no separate plot and management for ware and seed potato production. Mostly, potato tubers are sorted into ware and seed immediately after harvest. For most potato producers seed potato is usually considered as the by-product of ware potato. Only some farmers in the central and northwestern areas of Ethiopia have recognized the problems of using part of ware potato as planting material, such as disease transmittance and resulting yield loss. In the central and northwestern areas, some farmers practice positive selection[2] and some also grow seed potatoes on a separate piece of good quality land. In our survey in 2007, 13% of the farmers in the district Degem and 15%of the farmers in the district Jeldu in the central area and 8% of the farmers in the district Banja in the northwestern area produced seed potatoes by positive selection, whereas one per cent of the farmers in district Degem and 14% of the farmers in the district Jeldu and 6% of the farmers in the district Banja produced seed potato on separate plots (Table 2.1). In another study in the central and northwestern areas of Ethiopia, 9% of farmers were found to produce seed potatoes through positive selection and 2% of the farmers were found to produce seed potatoes on separate plots (Gildemacher et al., 2009b). In the southern area there is no practice of positive selection or use of separate plots for the production of seed tubers. According to Mulatu et al. (2005a) farmers in the eastern area of Ethiopia usually do not produce seed tubers on separate plots. In this area of the country, there is no positive selection either.

Seed potato storage methods

Seed potato storage is a common practice in all potato producing areas of Ethiopia. Farmers store seed potato by leaving the tubers in the soil un-harvested (postponed harvesting); by other traditional storage methods like in a local granary, on bed-like structures or the floor in their house; or by diffused-light storage (DLS). Because of storage and other postharvest problems Ethiopia loses 30 - 50% of its potato production (Endale et al., 2008b). Types of storage are described in more detail below.

[2] Positive selection means selecting only the healthy-looking mother plants, showing good production characteristics, for seed collection (Gildemacher et al., 2007)

Table 2.1. Summary of seed potato production and supply systems in major potato growing areas of Ethiopia.

Item	**Major potato growing area**			
	Central	Eastern	Northwestern	Southern
Seed system				
Informal	Major	Major	Major	Major
Alternative	Specialized seed growers	CCBSE	FFS and FRG	FRG
Formal	Cooperatives, SolaGrow PLC	None	None	None
Seed source and % of farmers using this source *				
Own savings	32 (Degem), 54 (Jeldu) [b]	44.6 [d]	65 [b]	40 [g]
Local market	29 (Degem), 31 (Jeldu) [b]	55.4 [d]	31 [b]	55 [g]
Purchase from villagers	10 (Degem), 12 (Jeldu) [b]	20.0 [d]	3 [b]	5 [g]
Specialized seed growers	29 (Degem), 3 (Jeldu) [b]	None [d]	2 [b]	None [g]
Type of potato variety available				
Local (%)	53 [a]	Almost all [d]	73 [a]	67 [f]
Improved (%)	47 [a]	Few [d]	27 [a]	33 [f]
Type of potato variety and % of farmers using this type				
Local (%)	50 [a]	Almost all [d]	90 [a]	70 [g]
Improved (%)	50 [a]	Few [d]	10 [a]	30 [g]
Source of improved varieties (% of farmers)				
Breeding centre	39 (Degem), 38 (Jeldu) (HRC) [a]	No figure (HU)	7 (ARC) [a]	Little [g]
Commercial seed grower	26 (Degem), 14 (Jeldu) [a]	No literature	2 [a]	None [g]
Trader (market)	13 (Degem), 21 (Jeldu) [a]	No literature	74 [a]	Most likely [g]
Relative	1 (Degem), 10 (Jeldu) [a]	No literature	3 [a]	Little
Neighbour	21 (Degem), 14 Jeldu [a]	No literature	12 [a]	Little [g]
District agricultural bureau	0 (Degem), 4 (Jeldu) [a]	No literature	1 [a]	Some [g]
NGO	None [a]	No figure (SHDI and FAO) [d]	None [a]	Some [g]
Utilization of total yield generated from improved varieties (% of total production)				
Kept for own seed	19 [a, **]	9 [g]	19 [a, **]	Some
Sold as seed	27 [a]	–	27 [a]	Some
Consumed at home	21 [a]	11 [h]	21 [a]	No literature
Sold as ware	28 [a]	80 (sold as ware or seed) [h]	28 [a]	Most
Gift	5 [a]	None [g]	5 [a]	No literature
Availability of high quality seed tubers				
% of farmers facing problems in getting high quality seed	64 [a]	Almost all [g]	77 [a]	Most
Seed renewal				
% of farmers who renewed seed	24 (Degem), 44 (Jeldu) [a]	No literature	44 [a]	No literature
Number of seasons until seed renewal)	3 [ab]	No literature	1 by 46% of the farmers [a]	No literature
Seed production method (% of potato farmers)				
Part of ware (by-product)	71 (Degem), 65 (Jeldu) [a]	Most [d]	75[a]	All [g]
Positive selection	13 (Degem), 15 (Jeldu) [a]	None [d]	8 [a]	No literature
On separate plot	1 (Degem), 14 (Jeldu) [a]	None [d]	6 [a]	No literature

Table 2.1. (continued)

Item	**Major potato growing area**			
	Central	Eastern	Northwestern	Southern
Seed storage methods (% of farmers)				
DLS (only for improved seed)	87 [i]	25 [i]	25 [a]	Few [g]
Postponed harvesting	3 (Degem), 1 (Jeldu) [a]	None [d]	37 [a]	Not practiced [g]
Local granary	None [a]	None [d]	None [a]	Most [g]
Jute sacks	47 (Degem), 46 (Jeldu) [a]	Most [d]	5 [a]	No literature
Heaped	45 [a]	Some [d]	21 [a]	No literature
Bed-like structure	10 (Degem), 1 (Jeldu) [a]	None [d]	33 [a]	None [g]
Seed quality				
Purity	Mixed [f]	Mixed (4 – 5 varieties) [d]	Mixed [f]	Mixed [g]
Physiological age	Unsuitable	Unsuitable	Unsuitable	Unsuitable
Size	72% of potato farmers (Degem), 66% of potato farmers (Jeldu) used medium [a]	17% of potato farmers used too small [d]	63% of potato farmers used medium [a]	No literature
Health	Degenerated seed tubers [f]	25% diseased [d]	Very poor	Poor [g]
Physical damage and rotten	No literature	17% [d]	No literature	No literature
Production and productivity				
Average area under potato per farm (ha)	0.11 (Degem), 0.19 (Jeldu) [a]	< 0.25 [d]	0.16 [c]	No literature
Productivity (in Mg ha^{-1})	8–10 [e]	8–9 [e]	7–8 [e]	7–8 [e]

Sources: [a] Field survey, [b] Gildemacher et al. 2009a, [c] Gildemacher et al. 2009b, [d] Mulatu et al. 2005a, [e] CSA 2008, [f] Guenthner 2006, [g] Own estimation, [h] Emana and Hadera 2007, [i]Tesfaye, 2008.
Acronyms: HRC – Holetta Research Centre, HU – Haramaya University, ARC – Adet Research Center, CCBSE – Cooperative Community Based Seed Enterprise, FFS – Farmers Field School and FRG – Farmers Research Group.
* Note that farmers in the Eastern region mentioned different sources and therefore the total for that region adds up to 120%.
****** Data available for the Central and Northwestern regions come from the same source, are averages for the two regions, and therefore the numbers are the same.

i. Postponed harvesting as storage mechanism

Postponed harvesting is the most commonly used storage method for ware potatoes in the highland and northwestern areas of the country to extend piece-meal consumption and also to wait for a better price (Endale et al., 2008b). According to these authors, tubers can be kept up to 4 months without major quality loss in cool highlands. This storage method is also used to store seed potatoes. Our survey revealed that about 37% of the farmers in Banja in the northwestern area of Ethiopia left the potato tubers for seed un-harvested in the field, whereas only 1% (Jeldu) to 3% (Degem) of the farmers in the central area used this method (Table 2.1). In a study undertaken in the central and northwestern areas of Ethiopia, Gildemacher et al. (2009b) found that 47% of the potato farmers leave seed potatoes in the soil un-harvested. This storage method was not reported in seed potato studies in the eastern area of Ethiopia. There is also no information on the presence of this storage type in the southern area of Ethiopia. Postponed harvesting as storage mechanism has been creating problems in potato production for it could allow more accumulation of tuber-borne diseases than early harvesting (Endale et al., 2008a). In-ground storage of potato is also associated with large losses: in the Gojam and Gonder areas of the northwest losses of up to 50% have been reported caused by tuber moth and ants (Tesfaye et al., 2008).

ii. Other traditional storage methods

Farmers also store seed potatoes in bags stacked on the floor in untidy places in the house where there is no ventilation, heaped loosely or put on a bed-like structure. Forty seven per cent of the farmers in the district Degem and 46% of the farmers in district Jeldu in the central area of Ethiopia (this study; Table 2.1) and 73.6% in the eastern area of Ethiopia (Mulatu et al., 2005a) used bags to store their seed potatoes. About 45% of the potato farmers of Jeldu district in the central area of Ethiopia and 21% of the farmers of Banja district in the northwestern area of Ethiopia heap their seed potatoes loosely while 33% of the farmers of Banja district in the northwestern area of the country use a bed-like structure (Table 2.1). Mulatu et al. (2005a) also found that about 26.4% of the farmers in the eastern area of Ethiopia piled up their seed potatoes in an open place or in a corner of their house. However, there are also farmers who store their potatoes in a better place. In a study made in the central and northwestern areas of Ethiopia, about 18% of the farmers were found to use light spaces in the house to store their seed potatoes (Gildemacher et al., 2009b). In the southern area farmers store seed potatoes in their home or in a store constructed for this purpose. Seed and ware potatoes are stored side by side in the same store or home. In the Shashemene district of the southern area, farmers cover stored ware and seed tubers with teff straw to protect the tubers from sun light. They use a thicker cover for the seed than for the ware. The farmers increase the thickness of the seed tuber cover a few weeks before planting. The farmers believe that an increase in the thickness of the cover will help the seed tubers to break dormancy and thereby encourage sprouting.

iii. Diffused light storage

Diffused light storage (DLS) is a storage method using a low cost rustic structure to store seed tubers. It maintains seed tuber quality by allowing diffusion of light and free ventilation which suppress sprout elongation and thereby slow-down aging of the sprout. In an experiment carried out in Holetta to quantify the effects of storage methods, Lemaga et al.

(1994) found that seed tubers stored in multi-layered burlap sacks (similar to farmers' dark storage method) produced significantly taller sprouts and lost significantly more weight than those stored in DLS. This shows that DLS has a better potential to keep quality seed tubers than the traditional storage method. Even though the storage performance differs from variety to variety, seed potatoes can be stored in DLS up to 7 months without considerable depreciation of seed quality (Endale et al., 2008b). The DLS is usually used for the storage of seed potatoes of improved varieties whereas the other storage mechanisms are used for the storage of seed potatoes of local varieties. The reason for this might be that farmers are not aware of the importance of DLS for the storage of local varieties[3].

In the central and northwestern areas of Ethiopia only 5% of potato farmers were found to use DLS (Gildemacher et al., 2009b) but the use of DLS for seed tubers of improved varieties is becoming common in the central area of Ethiopia. About 87% of the farmers in the central area and 25% in the northwestern area were found to use DLS for storage of seed potatoes of improved varieties (Tesfaye et al., 2008). The use of DLS is slowly increasing in the northwest. In the eastern area of Ethiopia, the use of DLS is restricted to the cooperative community based seed enterprises established by the FAO seed security project (Mulatu et al., 2005a). For the southern area of the country there is no literature on the storage methods. The reason for not using DLS, for about 22% of the farmers in the central area of Ethiopia and about 71% of the farmers in the northwestern area of Ethiopia was lack of awareness. Seed tubers stored in DLS systems may become infected or infested with tuber moths, aphids, late blight or bacterial wilt; the use of insect screens can keep insects out, but not the pathogens.

Seed quality

In this section we discuss the following aspects of potato seed quality: purity, genetic quality, health, size, physical damage and physiological age. In Ethiopia, quality of seed tubers is a serious problem because of varietal mix-up, poor storage mechanisms, prevalence of diseases and pests and poor knowledge of seed selection.

[3] Potato tubers stored in DLS or any light space, cannot be used for consumption. Storage in light results in high levels of glycoalkaloids, which are harmful after intake (Struik and Wiersema 1999). However, 3% of the farmers in district Jeldu in the central area and 2% of farmers in district Banja in the northwestern area were found to store ware potatoes in DLS. Glycoalkaloids protect tubers to some extent against certain pests and diseases (Tarn et al. 2006).

i. Seed potato purity

In all potato growing areas of Ethiopia most farmers use seed potatoes of unknown origin. Farmers obtain their seed tubers usually from the local market if they do not set aside tubers from their own previous season production. Different varieties of potato are mixed during harvest or trade. Mulatu et al. (2005a) studied tuber characteristics of the improved potato variety Al-624 released in 1987. The study revealed that only 46 to 52% of the tubers found in farmers' plots resembled tubers of this variety retained by the breeding institution (Haramaya University). On potato field inspections made in several villages of the districts Alemaya and Kersa in the eastern area an average of 4 - 5 varieties was found to be grown as a mixture per plot (Mulatu et al., 2005a). It was observed on seed potato markets in the central and northwestern areas that traders mixed seed tubers purchased from different growers (Guenthner, 2006). In the southern area, the same practice was observed. For instance, in the district Shashemene, phenotypically different potato plants were observed in the same field which might have occurred due to genetic differences or differences in physiological age of the seed tubers. Planting of mixed seed tubers results in a produce with a within-lot variation in cooking and processing qualities. There are also problems in timing of the harvest because of differences in maturity between plants.

ii. Seed potato genetic quality

Potato variety improvement research has been undertaken in Ethiopia since 1975 with the objective of developing high-yielding, late-blight resistant and widely adaptable varieties. In the last two decades (from 1987–2006) about 18 improved varieties, which are adaptable to altitudes ranging from 1000–3200 meters and receiving 750–1500 mm rainfall with on farm yielding ability ranging from 19–38 Mg ha^{-1}, were released (Gebremedhin et al., 2008).

Genetic quality also includes food and processing quality. According to Endale et al. (2008b), improved potato varieties, namely Digemegn, Zengena, Jalele, Gorebella, Guassa, Menagesha, Tolcha and Wechecha, had an acceptable dry matter concentration and specific gravity for processing. No processing is currently done in the northwestern area.

iii. Seed potato health

Late blight [*Phytophthora infestans* (Mont.) de Bary] is common in all potato growing areas of Ethiopia. In many parts of the country it is the cause for the shift of potato production from the long rainy season (meher) to off-season production, despite the high potential yield in the long rainy season (Bekele and Eshetu 2008). According to Bekele and Eshetu (2008), local varieties do not cope with the disease pressure in the main rainy season and often are wiped out, particularly in the highlands. When seed tubers become infected by *Phytophthora infestans* they may rot during storage or will fail to produce emerging and surviving plants.

Viruses [e.g., *Potato leaf roll virus* (PLRV) and *Potato virus Y* (PVY)] and bacterial wilt (*Ralstonia solanacearum*) are causing potato plant and tuber degeneration in Ethiopia. The prevalence of these diseases is high in the low to medium altitudes (Bekele and Eshetu 2008). On a seed degeneration experiment undertaken in Holetta Agricultural Research Center from 1997 - 2000, percent yield reductions due to viruses (mainly PLRV and PVY) were recorded of 62, 45, 44 and 41 in the varieties Tolcha, Genet, AL-624 and Awash, respectively (Bekele and Eshetu, 2008). Because these pathogens attack the foliage, root system and tubers, they are important throughout the crop cycle. Potato tuber moth, PTM (*Phthorimaea operculella*) is affecting seed potatoes in the field and stored in DLS (Bayeh et al., 2008).

Farmers can produce relatively healthy seed potatoes by planting on appropriate planting dates, by applying positive selection, by allotting separate, better-quality, isolated plots to seed production and by timely haulm destruction. There are efforts underway to produce healthy seed potatoes by farmers in some parts of Ethiopia even though they are limited. In the central area of Ethiopia farmers commonly destroy the haulm of the part of their potato field reserved for seed. Thirty nine to fifty four per cent of the farmers in the central area of Ethiopia had adopted the recommended haulm destruction date. According to Endale et al. (2008a) and Gebremedhin et al. (2008), disease and insect pressures in the highlands, especially late-blight pressure, was considerably reduced because of the use of disease-resistant varieties. Farmers also renew their seed stock. According to Gildemacher et al. (2009a, b), 44% of farmers in the central and northwestern areas of Ethiopia renew seed on average every three seasons, but only 15% of their seed stock each time. The improvement in the practices to produce better quality seed potato in the central area of Ethiopia is achieved because of the concerted efforts of the Ethiopia Institute of Agricultural Research (EIAR). Holetta Agricultural Research Centre of the EIAR has been assisting farmers in the central area of Ethiopia in providing seed and training through its farmers’ research group (FRG) and farmers’ field school (FFS).

Because of the use of home saved seed, use of seed potatoes of unknown origin from local markets, limited use of resistant varieties, poor storage practices like leaving potato underground un-harvested and only limited adoption of haulm killing and selection practices by farmers, the seed tubers used by most potato producers cannot be healthy. However, according to Endale et al. (2008a) and Gebremedhin et al. (2008), in the highland areas, disease and insect pressures, especially late-blight pressure, were considerably reduced because of the use of disease-resistant varieties.

iv. Seed potato size

Among the Ethiopian smallholder farmers in all areas, it is common practice to save tubers for seed that are too small and inferior to be sold for consumption (Mulatu et al., 2005a; Endale et al., 2008a; Gildemacher et al., 2007). Small-sized tubers may have two problems. The first one is delayed emergence and low sprout vigour and number because of low food reserve (Lommen, 1994; Lommen and Struik, 1994). The second is that they might be a progeny of an infected mother plant and thus infected by diseases, because infected mother plants usually give small tubers (Struik and Wiersema, 1999). In Ethiopia, the use of small potato tubers as seed might have contributed to the building up of high level of disease especially in the locally grown varieties.

However, there are areas where many farmers use medium-sized tubers for seed. For instance, 72% of farmers in district Degem and 66% of farmers in district Jeldu in central area and 63% of the farmers in district Banja in northwestern area, selected medium-sized tubers from the whole produce immediately after harvest, to save for seed (Table 2.1). Also Gildemacher et al. (2009b) found that 40% of the potato farmers in the northwestern area of Ethiopia selected medium sized tubers for seed.

v. Seed potato physical damage

Physical damage includes cuts, bruises and holes, inflicted on tubers during harvesting, storage, packaging and transportation. In a study undertaken on seed potato tubers stored on-farm by using a traditional storage method, in two districts of the eastern area, Kersa and Alemaya, 8% of the tubers were found to be damaged during harvest (Mulatu et al., 2005a). There is no information on physical damage of seed potatoes for the remaining three major potato growing areas.

In Ethiopia potato tubers are harvested, stored, packaged and transported with little care to prevent physical damage to the tuber, most likely because of the low level of knowledge about the consequence of physical damage by all parties involved. The tools used by farmers to dig out tubers from the soil might not be appropriate (too sharp or elongated ending). Physical damage in seed tubers may also occur during storage because of piling of one sack upon the other and lack of ventilation. Potatoes are usually packed in sacks which cannot protect tubers from any external pressure causing bruising and stabbing. Potato sacks are usually transported by pack animals and are tied by ropes on their back, which may cause bruising to tubers. Distant transportation takes place by lorries. In this case loading and unloading is done by throwing up and down the tuber sacks. The tubers may be loaded with other sharp or beneath heavy materials which might cause damage to the tubers.

vi. Seed potato physiological age

Effects of physiological age[4] on yield are of paramount importance for a country like Ethiopia where there is more than one potato production cycle per year, very poor seed tuber handling and poor storage conditions (Struik and Wiersema, 1999; Endale et al., 2008b). Multiple-season production has two physiology related problems, a short time gap (limited time for a seed tuber to break dormancy) between adjacent seasons and a long time gap (resulting in physiologically old seed with reduced vigor) between un-adjacent seasons. According to Endale et al. (2008a) farmers in the district Shashemene, West Arsi zone, in the southern area, abandoned production of the improved variety Genet despite its good yielding ability compared to other varieties, because of the short dormancy period (less than 52 days) whereas the period between the off-season (January to March) and the meher season (June to September) is about 2 months and the period between two successive seasons of the same type is 8 months.

In the southern area, farmers use seed tubers saved on farm and/or imported from other, distant places. We observed that the same farmer planted seed tubers from different origins on different plots in the same growing season. There is a difference in the physiological age of the seed tubers saved on farm and those imported. Field observations in Shashemene district in October 2009 indicated that the seed tubers imported from a low temperature area were

[4] Physiological age is the stage of development of a tuber, which is modified progressively by increasing chronological age, depending on growth history and storage conditions (Struik and Wiersema 1999). Chronological age is tuber age from the time of tuber initiation, expressed in days, weeks or months.

large in size, sprouted well and gave more stems per seed tuber planted than the local farm-saved seed tubers, which had been stored in this high temperature area. Farmers do not practice de-sprouting before planting. However de-sprouting might increase the number of stems per seed tuber planted. In the current plant stands, the low number of stems per plant contributes to a suboptimal development of the foliage, resulting in incomplete capture of the available incoming radiation. Therefore, increasing the number of stems per seed tuber planted by a de-sprouting treatment might be beneficial for final tuber yield.

Seed potatoes produced in high-altitude areas often have a good physiological condition. However, such seed tubers may contain latent bacterial wilt or late blight.

Seed availability and distribution

There are several sources of seed potato in Ethiopia: own savings, local open markets, village markets, breeding centres, NGOs, vegetable traders, district agricultural bureaus, specialized seed potato growers, relatives and friends. Seed tubers from most of these sources were originally not specifically designated for seed, but were simply produced as potato tubers that can be used as ware and seed. However, there are efforts underway to produce seed tubers by specialized seed growers and a private limited company. There are also about 18 improved potato varieties grown in Ethiopia. However, according to Gebremedhin et al. (2008) and Mulatu et al. (2005a), not all the 18 varieties have been widely distributed and grown by farmers due to the very limited capacity of the alternative seed supply system in the country.

Nevertheless there is difference in the proportion of tubers of improved and local varieties that are used as seed. For instance, our survey indicated that in the central and northwestern areas of Ethiopia, out of the total amount of tubers of improved varieties produced, 46% was used as seed, 49% was used for consumption and 5% was used as gift (Table 2.1). Without distinguishing between improved and local varieties, 24% and 75% of the total produce of tubers were used as seed and ware, respectively (Gildemacher et al., 2009b).

Seed tubers produced in the central area are sold to farmers in the vicinity as well as to those hundreds of kilometers away. The distribution to distant areas is usually undertaken by traders, agricultural bureaus or NGOs. The main destinations of the seed tubers produced in the central area are the central area itself and the western and southwestern areas. For instance seed tubers produced in the district Jeldu were used by many farmers within the district, neighbouring districts and far distant areas like Nekemte (E. Wellega), Dembidolo (W.

Wellega), Metu (Illubabor), and Gimbi (W. Wellega) (Endale et al., 2008a). The seed tubers produced in the cool central areas are most likely at a suitable physiological age and thus give better yield than seed tubers available in the other, warmer areas.

In the eastern area of Ethiopia, own savings and local markets are the two major sources (Mulatu et al., 2005a; Emana and Hadera, 2007). Seed potato transactions are usually undertaken by cash because of the bulkiness of tubers and the high amount of seed needed for a field prevents farmer-to-farmer seed exchange and gifts like in other crops (Mulatu et al., 2005a).

In the southern area of Ethiopia, seed tubers flow from place to place depending on season. Seed tubers can be transported from and to highland, mid altitude and irrigated areas. Some authors claim that there is a large volume of seed tubers flowing from irrigated areas to places where potato is produced under rain-fed conditions. For instance, Endale et al. (2008a) revealed that most of the farmers in the Shashemene area use seed tubers produced under irrigation in Wondogenet and Shemena areas. Seed potatoes produced in the southern area are also distributed to the western and southwestern areas of Ethiopia even though it might not be significant. In the Shashemene market seed tubers are sold mainly by men while ware is mainly sold by women. Seed tubers availed to Shashemene market were offered to be sold as seed and ware. The seed potato flows in northwestern and eastern Ethiopia are not documented.

Information flow

Farmers can obtain information on name, source, yielding ability, marketability and food quality of varieties and production practices from various sources, such as, family members, neighbouring farmers, extension agents, NGO employees, researchers, and potato traders. Gildemacher et al. (2009a) found that about 58.7% of the farmers in North Shewa and West Shewa zones of the central area and East Hararghe zone of the eastern area of Ethiopia obtain information on the aforementioned characteristics of varieties from farmers in their own community. Tesfaye et al. (2008) found that the majority of the farmers (62%) in the central area of Ethiopia obtained information on improved potato technologies from Holetta Research Centre, whereas 33% obtained it from fellow farmers and only 4% from the office of agriculture. Own community and research centres like Holetta Agricultural Research Centre are the major sources of information for seed potato technologies.

In Ethiopia, seed tubers are sold either packed in sacks without any label or loose in open markets. There is no way by which information about variety and quality is transferred from seller to buyer except trust. There is need for a system that differentiates high quality seed tubers from low quality tubers, given the importance of high-quality seed tubers, the mixing of different varieties and the sanitary condition of the tubers. Guenthner (2006) suggested a three colors tag system to show high, medium and low quality seed tubers. Colors were used as identification for illiterate farmers and criteria for different qualities were suggested.

2.5. Expert elicitation on improvement options

Improvement of seed potato systems

The mean weights given by experts to different seed system components regarding their importance in order to improve each of the existing potato seed systems in Ethiopia are given in Table 2.2. For all existing seed potato systems (informal, alternative, formal cooperative and formal PLC) experts deemed improvement of seed quality to be important. The importance in the improvement of seed availability and distribution was perceived to be higher in the alternative, formal cooperative and formal PLC seed systems than in the informal seed system. In the informal seed system the improvement of production and storage method was believed to be more important than in the remaining three seed systems.

Table 2.2. Weight (%) given by experts to different seed system components regarding their importance to be improved in each of four seed potato systems in Ethiopia.

Seed system component	Seed system			
	Informal (n =12)	Alternative (n = 12)	Formal cooperative (n = 11)	Formal PLC (n = 8)
Production methods	**16** ± **7.3**	10 ± 7.1	12 ± 7.5	8 ± 6.8
Storage methods	**14** ± **7.4**	10 ± 5.5	11 ± 7.1	8 ± 7.3
Seed quality	**23** ± **13.0**	**23** ± **16.0**	**21** ± **9.7**	**25** ± **12.0**
Seed availability and distribution	12 ± 7.7	**16** ± **13.2**	**21** ± **17.5**	**28** ± **17.6**
Information flow	13 ± 10.8	14 ± 12.3	**14** ± **9.2**	**14** ± **10.9**
Spread of new varieties	11± 6.1	12 ± 8.8	12 ± 5.7	9 ± 7.4
Cost-benefit ratio	11 ± 8.0	**15** ± **10.7**	9 ± 7.7	8 ± 9.3
Total	100	100	100	100

Note: figures in bold are components that received the three highest ranks within a seed system.

Improvement in seed tuber quality

The mean scores of experts' opinion on the importance of improvement of seed quality are given in Table 2.3. Experts believed that improvement in seed health, physiological age and genetic quality were more important than the improvement in purity, size and physical damage of seed tubers for all seed systems. The importance of improvement of seed health was perceived to be of top priority in all seed systems. With regard to the need for improvement in physiological age, experts gave relatively more weight in the less advanced seed systems (informal, formal cooperative and alternative) compared to the advanced formal seed system (formal PLC). Experts gave higher scores for the importance of improvement in seed genetic quality for alternative, formal-cooperative and formal-PLC seed systems than for the informal seed system. The reason might be that the alternative and formal seed systems are expected to multiply and disseminate seed tubers of new varieties.

Table 2.3. Weight (%) given by experts to seed quality characteristics regarding their importance to be improved in each of four seed potato systems in Ethiopia.

Seed quality	Seed system			
	Informal (n = 11)	Alternative (n = 10)	Formal cooperative (n = 10)	Formal PLC (n = 7)
Purity	12 ± 4.9	12 ± 5.5	11 ± 6.0	10 ± 4.9
Genetic quality	**14** ± **10.2**	**18** ± **10.9**	**18** ± **8.9**	**21** ± **8.8**
Seed health	**33** ± **11.7**	**36** ± **12.1**	**35** ± **17.4**	**35** ± **20.2**
Seed size	10 ± 5.4	9 ± 6.8	9 ± 8.9	10 ± 9.4
Physical damage	11 ± 6.6	7 ± 5.9	9 ± 6.2	9 ± 6.6
Physiological age	**20** ± **8.6**	**18** ± **10.3**	**19** ± **8.6**	**15** ± **6.9**
Total	100	100	100	100

Note: figures in bold are quality characteristics that received the three highest ranks within a seed system.

Roadmap towards improvement

The opinion of seed experts on the steps to be taken to improve the seed systems in Ethiopia is given in Table 2.4. For improving the informal seed system, the top 3 steps mentioned were improving the awareness and skill of farmers, improving quality of the seed tubers used by the farmers, and improving farmers' market access.

To improve the alternative seed potato system, experts suggested availing starter seed tubers of new varieties to farmers in the alternative seed system as the most important first step to be taken. Improving seed quality, designing sustainable seed quality control methods and reducing cost of seed production were listed with equal importance after availing of starter seed tubers of new varieties. Experts suggested the development of a seed quality control system that can be managed by the farmers themselves. There was also a suggestion on putting a realistic disease tolerance limit beyond which seed tubers can no longer be used as seed. In order to implement this suggestion, a uniform method for disease assessment needs to be established.

Table 2.4. Opinion of seed experts on the main three steps to be taken to improve each of the four seed potato systems in Ethiopia.

Steps	Seed potato system			
	Informal (n = 11)	Alternative (n = 10)	Formal cooperative (n = 9)	Formal PLC (n = 6)
Improving awareness or skill of farmers	**6**	1	**3**	**3**
Improving seed quality	**6**	**4**	1	1
Improving market access	**6**	2	**3**	**2**
Availing new varieties to farmers	4	**8**	**4**	**5**
Designing sustainable seed quality control methods	x	**4**	**5**	**2**
Expanding seed production	3	x	**3**	1
Using improved storage methods	5	x	1	1
Reducing cost of seed production	x	**4**	**3**	**2**
Improving production methods	3	1	x	x
Linking actors in the potato chain	x	3	2	1
Improving technology and information transfer	x	3	2	x

Note: figures are the number of times an item appeared in the list; x represents the items not marked as one of the three steps to be taken to improve seed systems; figures in bold are the improvement steps that received the three highest ranks within a seed system.

Experts suggested designing sustainable seed quality control methods and providing new varieties as starter seed to cooperative members as the top-2 steps to be taken to improve the formal cooperative seed potato system. Improving awareness and skill of the cooperative members on seed production technologies, improving market access, expanding seed tuber production, and reducing costs were mentioned as the third step to be taken to improve the formal cooperative seed potato system. The experts suggested the seed quality control method should be designed in a way it can be implemented by cooperative members. For improvement of the PLC-based seed system, providing seed of new varieties, and improving awareness and skills of farmers were mentioned as the main two measures to be taken; improving market access, designing control methods and reducing cost were mentioned as the third important steps. Some of the experts suggested the use of pro-poor varieties by PLC, i.e. varieties with the potential to become adopted by poor subsistence farmers. The PLC may create awareness by setting demonstration sites for the farmers.

Is it possible to have one overall seed system?

Experts perceived it to be unlikely to have one seed potato system in Ethiopia that satisfies the interests of all potato producers. They generally agreed that improvements are needed in all systems. This is in line with ideas from Maredia and Howard (1998) who stated that a well-functioning seed system is one that uses the appropriate combination of informal, formal, market and non-market channels to efficiently meet the demand for quality seeds. The experts suggested looking for ways in which the existing seed systems can support each other and supply quality seed tubers. The experts also emphasized the need for transforming alternative seed systems from the prevailing situation of unbranded seed production, to a self-regulating and self-certifying seed production.

2.6. Conclusions

In this study we describe the state of affairs of seed potato systems in Ethiopia and we attempt to elicit the main areas of improvement and the main steps to be taken in the roadmap towards these improvements. With regard to the current status of seed potato systems we conclude that in general all three seed potato systems operating in Ethiopia, i.e. the informal, alternative and formal system, have problems in undertaking their functions as a seed system. More specifically we conclude:

- Seed tubers supplied by the *informal* seed potato system (supplies 98.7% of seed tubers used in the country) are deemed to be poor in health, unsuitable in physiological age, poor in genetic quality, impure (varietal mix-up), physically damaged and inappropriate in size. Besides, in the informal seed potato system, seed tubers are produced usually as part of ware and stored under poor conditions. In this seed system farmers usually use varieties of unknown origin and improved varieties are not available to the majority of the farmers. Lack of awareness about the availability and use of improved technology and practices has also impeded adoption of potato technologies.
- The *alternative* potato system, which co-exists with the informal seed system in the central and eastern areas, supplies better quality seed tubers than the informal seed potato system. However, the amount of seed tubers supplied by the alternative seed potato system is very small (1.3%) and thus the system still has limited impact on improvement of potato production in Ethiopia.
- The *formal* seed system co-exists with the informal and alternative seed potato systems but only in the central area. It is at the incipient stage and its contribution to the overall seed system is negligible.

The most important problems of the seed systems in Ethiopia seem to be the insufficient seed tuber quality and the unavailability of seed tubers of improved varieties. This is supported by experts' suggestions for improvements in the existing seed systems.

- To improve the informal seed potato system experts listed increasing awareness and skills of farmers, improving seed tuber quality, and improving market access as top-3 steps.
- To improve alternative and formal seed systems experts listed availing new varieties, designing quality control methods and reducing cost of seed production as top-3 steps.
- To improve the overall seed potato supply in the country, experts postulated the co-existence and a good linkage of the three seed systems, and development of self-regulatory and self-certification in the informal, alternative and formal cooperative seed potato systems.

As a continuation of this study several studies are underway. These include analysis of options to improve the seed tuber quality and designing of an improved seed potato supply chain.

References

Almekinders, C. J. M., Louwaars, N. P., 1999. Farmers' seed production: New approaches and practices. 291 p. London: Intermediate Technology Publications.

Bayeh, M., Refera, A., Wubshet, B., Asayehegn, B., 2008. Potato pest management. In *Root and tuber crops: The untapped resources*, eds Gebremedhin, W., Endale G., Lemaga, B. 97–112. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Bekele, K., Eshetu, B., 2008. Potato disease management. In *Root and tuber crops: The untapped resources*, eds Gebremedhin, W., Endale, G., Lemaga, B. 79–96. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Bekele, K., Woldegiogis, G., Kelemework, F., Mela, A., Olanya, .O.M., Ewell, P.T., El-Bedewy. R., 2002. Integrated potato late blight management: Experience of farmer field school in Dendi district. In *Towards Farmers' Participatory Research: Attempt and achievements in the central highlands of Ethiopia*. Proceedings of client oriented evaluation workshop, 16–18 October 2001, Holetta, Ethiopia, eds Kenei, G., Gojjam, Y., Bedane, K., Yirga, Chilot., Dibabe. A., 56–67. Holetta, Ethiopia: Holetta Agricultural Research Centre.

CSA (Central Statistical Agency of Ethiopia), 2009. Agricultural sample survey: Report on area and production of crops, Addis Abeba, Ethiopia, 126 p.

Emana, B., Hadera, G., 2007. Constraints and opportunities of horticulture production and marketing in Eastern Ethiopia. Dry land coordination group (DCG) report no. 46. Ås, Norway.

Endale, G., Gebremedhin, W., Lemaga, B., 2008a. Potato seed management. In *Root and tuber crops: The untapped resources*, eds Gebremedhin, W., Endale, G., Lemaga, B. 53–78. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Endale, G., Gebremedhin, W., Bekele, K., Lemaga, B., 2008b. Post harvest management. In *Root and tuber crops: The untapped resources*, eds W. Gebremedhin, G. Endale, Lemaga, B. 113–130. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

EVD (Agency of Ministry of Economic Affairs), 2009. Introduction of a seed potato production system in Ethiopia. Project number 174384. Information available at www.evd.nl. Date of accession: 13/9/2009.

FAO. 2008. Potato World: Africa – International Year of the Potato 2008. http://www.potato2008.org/en/world/africa.html. Date of accession: 1/1/2009.

Gebremedhin W.,Endale, G. and Lemaga, B. 2008. Potato variety development. In *Root and tuber crops: The untapped resources*, eds Gebremedhin, W., Endale G., Lemaga, B. 15–32. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Getachew, T., Mela, A., 2000. The role of SHDI in potato seed production in Ethiopia: Experience from Alemaya integrated rural development project. *African Potato Association Conference Proceedings* 5:109-112.

Gildemacher, P., Demo, P., Kinyae, P.Nyongesa, M., Mundia, P., 2007. Selecting the best plants to improve seed potato. *LEISA Magazine* 23(2):10–11.

Gildemacher, P., Kaguongo, W., Ortiz, O., Tesfaye, A., Gebremedhin, W., Wagoire, W. W., Kakuhenzire, R., Kinyae, P., Nyongesa, M., Struik, P.C., Leewis, C., 2009a. Improving potato production in Kenya, Uganda and Ethiopia. *Potato Research* 52:173–205.

Gildemacher, P., Demo, P., Barker, I., Kaguongo, W., Gebremedhin, W., Wagoire W.W., Wakahiu, M., Leeuwis, C., Struik P.C., 2009b. A description of seed potato systems in Kenya, Uganda and Ethiopia. *American Journal of Potato Research* 86:373–382.

Guenthner, J.F., 2006. Development of on-farm potato seed tuber production and marketing scheme. Agricultural economics extension series no. 06-01, July 2006. University of Idaho, Moscow.

Lemaga, B., Hailemariam, G., Gebremedhin, W. 1994. Prospects of seed potato production in Ethiopia. In Proceedings of the Second National Horticultural Workshop of Ethiopia, eds E. Hareth and D. Lemma, 254–275. Addis Ababa, Ethiopia: Institute of Agricultural Research and FAO.

Lommen, W.J.M., 1994. Effect of weight of potato minitubers on sprout growth, emergence and plant characteristics at emergence. *Potato Research* 27:315–322.

Lommen, W.J.M., Struik, P.C., 1994. Field performance of potato minitubers with different fresh weights and conventional tubers: Crop establishment and yield formation. *Potato Research* 37:301–313.

Louwaars, N., 2007. Seeds of confusion: The impact of policies on seed systems. PhD dissertation, Centre for Genetic Resources, WUR**,** The Netherlands.

Maredia M., Howard, J., 1998. Facilitating seed sector transformation in Africa: key findings from the literature. Policy synthesis for USAID – Bureau for Africa, FS II Policy synthesis No. 33.

Mulatu, E., Osman E. I., Etenesh, B., 2005a. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. *Journal of New Seeds* 7(3):31–56.

Mulatu, E., Osman, E. I., Etensh, B., 2005b. Policy challenges to improve vegetable production and seed supply in Hararghe, Eastern Ethiopia. *Journal of Vegetable Science* 11(2):81–106.

Sthapit B., Ram., R., Pashupati, C., Bimal, B., Pratap, S., 2008. Informal seed systems and on-farm conservation of local varieties. In *Farmers, seeds and varieties: supporting informal seed supply in Ethiopia*, eds Thijssen, M.H., Bishaw, Z., Beshir A., de Boef, W.S., 133–137. Wageningen: Wageningen International.

Struik, P.C., Wiersema, S.G., 1999. Seed potato technology. Wageningen: Wageningen University Press, 383 p.

Tarn, T.R., Tai, G.C.C., Liu, Q., 2006. Chapter 5: Quality improvement. In *Handbook of potato production, improvement, and postharvest management*, eds Gopal J., Paul Khurama, S.M., 147–178. Binghamton, New York: Food Products Press.

Tesfaye, A. Bedane, K., Yirga, C., Gebremedhin, W., 2008. Socioeconomics and technology transfer. In *Root and tuber crops: The untapped resources*, eds Gebremedhin, W., Endale G., Lemaga, B., 131–152. Addis Ababa, Ethiopia: Ethiopian Institute of Agricultural Research.

Weltzien, E., vom Brocke, K., 2001. Seed systems and their potential for innovation: Conceptual framework for analysis. In *Targeted seed aid and seed system interventions: Strengthening small farmer seed systems in East and Central Africa*. Proceedings of a workshop held in Kampala, Uganda, 21–24 June 2000, ed. Sperling, L., 9–13. Kampala.

World Bank, FAO, IFAD., 2009. Gender in seed production and distribution. Gender in Agriculture Sourcebook. World Bank: Washington, DC, 764 p.

Chapter 3

Farmers' opinion on seed potato management attributes in Ethiopia: A conjoint analysis

Adane Hirpa[1,2,5], Miranda P.M. Meuwissen[1], Ivo A. Van der Lans[3], Willemien J.M. Lommen[2], Alfons G.J.M. Oude Lansink[1], Admasu Tsegaye[4] and Paul C. Struik[2]

[1]Business Economics, Wageningen University, The Netherlands
[2]Centre for Crop Systems Analysis, Wageningen University,
[3]Hawassa University College of Agriculture, Hawassa, Ethiopia
[4]Holetta Agricultural Research Centre, Holetta, Ethiopia

Published in: Agronomy Journal (2012) 104:1413–1424.

Abstract

A low adoption of recommended seed potato technologies in Ethiopia could be due to a lack of alternative seed potato production methods compatible with farmers' economic and agro-ecological conditions. A conjoint analysis (a technique used to measure relative contribution of product attributes) was conducted to elicit farmers' opinions on management attributes that they believed to affect yield and quality of potato. The study involved interviewing 324 farmers who grew seed potato in Jeldu and Welmera districts. The results showed that management attributes, such as storage method, hoeing combined with hill size, fertilizer rate (FR) and fungicide application (FA) frequency had larger effect on seed yield and quality than seed source, seed size, sprouting method, tillage frequency, and planting date. In both districts, using diffused light storage (DLS); hoeing twice, combined with big hills; and using recommended FR, combined with two FAs had significant positive effects on yield and quality of seed potato. In both districts, if all farmers switched to the best management attribute levels, potential increases in seed yield would be about two times the actual seed yield produced in 2010. The results suggest that it is possible to design better methods to produce seed potato compared with methods that farmers currently use. Extension personnel could use these results to recommend to farmers those management attributes that are the most important to improve yield and quality of seed potato in Ethiopia.

Abbreviations: DLS, diffused light storage; ETB, Ethiopian Birr; FA, fungicide application; FR, fertilizer rate.

3.1. Introduction

In Ethiopia, several research efforts have been made to develop new potato (*Solanum tuberosum*) technologies since the inception of potato research in 1975. Potato production technologies include improved potato varieties and new pre- and post-harvest management practices. Potato technology development aims to attain high-yielding, disease tolerant varieties and improved agronomic and postharvest management practices (Gebremedhin et al., 2008). As a result, a number of improved varieties with improved management practices have been developed and released to farmers. However, the majority of smallholder farmers are still producing their own potato varieties with relatively poor quality (Mulatu et al., 2005; Gildemacher et al., 2009a; Hirpa et al., 2010; International Potato Center, 2011).

Currently in Ethiopia, new potato varieties are released with one standard recommendation for production, although there are several alternative options. The recommended production method can produce high yields but it is adopted only by a few farmers due to its incompatibility with the diverse local environmental conditions that vary in agro-ecology, soil type, managerial capability, objectives of potato production, and availability and access to inputs and product markets. These different local environmental conditions require different production methods to achieve the 'optimum' yield and quality of a product in a given situation (Mamo et al., 2003; Reece and Sumberg, 2003; Scharf et al., 2005; Jack, 2011; Yu et al., 2011; Gao et al., 2012). To increase a number of adopters of the released potato varieties, it is important to identify alternative seed potato production methods that suit the local conditions of farmers. To develop production methods that are likely to be adopted by farmers, it is also essential to study the importance of seed potato management attributes with respect to seed yield and quality from a farmers' point of view.

The objective of this study was, therefore, to elicit farmers' opinions on the importance of seed potato management attributes with respect to their perceived effects on potato seed yield and quality and to quantify these effects. This knowledge could be used to develop alternative seed potato production methods more specific to local farm characteristics.

3.2. Methodology

The study entailed two main steps. First, a so-called Delphi study was conducted to identify and prioritize, among experts and farmers, seed potato management attributes (e.g., sprouting method, fertilizer rates) affecting yield and seed quality. Then, a two-part survey was carried out 1) by conducting face-to-face interviews among farmers to collect specific demographic and management data , and 2) by using a so-called conjoint task to elicit farmers' opinions on effects of selected management attributes on seed yield and quality.

Study Area

The study was carried out in Jeldu and Welmera districts because farmers in these districts produce the majority of seed potato of improved varieties in Ethiopia. Jeldu is located approximately 130 km west of Addis Ababa. About 45% of the district's area is highland at 2300 to 3200 m asl with an annual average rainfall from 900 to 1350 mm. Main crops are (in order of importance) barley, wheat, and potato. Welmera is located about 40 km west of Addis Ababa. This district, 40% of which is highland (2300 – 3380 m asl), receives an average annual rainfall ranging from 900 to 1100 mm. Main crops in the district include wheat, barley, and potato. The major soil type in both districts is Nitisol (FAO soil classification). According to Agegnehu and Fessehaie (2006), Nitisol in Welmera comprised of 56.1% clay, 28.6% silt, and 15.4% sand. The soil was acidic (pH = 4.7) and had organic carbon content of 1.7%.

The Delphi Study

A Delphi study was used to identify and prioritize the most relevant seed potato management attributes, among a wide range of possibilities, with respect to their importance to seed potato yield and quality. The Delphi technique is a survey method that looks for the most reliable consensus among a group of experts by means of questionnaires in different rounds (Linstone and Turoff, 1975). In the first round, the experts are asked to give their opinion on a number of issues. In subsequent rounds, the experts are asked the extent to which they agree with, and to comment upon the opinions from the whole group of experts, as collected in previous round(s) and put together and moderated by the researcher. It is regarded as more structured than conventional group interviews (Gordon, 1994). A modified Delphi approach was used, which avoids open-ended questions and uses a list of prepared possibilities instead (Dalkey and Helmer, 1963). During interviews, amendments to the list could be made.

The Delphi study was undertaken in September 2010 with five experts (three agronomist-breeders and two agricultural extension specialists from Holetta Agricultural Research Center, located in Welmera) and 20 farmers to identify and prioritize seed potato management attributes. Experts were selected based on their experience (> 10 yrs) in potato research and on-farm demonstrations. Ten farmers were selected from each of the two districts based on their experience (8 -10 yrs) in seed potato production. The number of experts in the Delphi study depended on the availability of experts with appropriate expertise during the study period. A literature study by Rowe and Wright (1999) shows that the number of experts may range from 3 to 98.

The Delphi survey was undertaken in two evaluation rounds. Two rounds were considered sufficient in this study as was also done by Snyder-Halpern et al. (2000). In the first round, experts and farmers were provided with a list of seed potato management attributes individually (Tables 3.1 and 3.2), and were asked to make any amendment to the initial list if needed, and then to rate the management attributes with respect to their perceived importance for yield and quality separately by dividing 100 points among the management attributes, and then to give an explanation for the scores given. The initial list of seed potato management attributes was based on literature review and the authors' experience. From the 20 farmers involved in the first round, only 12 could make the rating (four from Jeldu and eight from Welmera); the remaining eight farmers were illiterate and not able to divide 100 points among the management attributes. In Jeldu, farmers added grading and type of seed potato transport to the list of management attributes and removed negative selection and haulm destruction from the list. In Welmera, farmers added grading to the list for quality evaluation. The experts removed rotation and variety from the list for quality evaluation but did not make any amendment to the list for the yield evaluation. Results of the first round are presented in Table 3.1 (farmers) and Table 3.2 (Round 1, experts). There were some differences between the farmers in the two districts on their perceived importance of the management attributes for seed yield and quality. In Jeldu, the top three were seed source, fertilizer rate (FR) and tillage frequency for yield and seed source, storage method and rotation length for quality. In this paper tillage refers to ploughing the soil. In Welmera, the top three attributes were fungicide application (FA) frequency, FR and tillage frequency for yield and tillage frequency, FA frequency and seed source for quality.

In the second round of the Delphi study, only four experts were involved because the fifth was not available. In this round, experts were provided with the relative importance of the first round, accompanied by the anonymous farmers' and experts' comments about each attribute evaluated. The experts were asked to make amendments to the list if any and reconsider their own evaluations in the first round based on feedback given by others. In the second round, experts removed harvesting from the list of management attributes for yield evaluation and included grading for quality evaluation. The results of the second round are shown in Table 3.2 Round 2. The experts gave the four highest scores to FR, FA frequency, seed source, and storage method for seed yield and to FR, harvesting tools, seed source, storage method, and FA frequency for seed quality, with latter three received equal scores.

Table 3.1**.** Mean relative importance of management attributes for yield and quality of seed potato based on the opinion of farmers. Attributes with the largest effects or weights are in bold.

Attribute	Yield				Quality			
	Jeldu (n=4)		Welmera (n=8)		Jeldu (n=4)		Welmera (n=8)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	%							
Seed source	**25.0**	10.0	7.6	2.9	**22.0**	8.0	**7.5**	1.8
Seed size	5.5	1.7	5.0	1.9	4.3	3.0	5.1	2.7
Storage method	4.0	1.4	7.8	2.5	**8.7**	4.5	6.6	1.8
Sprouting method	5.0	3.8	6.0	1.9	2.7	1.7	5.8	1.0
Tillage frequency	**6.5**	1.7	**8.0**	3.7	4.7	1.7	**8.1**	3.4
Spacing	4.7	2.1	6.6	1.7	4.0	1.8	5.9	2.7
Seed rate	3.7	1.5	4.9	1.5	5.1	1.3	5.4	2.3
Planting date	4.3	1.0	6.5	1.5	4.0	0.8	6.4	1.6
Hoeing frequency	4.5	1.7	7.4	1.6	5.0	1.4	6.3	2.0
Hilling	3.3	1.5	7.1	1.4	5.8	2.5	6.8	2.1
FR†	**7.5**	2.4	**8.0**	1.5	5.8	2.5	6.6	3.1
FA‡ frequency	5.0	0	**8.0**	2.2	4.5	2.4	7.5	1.3
Negative selection	na	-	6.4	1.6	na	-	6.7	1.6
Harvesting tools	3.0	1.4	0.9	2.1	5.0	3.6	4.7	2.3
Rotation	4.5	1.0	6.2	0.9	**6.5**	3.1	4.9	2.1
Variety	**6.5**	4.0	2.6	1.8	3.7	2.1	3.1	1.2
Haulm destruction	na§	-	1.0	2.5	na	-	1.6	1.2
Grading	3.0	1.4	na	-	4.5	1.3	1.0	2.8
Type of transportation	2.0	1.4	na	-	3.7	2.5	na	-
Total	100	-	100	-	100	-	100	-

† FR, Fertilizer rate.
‡ FA, fungicide application.
§ na, not applicable, excluded from the list by the evaluators because it was not practiced or not important.

Survey on Demographic and Farm Characteristics and Farmers' Opinions about Seed Potato Management Attributes

After the Delphi study, a survey was carried out in Jeldu and Welmera from May to July 2011 in which 324 farmers (owners of a seed potato farm) were interviewed face-to-face using a pre-tested, structured questionnaire containing two parts. The interviews were done by one person. The first part of the questionnaire contained general questions on demographic characteristics and agricultural activities undertaken by the respondent with special emphasis on seed potato production and marketing activities. At the end of the first part, a respondent was asked to provide the maximum anticipated seed potato yield that could be produced in a normal year (normal weather conditions) if all necessary inputs and management practices were available.

Table 3.2. Mean relative importance of management attributes for yield and quality of seed potato based on the opinion of experts. Attributes with the largest effects are in bold.

Attribute	Yield				Quality			
	Round 1 (n=5)		Round 2 (n=4)		Round 1 (n=5)		Round 2 (n=4)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	%							
Seed source	**7.9**	2.4	**8.3**	1.2	6.6	3.8	**6.8**	0.5
Seed size	6.4	2.0	6.4	1.0	5.8	1.8	5.8	0.9
Storage method	7.5	2.9	**6.8**	2.9	**7.2**	1.9	**6.8**	1.3
Sprouting method	7.2	2.3	6.5	1.7	6.7	2.6	5.9	2.2
Tillage frequency	6.0	1.5	6.6	0.4	5.2	1.3	5.5	1.0
Spacing	6.5	1.2	6.1	0.9	5.9	0.7	5.9	0.3
Seed rate	6.1	1.9	5.5	1.7	5.3	2.7	4.4	2.3
Planting date	5.2	0.8	5.4	1.1	5.4	0.9	5.2	0.5
Hoeing frequency	5.6	2.2	5.6	1.4	4.4	0.9	4.2	1.0
Hill size	6.9	1.6	**6.8**	0.9	5.4	0.9	5.7	0.5
FR†	**11.0**	4.0	**9.0**	4.0	**9.0**	3.8	**7.0**	3.4
FA‡ frequency	8.6	2.0	8.0	2.2	6.0	1.2	6.8	1.5
Negative selection	**7.9**	3.5	6.0	0.9	**8.2**	1.3	6.5	1.3
Harvesting tools	1.0	2.2	na	-	**8.2**	3.1	**6.9**	1.4
Rotation	2.4	1.4	5.6	1.3	na	-	4.5	2.1
Variety	2.8	1.4	6.6	0.9	na	-	5.6	0.9
Haulm destruction	1.0	2.2	na	-	5.8	3.3	4.5	2.4
Grading	na§	-	na	-	na	-	2.0	2.4
Total	100	-	100	-	100	-	100	-

† FR, Fertilizer rate.
‡ FA, fungicide application.
§ na, not applicable, excluded from the list by the evaluators because it was not practiced or not important.

The second part of the questionnaire was a conjoint task to elicit farmers' opinions on the importance of seed potato management attributes (see below). The farmers were randomly selected from seed potato growers from the two districts, Jeldu and Welmera, 162 farmers in each district. The sample size comprised about 40% of the total number of seed potato growers in Jeldu and Welmera. The questionnaire was pre-tested with 10 respondents, five from each district to check for the question content and question order in the first part and to decide on the best way to present the conjoint task.

Questionnaire about Demographic and Farm Characteristics

The first part of the questionnaire consisted of demographic information (e.g., age, level of education, land ownership, income from crop and livestock productions) and agricultural activities related to seed potato production (e.g., experience in seed potato production, sources of seed potato, hoeing of seed potato fields, fertilizer applications). Descriptive statistical analysis was used to analyse the data.

Conjoint Task

The second part of the questionnaire consisted of a conjoint task to quantify farmers' opinions on the effect on seed yield and quality of different levels of the most important seed potato management attributes. Conjoint analysis is a technique widely used in marketing to measure relative contributions of different product attributes (e.g., flavor versus size) to the overall preference of a product (e.g., apple) (Green and Rao, 1971; Hair et al, 2006; Rao, 2008). This technique is also widely used outside of marketing, for example, to evaluate farmers' preferences for different characteristics of modern crop varieties (Baidu-Forson et al., 1997) and factors influencing smallholder farmers' adoption of dairy technologies (Makokha et al., 2007). In this conjoint analysis, farmers were asked to rate the expected yield and quality for fictitious seed potato management methods, referred to as profiles in conjoint analysis, which are combinations of chosen levels of different individual attributes.

Selection of seed potato management attributes and levels

As indicated earlier, the selection of seed potato management attributes and relevant attribute levels to be included in the conjoint study started with the list of prioritized attributes from the Delphi study and comments given about possible levels per attribute. However, the similarity among the attributes was also considered in order to reduce the number of management attributes for inclusion in the conjoint study, i.e. seed size, seed rate and seed spacing are highly related and only seed size was selected. It was assumed that when different seed sizes were presented to the farmers, the farmers would automatically infer seed rate and spacing.

Also, hoeing and creating hills are partly carried out simultaneously and therefore were combined into one attribute. Negative selection (removing diseased potato plants from the field), harvesting tools, rotation, difference in variety, haulm destruction and grading were excluded from the conjoint study because of their low importance found in the previous Delphi study. Finally, nine attributes were selected, two attributes with two levels, and the remaining seven attributes with three levels (Table 3.3).

Table 3.3. Seed potato production and postharvest management attributes and their levels.

Attribute	Level 1	Level 2	Level 3
1. Seed source†	Own	Market	Institution
2. Seed size‡	Small	Medium	Mixed
3. Storage method§	Local	DLS¶¶	-
4. Sprouting method¶	De-sprouting	Sprouting under special conditions	Storage
5. Tillage frequency	Three times	Four times	Five times
6. Planting date#	Earlier than recommended period	Within range of recommended period	-
7. Hoeing and hilling††	Hoeing once and small hill	Hoeing twice and small hill	Hoeing twice and big hill
8. FR‡‡	Below recommended rate	Recommended rate	Above recommended rate
9. FA§§ frequency	One time	Two times	Three times

† According to experts and farmers the three seed potato sources differed from each other in quality of seed tuber they supplied.

‡ Experts and farmers claimed that the seed sizes differed from each other in their progeny yield and quality. Medium seed size according to the farmers was equivalent to a hen's egg size of Ethiopian local breed. Any tuber sized below the hen's egg size was small and greater than the hen's egg size was large. The mixed size was constituted of small, medium, and large seed. The experts' definition of seed size was tuber diameter: small for 20-35 mm, medium for 36-45 mm, and large > 45 mm.

§ Local storage methods included postponed harvesting, bed like structure located under roof outside a house and storing tubers sacked or loose in their residential house.

¶ According to farmers seed potato tubers were usually de-sprouted 2-4 weeks before planting. Straw, sacks, and direct sunlight were used to advance sprouting.

Farmers planted seed potato earlier than the recommended period (May 18 – June 7) and within the recommended period (June 8 – 22).

†† Farmers believed that hilling was crucial for high seed yield and the larger hills produced higher yield. There was a large difference in the size of the hills among the farmers in the two districts.

‡‡ FR, fertilizer rate. The recommended fertilizer rate (level) was 90 kg P_2O_5 ha^{-1} plus 111 kg N ha^{-1} in the form of 195 kg DAP and 165 kg urea ha^{-1}. The first level included FR in a range from 25 kg P_2O_5 plus 31 kg N ha^{-1} to less than the recommended rate and the third level included above-recommended up to 125 kg P_2O_5 plus 154 kg N ha^{-1}.

§§ FA, fungicide application.

¶¶ DLS, diffused light storage.

Conjoint model

The assumption underlying the use of conjoint analysis is that the perceived yield or quality of a particular seed potato management method is made by separate additive contributions of the levels of its attributes. That is, the perceived yield/quality associated with method $(p = 1, ..., P)$ can be expressed as

$$U_p = \sum_{a=1}^{A} u_a(x_{ap}) + e_p \tag{1}$$

where, U_p is the perceived yield/quality of a method p, and $u_a(x_{ap})$ is the contribution of the level x_{ap} method p takes on attribute a. e_p is an error term, capturing all contributions to U_p that cannot be accounted for by contributions of the attribute levels. After obtaining farmers' ratings of a number of management methods specified in terms of a combination of attribute levels, the attribute-level contributions can be estimated by performing analysis of variance (equivalent to OLS regression). The conjoint analysis was used because of difficulty in analyzing the multitude of the attributes considered by field experiment, and to develop alternative seed potato production methods based on these same farmers' perceptions.

Equation 2 is a more complex version of Equation 1 in which it models the interaction between FR (attribute 8 and FA (attribute 9) frequency,

$$U_p = \sum_{a=1}^{9} u_a(x_{ap}) + u_8 u_9(x_{89p}) + e_p \tag{2}$$

where $u_8 u_9(x_{89p})$ is the contribution of the interaction between FR and FA frequency.

Generation of Profiles

A full factorial design with the management attributes as factors would generate so many profiles that the full design would be too difficult to handle. Therefore, an orthogonal fractional factorial design (Addelman, 1972) was used to generate 27 so-called calibration profiles that allowed for the unconfounded estimation of all nine main effects and the interaction between FR and FA frequency. These calibration profiles were used to estimate the attribute-level contributions. In addition, two so-called warming-up profiles and four holdout profiles were constructed. The warming-up profiles were rated by the respondents before all other profiles and they were used to acquaint the respondents with the task. Holdout profiles were rated between calibration profiles, and used for validation purposes. Thus, there were 33 (27 calibration, 2 warming-up, and 4 holdout) profiles. Because these profiles had to be rated twice (first for perceived yield, and second for perceived quality), the total number of profile ratings became 66. Such a large number of ratings was expected to create boredom to the respondents and thus to reduce the quality of the data. Therefore, 27 calibration profiles were systematically split into three profile blocks such as B1, B2, and B3, by creating a blocking factor that was orthogonal to the nine main effects and the to-be-estimated interaction effect. One third of the respondents rated the profiles in B1 and B2, another one third of the respondents rated the profiles in B1 and B3, and the remaining one third of the respondents rated the profiles in B2 and B3. Therefore, a total number of ratings for each respondent decreased from 33 (27 plus 6) to 24 (18 plus 6) per round.

Because of the low literacy level of the respondents, profile levels were presented in pictographs, so that respondents could easily understand. Figure 3.1 shows a pictograph of a profile. In all pictographs all attribute-levels were presented, so that respondents would get a good impression of the different options. However, those that were not part of a combination of attribute-levels of a specific pictograph were marked as red. Three groups of profiles were evaluated by equal numbers of respondents from each district, i.e. each group was evaluated by 108 respondents (54 respondents from each district).

Evaluation of Profiles

Profiles were evaluated first for yield and then for quality. Profile evaluation began by introducing respondents to the symbols used to represent attribute-levels (Figure 3.1). Nine pictographs, each containing symbols of levels of one attribute, were shown to respondents to explain what each symbol represented. Then, the interviewer asked the respondents to evaluate 48 (24 for yield evaluation and 24 for quality evaluation) pictographs one-by-one. Profiles for yield were evaluated on 0-10 Juster scale (Juster, 1966) in which 0 is 'I cannot produce seed potato by using this combination of attribute-levels' and 10 is 'I can produce seed potato at the maximum attainable yield level by using this combination of attribute-levels'. The anticipated maximum yield was used as the reference value to evaluate the profiles for yield because there was no one common actual maximum yield value to be considered as a reference. That is why anticipated maximum yield was considered as proxy for the actual maximum yield. The same scale was also used to evaluate the profiles for quality in which 0 is 'I cannot produce seed potato by using this combination of attribute-levels' and 10 is 'I can produce seed potato at the maximum attainable quality by using this combination of attribute-levels'. There was no defined standard for seed potato quality in Ethiopia. Therefore, quality was composed of three seed potato quality variables defined by respondents that participated in the pre-testing, i.e. 1) proportion of medium tuber size in total produce (the higher the proportion of medium sized tubers, the higher the quality); 2) disease pressure (the lower the infestation of potato plant by late blight, bacterial wilt and other diseases, the higher the quality); and 3) physical damage (the lower the proportion of bruised

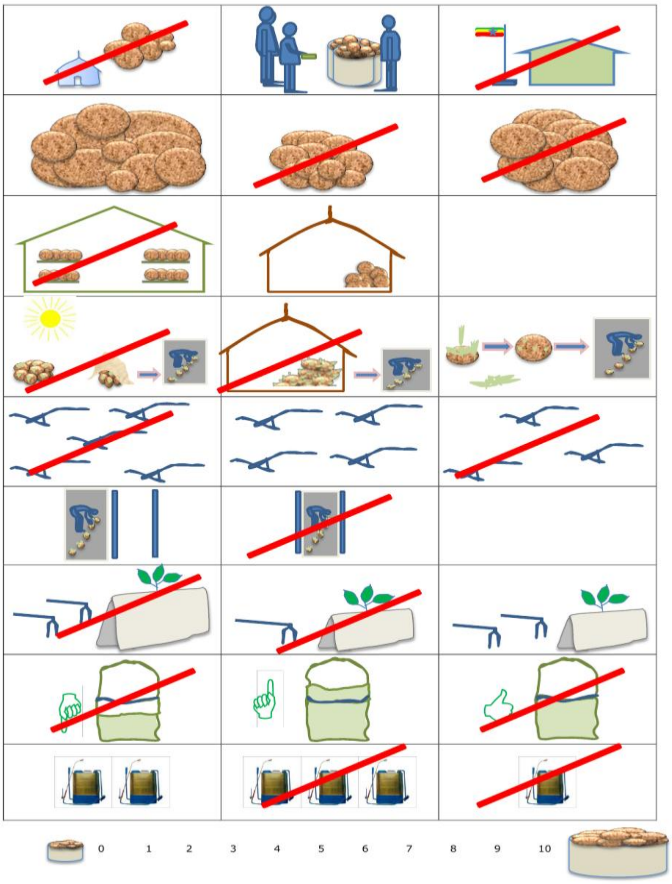


Figure 3.1. Pictograph of a conjoint profile. The pictograph represents one conjoint profile. Each row contains representation of all levels of one attribute. First row contains symbols for seed source; column 1–a residential hut and a pile of potato for own seed, column 2–persons and potato in sacks for market seed, and column 3–the Ethiopian flag and a building for seeds from a research institution. Second row contains symbols for the seed size; column 1–a pile of tubers of different sizes for the mixed seed size, column 2–a pile of tubers of a uniform small size for the small sized seed, and column 3–a pile of medium sized tubers for the medium sized seed. Third row contains symbols for storage methods; column 1–a building in which potatoes are stored on beds for diffused light storage (DLS), and column 2–a hut in which potatoes are piled for the local storage. Fourth row contains symbols representing the sprouting method before planting; column 1–the Sun, piled potatoes covered with straw and a person planting potato to represent sprouting under special conditions, column 2–sprouted tubers in a residential hut and a person planting seeds to represent in-store sprouting, and column 3–potato sprouts and a person planting potato to represent de-sprouting. Fifth row contains symbols for tillage frequency; column 1–five plows for five times of tillage; column 2–four plows for four times of tillage, and column 3–three plows for three times of tillage. Sixth row contains symbols for planting date; column 1–a symbol (a person planting potato) located to the left of two vertical bars to represent earlier than the recommended planting period, and a symbol (a person planting potato) located between two vertical bars to represent the recommended planting period. Seventh row contains symbols of hoeing frequency and hill size; column 1–two hoes and a big hill with a potato plant on a ridge to represent hoeing twice combined with a big hill size, column 2–one hoe and a small hill with a potato plant on a ridge for hoeing once combined with a small hill size, and column 3–two hoes and a small hill with a potato plant on a ridge for hoeing twice combined with a small hill size. Eighth row contains symbols for fertilizer rate (FR); column 1–a sack shaded below the blue line to represent below recommended FRs, column 2–a sack shaded above the blue line to represent above recommended FRs, and column 3–a sack shaded at the blue line to represent the recommended FR. Ninth row contains symbols for fungicide application (FA) frequency; column 1–two sprayers to represent two FAs, column 2–three sprayers to represent three FAs, and column 3–one sprayer for one FA.

and cracked tubers, the higher the quality). These quality components were explained to the respondents during the conjoint tasks of quality evaluation. Two potato varieties, Gudene and Jalene, were grown in the study areas. The evaluations were made for Gudene variety because it was grown by all respondents. Jalene was not grown by all of the respondents (12.35% in Jeldu and 41.36% in Welmera).

Analysis of the Conjoint Data

Data collected on a 0 to 10 scale were mean centered for each respondent to eliminate the different use of scale by the respondents (Endrizzi et al., 2011). Data were analyzed using factorial ANOVA in which the management attributes were included as factors. First, a factorial ANOVA was estimated to identify whether the main effects and hypothesized interactions of the selected seed potato management attributes on anticipated seed potato yield score and anticipated seed potato quality score were significant or not. (In the remaining part of the paper seed potato yield score and seed potato quality scores are referred to as yield score and quality score, respectively). Second, the predictive validity of the model was assessed by estimating Pearson correlation coefficients between predicted and observed scores for yield and quality of the holdout profiles. Estimates of the attribute-level contributions, as derived from the calibration profiles, were used to obtain the predicted scores. Third, interactions between selected respondents' characteristics (age, education, area of land allotted for seed potato production, experience in seed potato production, area of operated land, the number of oxen owned and anticipated maximum yield) and the seed potato management attributes were included in the models to determine whether the effect of management attributes on yield and quality depended on these characteristics. The selected respondent's characteristics were mean centred and included in the model for one-by-one examination of their contribution to the predictive power of the models. Finally, differences in perceived mean yield and quality scores of all attribute levels were estimated. Comparisons were made for the mean yield and quality for levels of each attribute to determine the contribution of the management attribute levels to the anticipated yield and quality. A Ryan-Einot-Gabriel-Welsch (REGWQ) Post hoc procedure (Howell, 2010) was used to compare the differences in contributions to yield and quality scores. REGWQ post hoc procedure was used because of its higher statistical power and better control of Type I error.

3.3. Results

Description of Farming Practices for the Conjoint Study

In both districts, seed potato farmers allotted a substantial area of total operated land to potato production: 28.6% (0.8 ha) was under potato production in Jeldu and 23.1% (0.6 ha) in Welmera (Table 3.4). Seed potato production was one of the most important agricultural activities in both districts, and comprised of 94% of the total land under potato production. It was also the main source of cash income (78.2% in Jeldu and 78.7% in Welmera) (Table 3.5). The area of rented land (land acquired by payment for temporary operation) and the area of land allotted to seed potato production were equivalent, indicating that many farmers rented the land mostly to produce seed potato (Table 3.4). Farmland was in scarce supply, and fragmented into a number of small plots for each farmer in the studied area. The problem of land fragmentation was more severe in Welmera (more than seven plots per farmer) than in Jeldu (about four plots per farmer) and the average area per plot of own land was also smaller in Welmera (0.21 ha) than in Jeldu (0.39 ha). Farmers produced seed potato from the seed of improved cultivars obtained from a research institution or from other seed producers in the area.

Production activities differed among the farmers in the two districts. Farmers in Jeldu used a higher FR, narrower inter- and intra-row spacing, and more frequent FAs than the farmers in Welmera (Table 3.4). There were large differences between the districts in the actual reported yield and the anticipated maximum yield. Farmers in Jeldu reported higher actual and anticipated yields than farmers in Welmera. In 2010, farmers produced only 45% and 41% of the anticipated yield in Jeldu and Welmera, respectively. The low yields in 2010 were partly due to poor weather conditions for potato production. Key informants indicated that excessive rainfall caused severe late blight problems for the 2010 potato crop.

Most of the farmers used their own seeds which consisted of medium sized seed stored under DLS in both districts. However, a small number of farmers used mixed sized seeds and local storage methods, more often in Welmera than in Jeldu.

Effects of Management Attributes

Table 3.6 presents the main effects and interaction between FR and FA frequency, and their interaction with the district on yield and quality scores. The main effects of the management attributes were significant for all attributes except for the effect of tillage frequency on yield.

Table 3.4. Demographics, agricultural land and production activities of seed potato farmers in two districts.

Factor	Jeldu		Welmera	
	Mean	SD	Mean	SD
	year			
Age	40	11.9	38	10.9
Experience in seed potato production	4.6	2.13	4.8	2.33
Number of years the farmers had been growing the seed potato once obtained from Holetta Agricultural Research Center or other farmers				
Gudene†	3.4	0.95	3.6	1.02
Jalene†	4.1	1.60	4.4	1.34
Number of seasons between two seed productions‡	1.6	0.71	1.7	0.64
	number			
Household size	7.0	2.74	5.9	2.59
Number of plots for all crops	4.4	2.55	7.5	4.54
Tillage frequency for seed potato	3.9	0.58	3.9	0.58
Hoeing frequency for seed potato crops	2.1	0.47	2.0	0.29
FA§ frequency on seed potato				
Gudene	2.4	0.58	2.2	0.63
Jalene	2.6	0.72	2.2	0.55
Oxen holding	2.3	1.68	2.7	1.72
	ha			
Total operated land	2.8	1.79	2.6	1.55
Landholding	1.7	1.29	1.6	1.21
Rented-in land	0.7	1.45	0.7	1.30
Sharecropped land	0.4	0.62	0.3	0.51
Land under potato	0.8	0.74	0.6	0.62
	cm			
Spacing between potato plants within rows	29	5.2	31	6.7
Spacing between rows	62	3.7	69	11.7
	kg ha^{-1}			
DAP on seed potato	155	69	135	72
Urea on seed potato	90	59	102	56
	Mg ha^{-1}			
Actual seed potato yield	15	11.0	10	6.8
Anticipated maximum yield				
Gudene	33	9.3	25	9.6
Jalene	36	11.5	27	10.4

† Gudene and Jalene are potato varieties.
‡ At both districts seed potato is produced in only one season per year. Ware potato is produced in two seasons per year in Jeldu.
§ FA, fungicide application.

The η^2 values show the effect size of the attributes. The model explained 27.2% of the total variation in yield scores due to management attributes and their interactions and 30.1% of the total variation in quality scores. The effects of the management attributes ranged from relatively small to medium. Of the total variation in yield explained by the model, 26.7, 18.0, 17.9, and 13.7% were due to FR, storage method, hoeing frequency combined with hill size, and FA frequency, respectively. Storage method, FR, hoeing frequency combined with hill size, and FA frequency had shares of 21.7, 18.2, 15.6 and 10.4% of the total variation of quality explained by the model in their respective order.

Table 3.5. Education level, farm income, and seed potato production activities of seed potato farmers in two districts.

Factor	Jeldu	Welmera
	% of farmers	
Education level		
Illiterate; Primary (1-6 years education); Secondary (7-12 years education); College (>12 years education)	16.0; 47.0; 37.0; 0	30.2; 41.4; 27.8; 0.6
Cash income per farmer†		
Seed potato; Other crops; Livestock	78.2; 17.1; 4.7	78.7; 12.4; 8.9
Occupation		
Sole farming; Farming and other activities	82.1; 17.9	91.4; 8.6
Seed source		
Own; Market; Institution	90.7; 1.9; 7.4	96.3; 1.9; 1.8
Seed size		
Small; Medium; Mixed	0.6; 81.5; 17.9	1.2; 77.2; 21.6
Storage methods		
Local; DLS‡	18.5; 81.5	28.4; 71.6
Planting date		
Recommended; Earlier than recommended	18.5; 81.5	60.5; 39.5
Seed size for seed rate adjustment§		
No; Yes	26.3; 73.7	11.8; 88.2
Negative selection¶		
No; Yes	100; 0	34; 66
Reason for negative selection is		
Bacterial wilt; Other	-	99.1; 0.9

† The total cash income was on average Ethiopian Birr (ETB) 36,410 in Jeldu and ETB 21,471 in Welmera. USD 1 was equivalent to ETB 17 on August 15, 2011.
‡ DLS, diffused light storage.
§ Seed size for seed rate adjustment means adjusting the seed rate (Mg/ha) based on the seed size.
¶ Negative selection is removing potato plants infected by bacterial wilt.

The hypothesized interaction between FR and FA frequency on yield and quality was significant. This indicates that the effect of FR depended on the levels of FA frequency. Interactions between seed source and district, planting date and district, and FR and FA frequency and district on yield were significant at $p < 0.001$ and the same held for interaction between seed source and district, planting date and district, FR and district, FA frequency and district on quality (Table 3.6). These results show that the effects of the management attributes on yield and quality were perceived differently by the farmers in two districts. However, the interactions between management attributes and district contributed less than 1% to the total variation explained by the models for yield as well as potato quality.

Validity Testing

To assess the validity of the conjoint model, values were predicted for the holdout profiles based on the model estimates. Table 3.7 shows the descriptive statistics of the Pearson correlation coefficients between these predicted values and the observed values for the holdout profiles. These coefficients were calculated for each respondent separately. The results show the low internal predictive validity of the model estimates. This could be due to high heterogeneity among the respondents.

Table 3.6. Main effects and interaction of seed potato management attributes on anticipated seed yield and quality. Four attributes contributing the most to the variance explained are in bold.

Source	df	Yield†			Quality†		
		F	η^2‡	% η^2 explained by the model	F	η^2‡	% η^2 explained by the model
Model	42	48.53***	0.272§	100	55.95***	0.301¶	100
a1 (seed source)	2	42.64***	0.011	4.18	99.85***	0.026	8.49
a2 (seed size)	2	17.12***	0.005	1.68	36.66***	0.009	3.13
a3 (storage method)	1	367.06***	0.049	**17.98**	509.41***	0.065	**21.65**
a4 (sprouting method)	2	48.30***	0.013	4.73	81.02***	0.021	6.89
a5 (tillage frequency)	2	0.42	0.000	0.00	26.70***	0.007	2.37
a6 (planting date)	1	102.92***	0.014	5.04	93.88***	0.012	3.99
a7 (hoeing frequency and hill size)	2	183.04***	0.049	**17.93**	183.15***	0.047	**15.57**
a8 (FR#)	2	272.85***	0.073	**26.73**	213.93***	0.055	**18.19**
a9 (FA†† frequency)	2	139.93***	0.037	**13.71**	122.29***	0.031	**10.40**
a8 × a9	4	19.87***	0.011	3.89	29.93***	0.015	5.09
a1 × district	2	7.11***	0.002	0.70	7.61***	0.002	0.65
a2 × district	2	4.74**	0.001	0.46	5.15**	0.001	0.44
a3 × district	1	2.15	0.000	0.00	6.48**	0.001	0.28
a4 × district	2	0.33	0.000	0.00	0.45	0.000	0.00
a5 × district	2	5.96**	0.002	0.58	2.76	0.001	0.23
a6 × district	1	14.17***	0.002	0.69	23.29***	0.003	0.99
a7 × district	2	0.66	0.000	0.00	0.003	0.000	0.00
a8 × district	2	2.13	0.001	0.21	7.22***	0.002	0.61
a9 × district	2	1.09	0.000	0.00	6.52***	0.002	0.55
a8 × a9 × district	4	4.93***	0.003	1.00	2.62*	0.001	0.44
Error‡‡	5466						
Total	5832						
Corrected Total	5831						

† Data were collected on 0 - 10 scale and mean centered: from rating given by a respondent, mean of his/her ratings was deducted.
‡ η^2 shows the effect size; trivial < 0.010, small = 0.01 – 0.059, medium = 0.083 – 0.109, large > 0.138 (Cohen, 1992).
§ R^2 = 0.272 (Adjusted R^2 = 0.266).
¶ R^2 = 0.301 (Adjusted R^2 = 0.296).
# FR, Fertilizer rate.
†† FA, fungicide application.
‡‡ df for error was adjusted by subtracting total number of respondent less one. Adjustments were also made to F and P values.
*** Significant at the 0.001 probability level.
** Significant at the 0.01 probability level.
* Significant at the 0.05 probability level.

Table 3.7. Descriptive statistics of correlation coefficients between the predicted and actual yield and quality values of holdout profiles in two districts.

Items	Yield		Quality	
	Jeldu	Welmera	Jeldu	Welmera
Number of respondents	161	162	160	159
Mean	0.24	0.36	0.40	0.43
Median	0.37	0.50	0.52	0.58
SD	0.58	0.55	0.51	0.48
Percentiles:				
25	-0.22	-0.03	0.04	0.23
75	0.77	0.87	0.83	0.83
90	0.90	0.96	0.96	0.88

Even though the internal validity of the model estimates was low, the results were considered robust for two reasons. First, the results obtained from the model (Table 3.6) were comparable to the results of Delphi study (Tables 3.1 and 3.2). Second, from a social sciences perspective, the adjusted R^2s values were relatively large for both yield (0.266) and quality (0.296).

Effect of Selected Characteristics of the Respondents

Table 3.8 presents increments in the values of degrees of freedom (df), F-ratio, and η^2 after the inclusion of interaction between selected respondents' characteristics (age, education, area of land allotted for seed potato production, experience in seed potato production, area of operated land, a number of oxen owned and the anticipated maximum yield) and management attributes to evaluate whether the effects presented in Table 3.6 are contingent upon those respondents' characteristics or not. The selected respondents' characteristics were mean-centered to enable better interpretation of the results. The analysis was done by including the interactions with all management attributes for one characteristic at a time, in addition to the main effect in the model (Table 3.6). So the first row in Table 3.8 gives the results when interactions with age were added to the main effect, the second row gives the results when interactions with education were added to the main effect, and so on. The results were aggregated to minimize the number of presented tables. The interactions between management attributes and age, education, area of land allotted for seed potato production, area of total operated land, and the number of oxen owned for yield and quality were not statistically significant (with corresponding very small η^2's) indicating that the results of the main analyses were not affected by these respondents' characteristics. However, the interaction between the anticipated maximum seed yield and management attributes was significant ($p<0.001$) with small η^2 of 0.01. The interaction between experience in seed potato production and management attributes was significant ($p<0.01$) with η^2 of 0.005 for perceived quality only. This indicates that the main effect of management attributes on yield was moderated by anticipated maximum yield while main effect of management attributes on quality was moderated by experience in seed potato production. However, the effect sizes for the interaction of the management attributes with both characteristics were small.

Effects of Management Attribute-levels on Yield and Quality

This section describes the contribution of different levels of individual attributes for yield and quality. The F-ratios in Table 3.6 only show whether the management attributes had significant effects on yield and quality or not, but do not show which levels had different effects. Table 3.9 presents pairwise comparisons among levels for each attribute in their effects on yield and potato quality. The level with the lowest contribution was set as zero and the values for the remaining levels were computed by taking zero as a reference value. Of all seed sources, the contributions of the market seed level were the lowest for yield and quality in both districts, indicating a low trust for market seed by farmers (Table 3.9). Own seed scored significantly higher for both yield and quality in both districts. In Jeldu, the seed from research institution scored the highest contributions for yield whereas in both districts it scored the highest contributions for quality. However, contributions of seeds from the research institution were only significantly different from own seed for yield in Jeldu and for quality in Welmera. For seed size, the lowest yield and quality scores were from using small and/or mixed seeds (Table 3.9).

For seed size, the lowest yield and quality scores were from using small and/or mixed seeds (Table 3.9). There were no significant differences between the contributions of small seed and mixed seeds for yield and quality in both districts. The contributions of medium size seeds were significantly higher than those of small seed and mixed seeds for yield and quality in both districts. The differences in contributions of yield and quality for the same levels of seed source were larger in Welmera than in Jeldu, indicating that farmers in Welmera were more concerned about the seed source than farmers in Jeldu. This could be because of a higher disease pressure in Welmera (e.g., prevalence of bacterial wilt) than in Jeldu (no bacterial wilt) (Table 3.5). DLS storage method had significantly higher contributions than local storage methods for seed yield and quality in both districts (Table 3.9). For sprouting method, the contributions of in-storage sprouting method were significantly higher than those of de-sprouting and sprouting (sprouting under special conditions) for yield and quality in both districts (Table 3.9). There were no significant differences between the contributions of de-sprouting and sprouting.

Table 3.8**.** Increment in the values of df, F-ratio of the main effects in the Table 3.6 after the inclusion of one characteristic at a time as an interaction term to each management attribute and the predetermined interaction (a8 ×a9). The presented results are aggregates of the results of interaction between each respondent's characteristics and management attribute.

Covariate	Increment in df due to inclusion of covariates	F- ratio	
		Yield	Quality
Age × (a1, a2, ..., a9, a8 x a9)	20	1.10	0.84
Education × (a1, a2, ..., a9, a8 x a9)	20	1.22	1.34
Land allotted for seed potato × (a1, a2, ..., a9, a8 x a9)	20	0.95	1.36
Experience × (a1, a2, ..., a9, a8 x a9)	20	0.95	1.79*
Operated land x (a1, a2, ..., a9, a8 x a9)	20	0.96	0.68
Oxen × (a1, a2, ..., a9, a8 x a9)	20	1.13	0.92
Anticipated maximum yield × (a1, a2, ..., a9, a8 x a9)	20	2.62***	-

* Significant at the 0.001 probability level.
*** Significant at the 0.01 probability level.

In Jeldu, there were no significant differences between contributions of three and four times of tillage for yield; the contributions of three and four times of tillage were significantly different for yield in Welmera and for quality in both districts. Tilling the soil four times before planting resulted in higher contributions than tilling the soil three times (Table 3.9). Differences between the contributions of four and five times of tillage were not significant for yield and quality in both districts.

For planting date, planting earlier, as opposed to planting within the recommended time range, had the largest contributions for yield and quality in both districts (Table 3.9). The differences between the contributions of hoeing once combined with small hill size and hoeing twice combined with small hill size were not significant for yield, but were significant for quality in both districts, with hoeing twice receiving higher scores than hoeing once (Table 3.9). Therefore, hoeing frequency was more important for quality than for yield. In both districts, the largest contributions were observed from hoeing twice combined with big hill size for yield and quality.

Table 3.10 shows relative contributions of interaction between FR and FA frequency to yield and quality scores in two districts. The contributions were the largest for yield and quality in both districts when recommended FR was combined with two FAs. The differences in contributions between the highest and lowest scoring practices were higher in Welmera (2.17 for yield and 1.78 for quality) than in Jeldu (2.11 for yield and 1.56 for quality) and the same differences were for contributions of other combined effects. The contributions for recommended FR combined with two FAs were also significantly higher than the contributions of lower or higher FRs combined with any FA frequency or of the recommended FR combined with any FA, except three FAs for yield in Welmera and for quality in both districts. The contributions of the above-recommended FR combined with any FA frequency were smaller than those of recommended FR combined with any FA frequency. This indicates that using the above-recommended FRs was not important for improving quality and yield.

Table 3.9. Relative contributions of seed potato management attribute levels to overall yield and quality scores (data collected on 0 - 10 scale and mean centered) in two districts. The lowest contribution within an attribute and district was set as zero (the relative contributions are the differences from the lowest value within attribute and district). The higher the value of the relative contribution, the larger the effect.

Attribute	Relative contribution for yield†		Relative contribution for quality†	
	Jeldu	Welmera	Jeldu	Welmera
Seed source				
Own	0.19b	0.56a	0.30a	0.63b
Market	0.00c	0.00b	0.00b	0.00c
Institution	0.39a	0.48a	0.49a	0.79a
Seed size				
Small	0.04b	0.07a	0.00b	0.01b
Mixed	0.00b	0.00a	0.06b	0.00b
Medium	0.41a	0.15a	0.50a	0.23a
Storage method				
Local	0.00b	0.00b	0.00b	0.00b
DLS	0.92a	0.78a	1.02a	0.81a
Sprouting method				
De-sprouted	0.00b	0.00b	0.00b	0.02b
Special conditions	0.10b	0.12b	0.01b	0.00b
In storage	0.51a	0.45a	0.56a	0.49a
Tillage frequency				
Three	0.16a	0.00bc	0.00b	0.00b
Four	0.00a	0.19a	0.41a	0.21a
Five	0.15a	0.11ac	0.30a	0.28a
Planting date				
Earlier	0.00b	0.00b	0.00b	0.00b
Recommended	0.62a	0.28a	0.59a	0.20a
Hoeing frequency and hill size				
Once and small hill	0.11 b	0.06 b	0.00c	0.00c
Twice and small hill	0.00 b	0.00 b	0.23b	0.22b
Twice and big hill	0.86 a	0.92 a	0.87a	0.87a

† Similar letters within an attribute and district indicate that contributions do not differ significantly according to Ryan-Einot-Gabriel-Welch (REGWQ) test ($\alpha = 0.05$).

It was expected that if all farmers participating in this study used the best levels of the seed potato management attributes, yield could increase considerably. The overall mean yield scores, 3.53 in Jeldu and 4.27 in Welmera. When the contribution of best levels (see below) were added to these means, this resulted in scores (on the original 0-10 Juster scale) equal to 9.0 in Jeldu and 8.5 in Welmera. In Jeldu, the contributions of the best levels of the management attributes before setting the lowest contributions as zero were 0.45 for seed source, 0.52 for seed size, 0.71 for storage method, 0.56 for sprouting method, 0.31 for tillage frequency, 0.56 for planting date, 0.79 for hoeing frequency combined with hill size, and 1.58 for interaction between FR and FA. In Welmera, these contributions were 0.39 for seed source, 0.26 for seed size, 0.57 for storage method, 0.44 for sprouting method, 0.27 for tillage frequency, 0.32 for planting date, 0.77 for hoeing frequency combined with hill size, and 1.20 for interaction between FR and FA. The results indicated that if all farmers switched to the best management attribute levels, they could produce 90% and 85% of anticipated maximum yield (33 Mg ha^{-1} in Jeldu and 25 Mg ha^{-1} in Welmera) (Table 3.3), in Jeldu and Welmera, respectively. Therefore, the yield could be increased by about 200% of the actual yield observed (15 Mg ha^{-1} in Jeldu and 10 Mg ha^{-1} in Welmera) (Table 3.3).

Table 3.10. Relative contributions of interaction between fertilizer rate (FR) and fungicide application (FA) frequency to overall yield and quality scores in two districts. The lowest contribution within a district was set as zero (the relative contributions are the differences from the lowest value within attribute and district). The higher the value of the relative contribution, the larger the effect.

Interaction between FR and FA	Estimated contribution for yield†		Estimated contribution for quality†	
	Jeldu	Welmera	Jeldu	Welmera
Below-recommended FR and one FA	0.00g	0.00d	0.36cd	0.00f
Below-recommended FR and two FAs	0.24fg	0.63c	0.00e	0.17ef
Below-recommended FR and three FAs	0.43def	0.92c	0.38cd	0.65d
Recommended FR and one FA	0.61de	0.93c	0.44cd	0.66d
Recommended FR and two FAs	2.11a	2.17a	1.56a	1.78a
Recommended FR and three FAs	1.50b	2.07a	1.23ab	1.62ab
Above-recommended FR and one FA	0.36ef	0.92c	0.24de	0.47de
Above-recommended FR and two FAs	0.70d	1.34b	0.67c	1.25c
Above-recommended FR and three FAs	1.08c	1.34b	1.09b	1.39bc

† Similar letters within an interaction of the attributes and district indicate that contributions do not differ significantly according to Ryan-Einot-Gabriel-Welch (REGWQ) test ($\alpha = 0.05$).

3.4. Discussion

The objective of this study was to elicit farmers' opinion on the importance of seed potato management attributes with respect to their perceived effects on potato yield and quality. This knowledge will be used to develop alternative seed potato production methods that better account for farm and farmer characteristics. The results of this study indicated that the most important seed potato management attributes based on their perceived effects on yield and quality were storage method, hoeing frequency combined with hill size, FR and FA frequency (Tables 3.2, 3.6, 3.9, and 3.10).

Storage of seed tubers in DLS was perceived to improve seed potato yield and quality compared to local storage methods as indicated by the significant effects of the attribute on yield and quality (Table 3.6) and the differences in mean scores (Table 3.9). The DLS storage method was also already used by 81.5% of the farmers in Jeldu and 71.6% of the farmers in Welmera (Table 3.5). These values are similar to the result reported by Tesfaye et al. (2008), where, 87% of the farmers in the central potato growing area of Ethiopia used DLS to store seeds of improved potato varieties. However, the local storage method was still used by 18.5% of the farmers in Jeldu and 28.4% in Welmera (Table 3.5). Thus, a shift from the use of local storage to DLS could considerably enhance yield and quality of seed potato in both districts, and potentially in other places where potato is grown for seed.

Hoeing twice combined with creating a big hill size was perceived to be more important than hoeing once or twice combined with a small hill size (Table 3.9). Hoeing twice was the average hoeing frequency reported by the farmers (Table 3.4). This hoeing frequency is also similar to that recommended by Holetta Agricultural Research Center (Tesfaye et al., 2007). Thus hoeing frequency was at the maximum level in the study, and seed yield and quality could be improved through a shift from a small hill size to a big hill size.

For the interaction between FR and FA frequency, the largest contributions were from the combined effects of the recommended FR and two FAs. The respondents believed that the shift from recommended FR to above-recommended FRs would decrease their yields. The average FR used by the farmers was below the rate recommended by Holetta Agricultural Research Center and the average number of FAs was 2.4 in Jeldu and 2.2 in Welmera (Table 3.4). Gildemacher et al. (2009b) also revealed that farmers in the central potato growing area of Ethiopia used below-recommended FR. Therefore, as perceived by the respondents, yield and quality could be increased in both districts by a shift from the use of the prevailing combination, i.e. below-recommended FR combined with two FAs, to below-recommended FR combined with three FAs, or to recommended FR combined with two FAs. However, the perceived impact from increasing FR was larger than that from changing the number of FA during the growing season, especially when fungicide was already applied two times (Table 3.10).

Even though the interactions between the districts and management attributes on yield and quality for some of the attributes were significant, their effect sizes were very small. This indicates that the difference between the districts was not important. Age, education, area of land allotted for seed potato, area of total operated land and a number of oxen owned did not have a significant effect on yield and quality scores as showed by the insignificant interaction between above mentioned characteristics and the management attributes (Table 3.8). Therefore, these respondents' characteristics are not important for developing alternative seed potato production methods and for advising seed potato farmers by the extension personnel. The predictive power of the yield model was slightly improved by considering the anticipated yield; however, the effect size ($\eta^2 = 0.01$) was small.

3.5. Conclusions

In both districts, storage method, hoeing frequency combined with hill size, FR and FA frequency were the most important seed potato management attributes that farmers expected to affect seed yield and quality. Therefore, in Jeldu and Welmera, seed yield and quality could be substantially improved 1) if a larger number of farmers switch from using local storage to using DLS, 2) if farmers make a big hill size instead of a small hill size, and 3) if farmers switch from using the prevailing combination of FR and FA frequency, i.e. below recommended FR combined with two FAs to a) below-recommended FRs combined with three FAs, or b) recommended FR combined with two FAs. If all farmers participating in this study adopted the best levels of all the studied management attributes, potato yield could increase about twofold compared with the actual yield observed in 2010.

The results of this study are not merely intended to improve potato production in the studied areas, but to improve seed production in other, less advanced areas, too. It is expected that farmers will respond to higher yields and be more likely to adopt practices from which they expect to receive higher yields or better potato quality. The farmers in the relatively advanced areas included in this study had some experience with different levels of seed production (from very basic to more advanced), and therefore, were able to estimate the effects of different attribute levels. The relative contributions of the attribute levels obtained enable researchers to compare different production practices.

The differences in the perceived effects of the management attributes on the anticipated yield and quality could be used to design alternative seed potato production methods from which farmers in other economic and agro-ecological conditions can choose to improve their production methods, especially when these perceived effects could be accompanied by the estimated cost to change the current production practices. The results could be also used by extension personnel to recommend farmers the most important management attributes to improve yield and quality of seed potato in Ethiopia.

References

Addelman, S., 1972. Recent developments in the design of factorial experiments. Journal of the American Statistical Association 67(337):103-111.

Agegnehu, G., Fessehaie, R., 2006. Response of faba bean to phosphate fertilizer and weed control on Nitisols of Ethiopian highland. Italian Journal of Agronomy 2:281-290.

Baidu-Forson, J.B.R., Waliyar., N.F., 1997. Utilizing conjoint utility analysis to design modern crop varieties: Empirical example for groundnut in Niger. Agricultural Economics 16:219-226.

Cohen, J., 1992. A power primer. Psychological Bulletin. 112:155-159.

Dalkey, N., Helmer, O., 1963. An experimental application of Delphi method to the use of experts. Management Science 9(3):458-467.

Endrizzi, I., Menichelli, E., S.B. Johansen, Olsen, N.V., Naes, T., 2011. Handling of individual differences in rating-based conjoint analysis. Food Quality and Preference 22:241-254.

Gao, Q., Li, C., Feng, G., Cui, Z., Chen X., Zhang F., 2012. Understanding yield response to nitrogen to achieve high yield and high nitrogen use efficiency in rainfed corn. Agronomy Journal 104:165-168.

Gebremedhin, W., Gebre, E., Lemaga, B., 2008. Potato variety development. In: Gebremedhin, W., Gebre, E., Lemaga, B., (Eds.), Root and tuber crops: The untapped resources. EIAR 2008, Addis Ababa, Ethiopia. 15-32.

Gildemacher, P., Demo, P., Barker, I., Kaguongo, W., Gebremedhin, W., Wagoire, W.W., Wakahiu, M., Leeuwis C., Struik, P.C., 2009a. A description of seed potato systems in Kenya, Uganda and Ethiopia. American Journal of Potato Research 86:373-382.

Gildemacher, P., Kaguongo, W., Ortiz, O., Tesfaye, A., Gebremedhin, W., Wagoire, W.W., Kakuhenzire, R., Kinyae, P.M., Nyongesa, M., Struik, P.C., Leeuwis, C., 2009b. Improving Potato Production in Kenya, Uganda and Ethiopia: A system diagnosis. Potato Research 52:173-205.

Gordon, T.J., 1994. The Delphi Method. AC/UNU Millennium Project, Futures Research Methodology. Accessed July 2011, available at http://millennium-project.org/FRMv3_0/04-Delphi.pdf.

Green, P.E., Rao, V.R., 1971. Conjoint measure for quantifying judgment data. Journal of Marketing Research 8 (August):355-363.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R.L., 2006. Multivariate Data Analysis, 6th edition. Pearson Education, New Jersey.

Hirpa, A., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Oude Lansink, A.G.J.M., Tsegaye, A., Struik, P.C., 2010. Analysis of seed Potato systems in Ethiopia. Am. J. Pot. Res. 87:537-552.

Howell, D.C., 2010. Statistical Methods for Psychology, 7th edition. Wadsworth, Cengage learning.

International Potato Center (CIP), 2011. Roadmap for investment in the seed potato value chain in eastern Africa. Lima, Peru. 27 pp.

Jack, B.K. 2011. Constraints on the adoption of agricultural technologies in developing countries. White paper, Agricultural Technology Adoption Initiative, J-PAL (MIT) and CEGA (UC Berkeley).

Juster, F.T., 1966. Consumer buying intentions and purchase probabilities: An experiment in survey design. Journal American Statistical Association 61(315):658-696.

Linstone, H.A., Turoff, M., 1975. Introduction. In Linstone, H.A., Turoff, M., (Eds.). The Delphi method: Techniques and applications (pp. 3-12). Reading, MA: Addison-Wesley Publishing Company.

Makokha, S.N, Karugia, J., Staal, S.J., Oluoch-Kosura, W., 2007. Valuation of cow attributes by conjoint analysis: A case study of western Kenya. African Journal Agriculture and Resource Economics 1(2):95-113.

Mamo, M., Malzer, G.L., Mulla, D.J., Huggins, D.R., Strock, J., 2003. Spatial and temporal variation in economically optimum nitrogen rate for corn. Agron. J. 95:958-964.

Mulatu, E., Osman, E.I., Etenesh. B., 2005. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. Journal of New Seeds. 7(3):31-56.

Rao, V.H., 2008. Development in conjoint analysis. Handbook of marketing models, International Series in Operations Research and Management Sciences 121, part 2:23-53.

Reece, J.D., Sumberg, J., 2003. More clients, less resources: toward a new conceptual framework for agricultural research in marginal areas. Technovation 23:409-421.

Rowe, G., Wright G., 1999. The Delphi technique as a forecasting tool: Issues and analysis. International Journal of Forecasting. 15:353 – 375.

Scharf, P.C., Kitchen, N.R., Sudduth, K.A., Davis, J.G., Hubbard, V.C., Lory, J.A., 2005. Field-scale variability in optimal nitrogen fertilizer rate for corn. Agronomy Journal 97:452-461.

Snyder-Halpern, R., Thompson, C.B., Scheffer. J., 2000. Comparison of mailed vs. internet applications of the Delphi technique in clinical informatics research. Accessed November 2011, available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2244113/pdf/procamiasymp00003-0844.pdf.

Tesfaye, A., Bedane, K., Yirga, C., Gebremedhin. W., 2008. Socioeconomics and technology transfer. In Root and tuber crops. In: Gebremedhin, W., Gebre, E. Lemaga B., (Eds.), Root and tuber crops: The untapped resources. EIAR 2008, Addis Ababa, Ethiopia. p. 131-152.

Tesfaye, A., Kaguongo, W., Gebremedhin, W., Lemaga, B., Nigussie, D., 2007. Adoption and impact of potato production technologies in selected districts of Oromiya and Amhara Regions of Ethiopia. Unpublished report.

Yu, B., Nin-Pratt, A., Funes J., Gemessa. S.A., 2011. Cereal production and technology adoption in Ethiopia. International Food Policy Research Institute (IFPRI). Working paper 31. Accessed February 2012, available at http://www.ifpri.org/publication/cereal-production-and-technology-adoption-ethiopia-0.

Chapter 4

Cost-effective seed potato production in Ethiopia

Adane Hirpa[1,2], Miranda P.M. Meuwissen[a], Willemien J.M. Lommen[2], Admasu Tsegaye[3], Paul C. Struik[2] and Alfons Oude Lansink[1]

[1]Business Economics, Wageningen University, The Netherlands,
[2]Centre for Crop Systems Analysis, Wageningen University,
[3]Addis Ababa University, Ethiopia.

Submitted to: Potato Research

Abstract

Improved potato varieties can increase potato yields of smallholders and thus contribute to food security improvement in Ethiopia. However, the uptake of these varieties by farmers is very limited so far and is one of the causes of insufficient seed quality in the seed potato system in Ethiopia. The objective of this study was to develop cost-effective seed potato production plans for farmers in Ethiopia. The paper used integer linear programing and the perceived contributions of production and postharvest management and costs to determine cost-effective plans. Results show that in districts of Jeldu and Welmera several plans were developed from which farmers can choose an affordable plan that will enable them to produce seed potato with reasonable yield and quality levels. Results also show that yield and quality levels could be simultaneously improved at relatively low extra costs. In both districts, most plans were robust at 50% increases in the rental values of land, prices of seed, wage rates, and prices of agrochemicals. Findings can be used by potato development practitioners to advise farmers on the adoption of seed potato technologies that are compatible with their financial resources.

Key words: Cost-effective production; linear programming; management attributes; seed potato; production plan; Ethiopia.

4.1. Introduction

In Ethiopia, potato (*Solanum tuberosum* L.) can play an important role in improving food security and cash income of smallholder potato growers. Potato production can be increased through increases in acreage and productivity. Currently, only 2% of the potential area is under potato production and the average productivity of potato is less than 10 Mg/ha. The low productivity is partly due to the use of poor quality seed potatoes of inferior varieties by most potato growers (Mulatu et al., 2005; Gildemacher et al., 2009; Hirpa et al., 2010; International Potato Centre, 2011). So far, there is no formal institution involved in the production, supply or certification of seed potatoes. Currently, a small amount of good quality seed is supplied by agricultural research institutions, mainly to introduce and demonstrate the impact of improved varieties and cultural practices.

Available improved potato varieties are characterized by high yields and biotic and abiotic stress tolerances. However, the uptake of these varieties by farmers is very limited. The limited uptake is partly a result of limited supply of seed, which in turn is caused by the fact that there is no efficient seed potato system in place (Gildemacher et al., 2009; Hirpa et al., 2010). Farmers, who adopted improved potato varieties, use suboptimal seed production management practices and produce below their potential (Hirpa et al., 2012). According to Gildemacher et al. (2009), seed potatoes of improved varieties comprised only 1.3% of the total supply of the seed potato in Ethiopia. In Sub-Saharan Africa (including Ethiopia), there is high demand for seed potato of improved varieties (Gildemacher et al., 2011). Therefore, supply of a larger amount of quality seed potato (potatoes that comply with seed health, physiological and genetic quality criteria) of improved varieties is required to increase potato production in the country.

Production and supply of a larger quantity of quality seed potato of improved varieties require an increase in the number of seed potato producers of improved potato varieties. Currently, improved varieties are released to farmers together with an advice for a standard, recommended package of seed potato cultural practices. The low adoption of improved potato varieties and management practices could be caused by high costs related to the adoption of the recommended production method; studies show that new agricultural technologies often require more inputs than existing technologies and farmers are reluctant to adopt them to avoid risk of failure (Foster and Rosenzweig, 2010; Langyintuo and Mungoma, 2008; Yesuf and Bluffstone, 2007; Yu et al., 2011). Reluctance in the uptake of new technologies can be more serious in a situation where markets for credit and insurance are missing (Yesuf and Bluffstone, 2007). In Ethiopia, lack of credit is one of the major constraints for adoption of new agricultural technology (Croppentedt et al., 2003) and a crop insurance market for most crops including potato is missing (Araya, 2011; Yesuf and Bluffstone, 2007). Therefore, availing low-cost alternative production methods can be one of the means to increase uptake of improved varieties and management practices. Low-cost alternative seed potato production methods could give lower, but acceptable seed potato yield and quality. Subsequently, farmers can decide to invest in the production of seed potato methods with higher seed yield and quality levels than the existing production method. A study of Yesuf and Bluffstone (2007) among Ethiopian farmers showed that the perceived level of risk decreased once the success had convinced farmers that technologies were viable.

The objective of this study was to develop cost-effective seed potato production plans for farmers in Ethiopia. The study uses integer linear programming and the results from a previous study on the perceived contributions of seed potato management attributes levels on seed potato yield and quality (Hirpa et al., 2012) to compute the costs of combinations of seed potato management attributes. The empirical application focuses on farmers in districts of Jeldu and Welmera. The results also show that yield and quality levels could be simultaneously improved at relatively low extra costs. The knowledge acquired can be used by seed potato production practitioners to advise farmers on the adoption of seed potato technologies that are compatible with their financial resources. The knowledge is also useful for researchers to develop viable alternative production methods in the processes of variety development.

4.2. Framework and model specification

Consider a farmer producing seed potato using multiple seed potato management attributes. The farmer's technology set (*T*) is given by:

$$T = \{(p, q) : p \text{ can produce } q\} \tag{1}$$

where q is a combination of seed potato yield and quality and p is a specific combination of seed potato management attribute-levels (or production method). A technology set is a list of all technically feasible combinations of inputs and outputs (Fare and Primont, 1995).

Linear Programming (LP) is a mathematical technique that optimizes a linear function of decision variables (in this case, seed potato management attribute levels) subject to linear constraints that are expressed as equality, inequality or bounds in decision variables (Murty, 2010). Integer linear programming (ILP) is a special case of LP in which all decision variables are restricted to integer values. This study used ILP to identify cost-effective methods of seed potato production that give a minimum level of seed yield and quality. The use of ILP in this study is innovative because it uses perceived contributions of seed potato management attributes levels to seed potato yield and quality that were obtained through conjoint analysis. Substantially higher costs and time would have been required if this information had to be gathered through field experimentations. A similar method as in our study was used by Gladwin et al. (2001) to develop multiple livelihood strategies of women farmers in Africa; by Fuglie (2004) to assess least-cost animal rations; Valeeva et al. (2007) to optimize costs of attaining different levels of chemical and microbial food safety in the dairy chain in The Netherlands; and by Breusted et al. (2011) to assess how the competitiveness of organic farming is affected by the abolishment of EU milk quota and to investigate to what extent price adjustment might alleviate the effect of these policy changes.

Data on relative contributions of management attribute levels to seed potato yield and quality and costs of an amount of seed potato that could be produced on 0.5 ha were used to develop least cost combinations (LCC) of the management attributes of seed potato production that give certain levels of seed yield and quality for a given ILP specified as

$$\min z = \sum_{a=1}^{A}\sum_{l=1}^{L} C_{al}x_{al} \tag{2}$$

Subject to:

$$\sum_{l=1}^{L} x_{al} = 1, \forall a \in A \tag{3}$$

$$\sum_{a=1}^{A}\sum_{l=1}^{L} r_{alk}x_{al} \geq R_k \tag{4}$$

$$x_{al}: \text{binary variable } \forall x_{al}; a = 1,2,...,A, l = 1,2,...,L \tag{5}$$

where

z, total extra cost of method of production and storage, Ethiopian Birr (ETB) per amount of seed potato that could be produced from 0.5 ha;

A, number of seed potato management attributes;

L, number of levels within an attribute;

C_{al} extra cost of level l within attribute a, $\forall a \in A$; x_{al}, level l within attribute a, $\forall a \in A$;

r_{alk}, increase in yield level (k = 1) or quality level (k = 2) achieved due to selection of attribute-level l within attribute a, $\forall a \in A$;

R_k, required yield level (k = 1) or quality level k = 2).

4.3. Description of data

Two types of data were used: perceived relative contributions of seed potato management attribute-levels to yield and quality, and costs.

Relative contribution of management attribute levels to yield and quality

Data on relative contribution of management attribute levels to seed potato yield and quality were adopted from Hirpa et al. (2012). The management attributes considered were seed source, seed size, storage method, sprouting methods, tillage frequency, planting date, hoeing frequency combined with hill size, and the combination of fertilizer rate and fungicide application frequency. The relative contribution of the levels of the management attributes to seed potato yield and quality was estimated by conducting two consecutive studies: a Delphi study and a conjoint analysis.

The Delphi study was conducted to identify the management attributes and their levels and to prioritize them based on their contribution to seed yield and quality. This study was conducted in September 2010 using five experts and 20 farmers in two major seed potato growing districts, Jeldu and Welmera, in Ethiopia.

The relative effects of the selected management attributes on seed yield and quality were quantified by a conjoint analysis. Conjoint analysis is a technique that is widely used in marketing to measure contributions of different product attributes (e.g. flavour versus size) to the overall preference of a product (e.g., apple) (Green and Rao, 1971; Hair et al., 2006; Rao, 2008). This study used the opinions of 324 seed potato farmers from the two major seed potato growing districts, Jeldu and Welmera. The data were collected through face-to-face interviews using a 0-10 scale (Juster, 1966), mean-centred (to eliminate different use of scale by the respondents (Endrizzi et al., 2011)) and analysed using factorial ANOVA, in which the management attributes were included as factors. Details can be found in Hirpa et al. (2012).

The contributions have artificial units that indicate the relative effect of seed potato management attribute levels on seed yield and quality. The higher the value of the contribution, the higher the positive effect of the management attribute level has on seed yield or quality. From this point onwards, the units of the contributions are referred to as ‘points’. Each contribution within a seed management attribute can be interpreted as the relative effect of that particular attribute level, in terms of points, on seed yield and quality when that level is selected.

Table 4.1 presents the relative contributions (for yield in columns 2 and 5 and for quality in columns 3 and 6). The sum of the relative contribution for the attribute levels that compose a certain production method represents the total effect of this production method on the improvement of seed potato yield and quality, relative to the production method with the minimum yield and quality levels. From here, method of seed potato production is referred to as plan. The maximum yield and quality levels refer to the plan in which, for each attribute, a level with the highest relative contribution was selected. The sum of the highest relative contributions at each attribute shows the maximum yield and quality levels achievable in this study. The sums of the highest relative contributions in points were 5.96 for yield and 6.00 for quality in Jeldu and 5.50 for yield and 5.45 for quality in Welmera.

Costs of seed potato production

Partial budgeting (Huirne and Dijkhuizen, 1997) was used to calculate extra costs resulting from the change in attribute level within an attribute, relative to the attribute level representing the lowest cost (Table 4.1, columns 4 and 7). The extra costs were computed for an amount of seed potato that could be produced on 0.5 ha of land. In the 2010 growing season, many farmers (43.8% in Jeldu and 28.4% in Welmera) used 0.5 ha to produce seed potato. Costs were calculated for each seed potato management attribute level based on the data given in Appendix Tables 1, 2, and 3. Data on farm gate price of seed potato, rental value of land, proportion of tubers appropriate for seed from total tubers harvested, seed rates, fertilizer rate, and anticipated maximum yield were collected from a sample of 324 randomly selected seed growers from two districts, Jeldu and Welmera. Data on amount of human and ox labour, seed potato yield, average prices of market seeds over five years, and proportion of seed sizes when a given seed size was planted were collected from 20 farmers, 10 from each district, who had recorded at least some of the inputs used in seed potato production. The sample farmers were among the 324 farmers and the data were from their records and memories. Data on wage rates (for hoeing and harvesting, ox with operator, and fungicide application), cost to transport seed from storage places to farms and produce from farms to storage places, prices of fertilizers and fungicide, and payments made on contract basis for de-sprouting, sprouting under special condition, guarding, and grading and store loading, were obtained from the sample farmers. Details of the cost calculation and assumptions made are given for each attribute level as follows.

Seed source and size

Own seed is seed produced by a farmer in the previous production cycle for own use in the next cycle. Costs of land, seed, labours, fertilizers, fungicide, transportations, and storage; and amount of yield that could be produced when a particular seed size was planted were used to calculate costs of production of own-small, own-medium, and own-mixed seed potatoes (Appendix Table 2). To complete the cost computation of own seeds two assumptions were made: 1) previous own seed was used to produce the own seed under consideration, and 2) diffused light storage (DLS) with a capacity of 10 to 12 Mg was used to store the seeds.

Market seed is seed potato obtained from nearby open markets. Prices for market seed were obtained from farmers (Appendix Table 1). Only purchase costs were considered. Storage costs were not included because farmers usually buy seed potatoes a few days before planting.

Institution seed is seed potato produced and supplied by a formal institution. Holetta Agricultural Research Centre was the only formal institution that supplied seed potato to farmers in the two districts. The research centre supplied a small amount of seed potato free of charge to demonstrate and popularize improved potato varieties. Therefore, there were no actual prices for institutional seed potato and prices of seed potato obtained from specialized seed potato growers were used as proxies for institution-seed potato prices (Appendix Table 1).

Storage method

Seed potatoes are stored using traditional local storage methods or DLS. Local seed potato storage methods include bed-like structure situated under roof outside or inside a residential house, residential house and postponed harvesting. For the sake of simplicity, all local storage methods were assumed to have the same storage characteristics and their costs were set as zero. For DLS, it was assumed that additional costs for construction had to be made. In both districts, DLSs varied in their sizes and economic lives. During field observations made in 2011, DLSs were found to vary in size from 12 - 160 m^2 and in economic life from 5 to 20 years.

Table 4.1. Relative contribution to yield and quality and extra costs of different levels of seed potato management attributes in two districts. Extra costs are calculated for seed tubers produced on 0.5 ha.

	Jeldu			Welmera		
Attributes	Yield (in points)[a]	Quality (in points)[a]	Extra costs (ETB/0.5 ha)	Yield (in points)[a]	Quality (in points)[a]	Extra costs (ETB/0.5 ha)
Seed source and size						
Own-small	0.23	0.30	330	0.62	0.65	0
Own-mixed	0.19	0.36	751	0.56	0.63	623
Own-medium	0.60	0.80	208	0.71	0.86	143
Market-small	0.04	0.00	0	0.06	0.02	25
Market-mixed	0.00	0.06	1010	0.00	0.00	1390
Market-medium	0.41	0.50	950	0.15	0.23	1050
Institution-small	0.43	0.49	850	0.54	0.81	925
Institution-mixed	0.39	0.54	3025	0.48	0.80	2690
Institution-medium	0.80	0.99	3110	0.63	1.02	2810
Storage method						
Local	0.00	0.00	0	0.00	0.00	0
DLS[b]	0.91	1.02	16000	0.78	0.82	16000
Sprouting method						
De-sprouted	0.00	0.00	14.4	0.00	0.02	15
Special action	0.10	0.01	144	0.12	0.00	170
In store	0.51	0.56	0	0.45	0.49	0
Tillage frequency						
Three	0.16	0.00	0	0.00	0.00	0
Four	0.00	0.41	105	0.19	0.20	175
Five	0.15	0.30	210	0.11	0.27	350
Planting date						
Earlier	0.00	0.00	0	0.00	0.00	0
Recommended	0.61	0.59	1010	0.28	0.20	1099
Hoeing frequency and hill size						
Once and small	0.12	0.00	0	0.06	0.00	0
Twice and small	0.00	0.23	280	0.00	0.22	310
Twice and big	0.86	0.87	380	0.92	0.86	464
Interaction between FR[c] and FA[d]						
Below recommended FR and once FA	0.00	0.36	0	0.00	0.00	0
Below recommended FR and twice FA	0.25	0.00	655	0.63	0.17	660
Below recommended FR and thrice FA	0.43	0.38	1310	0.92	0.65	1320
Recommended FR and once FA	0.62	0.46	902	0.93	0.66	894
Recommended FR and twice FA	2.11	1.56	1557	2.17	1.79	1554
Recommended FR and thrice FA	1.50	1.25	2212	2.08	1.62	2214
Above recommended FR and once FA	0.36	0.24	1214	0.92	0.47	1189
Above recommended FR and twice FA	0.70	0.67	1869	1.34	1.25	1849
Above recommended FR and thrice FA	1.08	1.09	2524	1.34	1.39	2509

[a] Adopted from Hirpa et al. (2012).
[b] DLS represents diffused-light storage.
[c] FR represents fertilizer rate.
[d] FA represents fungicide application.

Overload was one of the reasons for the short economic lives of some of the DLSs. Farmers loaded 0.12 to 0.20 Mg seed potato per m^2 against a recommended load of 0.10 Mg seed potato per m^2. A DLS of average economic life of 10 years that has a size of 30 m^2 was used to estimate cost of storage. This is an ideal size of DLS with a storage capacity of 10 to 12 Mg seed potato. The costs of construction for an average DLS were approximately the same in both districts and estimated at 16,000 ETB.

Sprouting method

Seed potato sprouting methods are in-store sprouting, de-sprouting and sprouting under special condition. In-store sprouting is leaving seed potato to sprout where it is stored. The cost of the in-store sprouting method was set to zero. De-sprouting was practiced to remove apical dominance. Cost of de-sprouting was wage paid for labour to de-sprout 1.2 Mg of seed potato in Jeldu and 1 Mg in Welmera. Sprouting under special conditions is a method used to advance sprouting. In the studied areas, farmers used storage in straw, sacks and sun to advance sprouting. In the cost estimation of sprouting under special condition, only cost of labour was considered.

Tillage frequency, planting date and hoeing/hill size

Costs for land tillage frequency were calculated per 0.5 ha. The costs included ox labour and operator. The data on number of ox days per tillage and wage rates are given in Appendix Table 1. Costs differed between the two planting dates, earlier than recommended period and recommended, because of difference in labour efficiency. Labour efficiency in earlier than recommended planting period was higher than in recommended planting period because of lower workability of soil and interruption of agricultural activities due to rainfall in the latter. Because of high rainfall, hoeing and hill making are slower in the recommended period compared to the earlier than recommended period. According to key informants, in Jeldu and Welmera, amounts of labour used for hoeing and hilling of seed potato fields planted earlier than the recommended period were lower by 50% than the amount of labour required for the same size of seed potato field planted in the recommended period. Fungicide application frequency was found to increase by one application for potato planting in the recommended period compared to potato planted earlier than the recommended period because of higher incidence of late blight (caused by *Phytophthora infestans*) on the former.

Costs of hoeing frequency and hilling size were estimated based on the amount of labour required for hoeing and hilling (Appendix Table 1). Further assumptions were made to estimate costs of the two types of hill sizes. The labour required to make big hills was assumed to be two times that of the labour required to make small hills. The average number of labour days required for first hoeing, and second hoeing combined with hilling is given in Appendix Table 1.

Fertilizer and fungicide

Costs of fertilizer rate (FR) and fungicide application (FA) comprised prices of fertilizers (DAP and urea) and fungicide at a nearby store and costs of labour to apply fertilizers and fungicide on the potato field. Data on the amount of fertilizer for the three rates (below recommended, recommended, and above recommended), FA frequency, amount of fungicide per application, prices of fertilizers, price of fungicide, costs of labour to apply fertilizers and fungicide are presented in Appendix Table 3.

4.4. Data analysis

The ILP model was specified in a Microsoft Excel spread sheet and solved using solver with integer tolerance of 0% to develop optimal seed potato production and postharvest management plans. The optimal plans were developed for three scenarios, representing three situations. The first scenario comprised optimal plans developed for farmers who wanted to start seed potato production or develop a new plan of seed production. The second scenario developed optimal plans for farmers using DLS. Most seed potato growers use DLS to store seed potatoes of improved varieties (Tesfaye et al., unpublished data, 2007; Hirpa et al., 2012). The third scenario generated plans for seed growers who either want to increase yield, while keeping quality at a fixed level (i.e. average quality of all farms), or want to increase seed quality while keeping yield at a fixed level (i.e. average yield of all farms). This scenario developed plans that enable seed growers to respond optimally to market incentives that reward either only higher yields (‘bulk’ production) or increasing quality (potatoes for specific markets).

In the first scenario, the first optimal plan was developed by relaxing the constraint on yield and quality levels (inequality constraint (4)). The second and subsequent plans were developed by imposing inequality constraint 4. Yield and quality for each subsequent optimization were set to be greater than or equal to the yield and quality levels of the preceding optimal plan plus 0.001 points to force the model to generate a next optimal plan rather than to repeat a plan. The process continued until the model stopped generating a new optimal plan.

The second scenario used the same constraints and processes as the first scenario but included a constraint that forced DLS to be included in the optimal plans. The third scenario also used the same constraints and processes as the first scenario except that optimal plans were developed for two cases. In case (a), quality level of a plan was fixed in a range around its average value (average value minus 0.01 and plus 0.01), and in case (b), yield level of a plan was fixed in a range around its average value (average value minus 0.01 and plus 0.01). The fixed ranges allowed for the development of a number of optimal plans.

For each plan, sensitivity analyses were conducted at 25% and 50% increases in rental value of land, prices of seed potatoes (seed potatoes used to produce own small, own mixed, and own medium size seed potatoes), wage rates of human and oxen labours, and agrochemicals (fertilizers and fungicide).

4.5. Results

This section presents results of cost-effective methods of seed potato production under three scenarios.

Scenario I

Figures 4.1 and 4.2 present minimum total extra costs of plans of seed potato production to achieve certain seed yield and quality levels in Jeldu and in Welmera, respectively. In this scenario, 14 plans in Jeldu and 19 plans in Welmera were generated before the model stopped giving an optimal plan. Minimum total extra costs increased gradually with the gradual increases in seed yield levels and seed quality levels for Plans 1 through 11 in Jeldu and 1 through 15 in Welmera. For Plans 12 through 14 in Jeldu and 16 through 19 in Welmera, the costs increased abruptly. The abrupt increase in the costs in both districts was caused by the inclusion of DLS in the plans (Figure 4.1 for Jeldu and Figure 4.2 for Welmera). Plans 7 to 11 in Jeldu and 10 to 15 in Welmera gave near to average and above average of their respective districts yield and quality levels at low extra costs (less than ETB 6100 per 0.5 ha in Jeldu and less than ETB 3500 per 0.5 ha in Welmera.

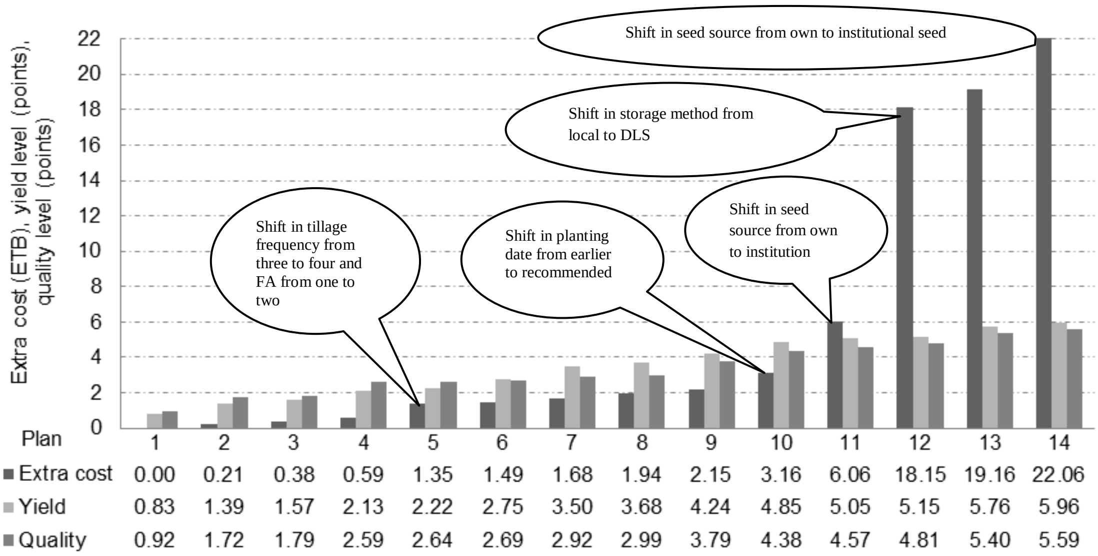
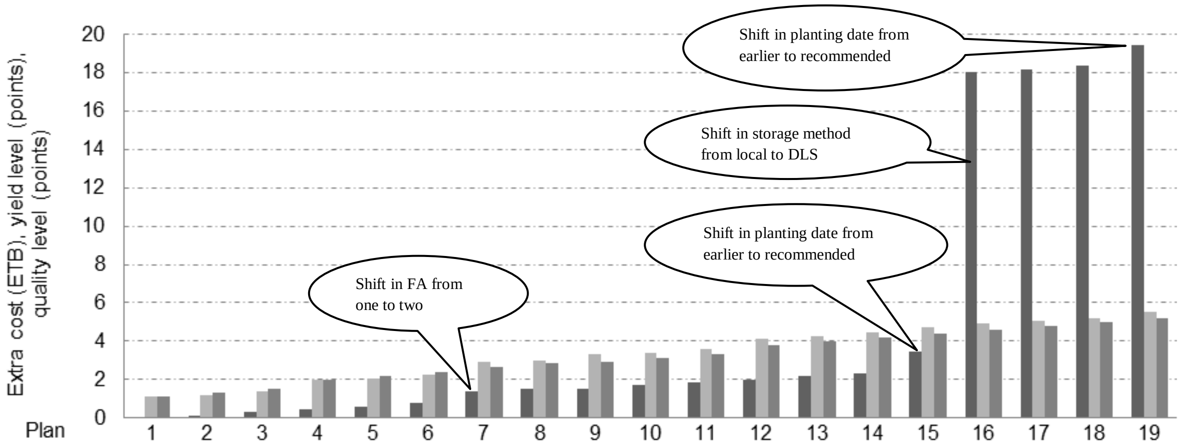


Figure 4.1. Minimum total extra costs of plans of seed potato production to achieve certain yield and quality levels of seed potato in Jeldu. FA represents fungicide application frequency; DLS represents diffused light storage.

In this scenario, all plans were robust to a 50% increase in rental value of land in both districts and wage rates (human and bullock labours) in Jeldu. In Jeldu, all plans except Plan 2 and 7 were robust to 50% increase in prices of seed potatoes (seed potatoes used to own small, own mixed and own medium). In Welmera, more than 60% of the plans were robust to a 50% increase in prices of seed potatoes (only Plans 2, 5, 8, 10, 13, and 17 changed at a 25% increase and Plans 3 and 11 changed at 50% increase). In Welmera, 25% increase in wage rates changed Plan 8 and a further increase in wage rates changed one more plan, Plan 7. Of total plans 65% in Jeldu and 74% in Welmera were robust to a 50% increase in the prices of agrochemicals (fertilizers and fungicide).

Scenario II

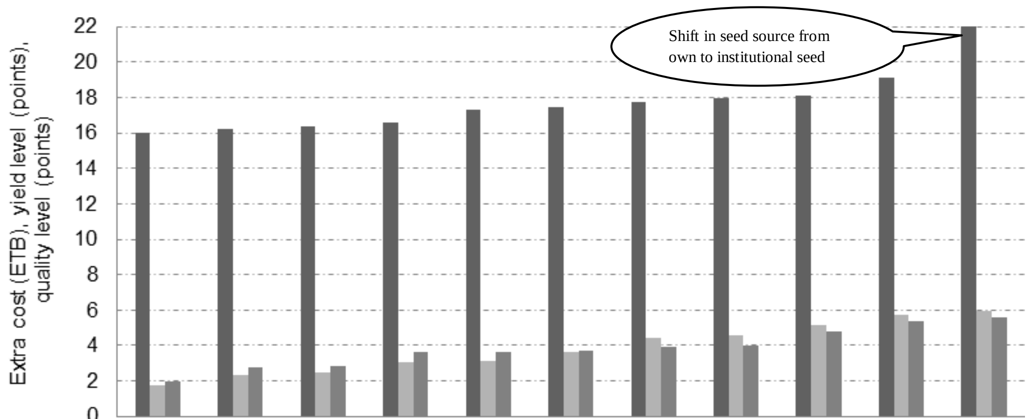
Figures 4.3 and 4.4 present minimum total extra costs required to achieve certain yield and quality levels of seed potato when DLS was included in all plans in Jeldu and Welmera, respectively. In this scenario 11 plans in Jeldu and 15 plans in Welmera were generated. In both districts, minimum total extra costs increased gradually across plans with the gradual increases in yield and quality levels (Figure 4.3 for Jeldu and Figure 4.4 for Welmera).



Plan	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Extra cost	0.00	0.14	0.32	0.46	0.61	0.78	1.36	1.50	1.55	1.70	1.87	2.02	2.16	2.34	3.44	18.02	18.16	18.34	19.44
Yield	1.13	1.22	1.41	1.99	2.08	2.27	2.92	3.01	3.30	3.39	3.58	4.16	4.25	4.44	4.72	4.94	5.03	5.22	5.50
Quality	1.14	1.35	1.55	2.00	2.21	2.41	2.66	2.87	2.93	3.14	3.34	3.79	4.00	4.20	4.40	4.61	4.82	5.02	5.22

Figure 4.2. Minimum total extra costs of plans of seed potato production to achieve certain yield and quality levels of seed potato in Welmera. FA represents fungicide application frequency; DLS represents diffused light storage.

Like in Scenario I, all plans were robust to a 50% increase in rental value of land in both districts and wage rates in Jeldu. Of total plans, about 82% in Jeldu and about 54% in Welmera were robust to 50% increase in prices seed potatoes. In Welmera, 87% of the plans were robust to 50% increase in wage rates. A 25% increase in the price of agrochemicals did not change 83% of the plans in Jeldu and 99% of the plans in Welmera but a further increase in the price by 50% decreased the robust plans to 55% in Jeldu and 60% in Welmera.



Plan	1	2	3	4	5	6	7	8	9	10	11
Extra cost	16.00	16.21	16.38	16.59	17.35	17.49	17.77	17.94	18.15	19.16	22.06
yield	1.74	2.30	2.48	3.04	3.13	3.66	4.41	4.59	5.15	5.76	5.96
quality	1.94	2.74	2.81	3.61	3.66	3.71	3.94	4.01	4.81	5.40	5.59

Figure 4.3. Minimum total extra costs of plans of seed potato production to achieve certain yield and quality levels of seed potato when DLS is included in all plans in Jeldu.

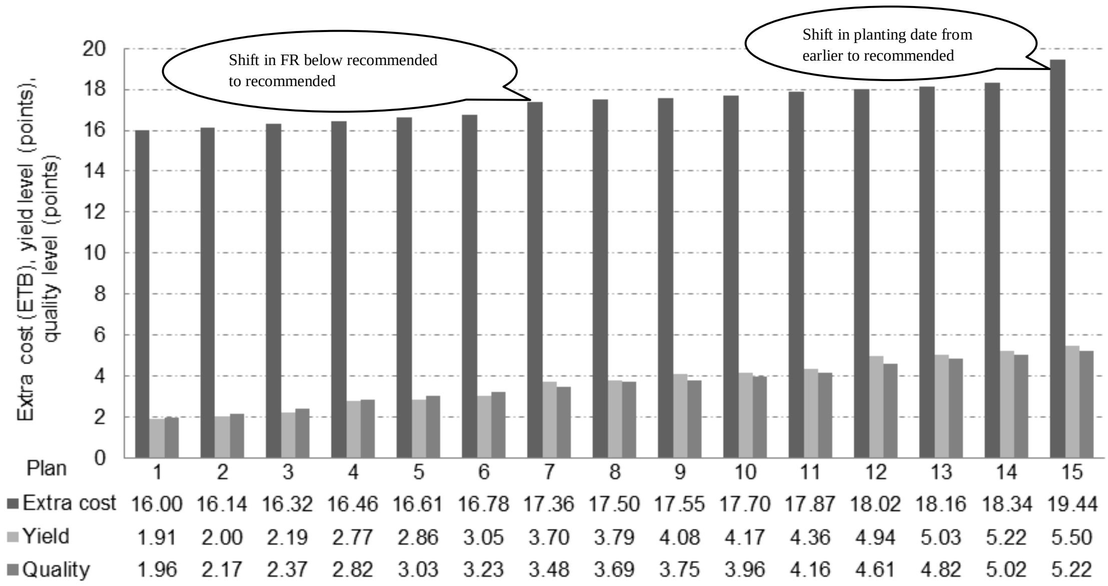


Figure 4.4. Minimum total extra costs of plans of seed potato production to achieve certain yield and quality levels of seed potato when DLS is included in all plans in Welmera. FA represents fungicide application frequency.

Scenario III

In this scenario, optimal plans were developed for two cases, (a) quality level of a plan was fixed in a range around its average value, and (b), yield level of a plan was fixed in a range around its average value. Figures 4.5 (for Jeldu) and 6 (for Welmera) present minimum total extra costs required to achieve certain yield and quality levels of seed potato for two cases, (a) and (b). In Jeldu, four plans for case (a) and nine plans for case (b) were generated of which the last three plans in case (b) required higher costs than the remaining plans. The higher costs of these plans were caused by the inclusion of DLS in the plans (Figure 4.5). In Welmera, four plans for case (a) and eight for case (b) were developed of which one plan in case (a) and four plans in case (b) required higher costs than the remaining plans because of the inclusion of DLS instead of local storage (Figure 4.6).

In this scenario, seed potato production plans were robust to a 50% increase in rental value of land, seed potatoes costs, and wage rates in both districts and to a 25% increase in the price of agrochemicals in Jeldu. In Jeldu, 50% increase in the price of agrochemicals changed no plan in case (a) and two plans (Plans 3 and 5) in case (b). In Welmera, 25% increase in the price of agrochemicals changed Plan 3 in case (b) and a further increase in the price by 50% did not change any additional plan.

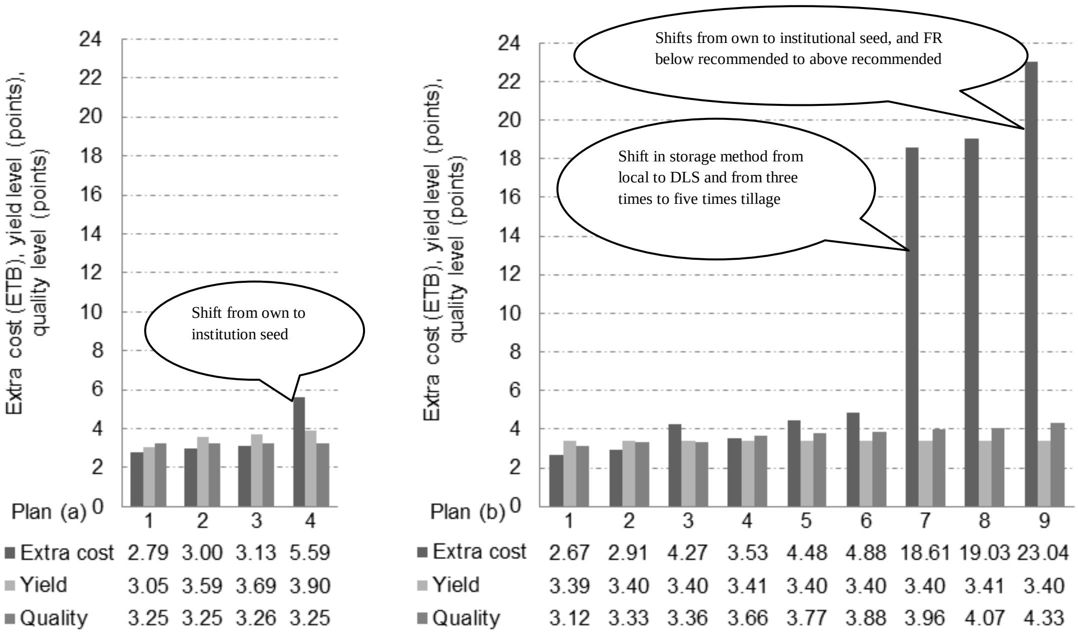


Figure 4.5. Minimum total extra costs of plans of seed potato production to achieve certain yield and quality levels of seed potato when quality is fixed at average level of 3.25 to 3.27 (a) and yield is fixed at average level of 3.39 to 3.41 (b) in Jeldu. DLS represents diffused light storage; FR represents fertilizer rate.

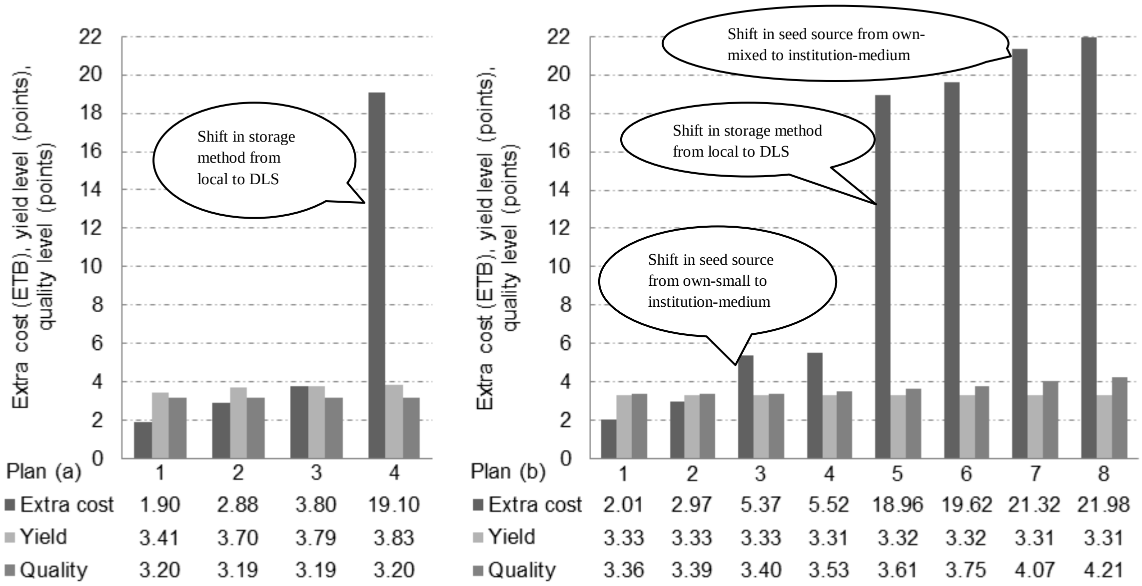


Figure 4.6. Minimum total extra costs of plans of seed potato production to achieve certain yield and quality levels of seed potato when quality is fixed at average level of 3.18 to 3.20 (a) and yield is fixed at average level of 3.31 to 3.33 (b) in Welmera. DLS represents diffused light storage.

4.6. Discussion

This study uses an integer linear programming model and the perceived impacts of management attributes to yield and quality to determine cost effective seed potato production plans. The results showed that, in both districts, alternative plans could be developed from which farmers can select based on the amount of money they can allocate to seed potato production.

In the first scenario, there were 14 cost effective plans in Jeldu and 19 in Welmera. Among these plans, some had low costs (e.g., Plans 9 to 11 in Jeldu and Plans 12 to 15 in Welmera) but gave yield and quality levels comparable to high cost plans (plans with DLS) suggesting a potential for improving yield and quality levels with local storage methods. These low-cost plans, except Plan 13 in Welmera, were robust to a 50% increase in the rental value of land, prices of seed potatoes, wage rates, and prices of agrochemicals.

In both districts, the majority of plans in the first scenario contained own medium sized seed, local storage method, in-store sprouting method, three times of tillage, earlier than recommended planting date, hoeing twice combined with big hill size, and recommended FR combined with two FA frequency. However, there were some differences between the plans in the two districts. Some plans in Jeldu but none in Welmera contained small-sized market seed indicating that market seed was more important for farmers in Jeldu than in Welmera. This result supports the finding of Hirpa et al. (2012) that revealed a low trust in market seed by farmers in both districts because of diseases; also they found that the extent of miss trust was higher in Welmera than in Jeldu which was attributed to the prevalence of bacterial wilt in Welmera (no bacterial wilt in Jeldu). There were more plans in Welmera than in Jeldu that contained four times of tillage and hoeing once combined with small hill size, indicating farmers in Welmera gave higher emphasis to tillage and less emphasis to hoeing than farmers in Jeldu.

In the second scenario, most of the plans (Plans 1 through 8 in Jeldu and Plans 1 through 11 in Welmera) required higher costs than plans with roughly similar yield and quality levels in the first scenario, indicating that the inclusion of the DLS in the plans contributed more to the rise of costs than to the improvement in yield and quality levels. In this scenario, plans that comprised management attributes such as recommended FR combined with two FAs and twice hoeing combined with big hills (e.g., Plans 9 through 12 in Jeldu and Plans 12 through 15 in Welmera) gave high yield and quality levels, indicating a seed potato grower who had DLS had to use high levels of other management attributes to reap a maximum benefit from seed potato production. In both districts, most plans included own medium-sized seed, three times of tillage, earlier than recommended period, hoeing twice combined with big hill size, and recommended FR combined with two FA frequencies. In Jeldu, some plans comprised market seed and institutional seed but in Welmera, all plans comprised own seed indicating the difference in the importance of seed source between the districts.

The third scenario developed plans that enable seed growers to either improve quality or to improve seed potato yield. The scope for improvement in yield level when quality levels were fixed around its average value, and the scope of improvement in quality level when yield levels were fixed around its average value were lower than the scope of improvement in scenario I. This is reflected by the finding of a few numbers of plans and low yield (Figure 4.5 and 4.6 case (a)) and low quality levels (Figure 4.5 and 4.6, case (b)). The plans in this scenario could be used when there was a market that can pay a premium to a specified yield or quality. Currently, in Ethiopia, there is no market that demands seed potato of a specified yield or quality level.

According to our survey, seed potato growers were highly heterogeneous in plans they followed to produce seed potato in 2010. Plans (one for Jeldu and one for Welmera) developed by using attribute levels used by the majority of seed potato growers to produce seed in 2010 were followed only by 9.9% in Jeldu and 13.0% in Welmera. These plans were not similar to any of the plans developed through optimization. The attribute levels used by the majority of the farmers were own medium-sized seed (75.9% in Jeldu and 74.7% in Welmera), DLS (81.5% in Jeldu and 71.6% in Welmera), in-store sprouting (100% in both districts), four times of tillage (70.4% in Jeldu and 66.0% in Welmera), planting earlier than recommended period in Jeldu (81.5%), planting within the recommended time range in Welmera (60.5%), hoeing twice combined with big hill size (59.3% in Jeldu and 80.9% in Welmera), and below recommended FR combined with two FAs (48.8% in Jeldu and 56.2% in Welmera). By advising farmers to adopt plans that are affordable to them, it is possible to classify farmers into groups based on the plans they use, and provide demand driven supports. The supports could be technical advises and inputs supply.

The plans developed in this study were based on relative contributions of selected seed potato management attributes levels to seed yield and quality and minimum extra costs required to shift to other attribute levels. The change in the plans could be caused by changes in the extra costs. The amount of extra costs is affected by changes in the rental values of land, prices of seed potatoes, wage rates and prices of agrochemicals. For instance, between 2010 and 2011 price of DAP increased by about 25%. The result of the sensitivity analysis showed that most plans were robust for 25 and 50% increases of rental values of land, prices of seed potatoes, wage rates and prices of agrochemicals in all scenarios and in both districts.

4.7. Conclusions

This paper developed cost-effective plans for seed potato production in two regions in Ethiopia, i.e. Jeldu and Welmera. The plans were developed for three scenarios representing different situations for farmers. In the first scenario representing farmers that start seed potato production or develop a new plan for seed production (scenario I), 10 (out of 14) in Jeldu and 14 (out of 19) in Welmera required relatively low extra costs (less than 28% of largest extra cost plan in Jeldu and 18% of largest extra cost plan in Welmera) but gave substantially higher seed potato yield levels (84.7% of largest yield level plan, in Jeldu and 85.8% in Welmeral of largest yield level plans) and quality levels (81.7% of largest quality level plan in Jeldu and 84.3% of largest quality level plan in Welmeral). Therefore, in Jeldu and Welmera, seed potato growers could improve seed yield and quality levels compared to default levels by adopting an affordable plan. These low-cost optimal plans can also attract non-adopters to adopt improved potato varieties, and production and postharvest management practices.

Results of the scenario representing farmers using DLS (scenario II) showed that seed potato growers could improve seed potato yield and quality levels by applying management attributes with higher yield and quality contributions (for example, use of recommended fertilizer rate combined with two fungicide applications) than those with lower yield and quality contributions (for example, use of below recommended fertilizer rate combined with two fungicide applications).

The results of the third scenario demonstrated that the scope for improving yield when quality is held constant at the average level is very small. Also, the scope for improving quality when fixing yield at the average level is very small. These outcomes suggest that quality and yield improvements more likely go together. Nevertheless, seed growers can use these plans if the market rewards only improving quality rather than yield and vice versa.

The results of this study can be used by extension service officers to recommend farmers a plan that they deem affordable and that enables farmers to achieve acceptable yield and quality levels. In both districts, farmers currently use a wide variety of plans to produce seed potato. This situation could be an obstacle to designing and delivering advices that can help farmers to improve seed potato production. The plans developed in this study can help experts to categorize farmers into different groups based on the plans they prefer to follow and give advice to farmer groups rather than farmers individually. For researchers, the knowledge is useful to develop viable alternative plans of seed potato. For policy makers, the model can be used as a tool to steer cost-effective food security improvements in Ethiopia.

References

Araya, N.S., 2011. Weather insurance for farmers: experience from Ethiopia. Paper presented at the International Fund for Agricultural Development (IFAD) Conference on New Directions for Smallholder Agriculture, 24-25 January, 2011, Via Paolo Di Dono, 44, Rome 00142, Italy. Accessed April 2012, available at http://www.ifad.org/events/agriculture/doc/papers/araya.pdf.

Breustedt, G., Latacz-Lohmann, U., Tiedemann, T., 2011. Organic or conventional? Optimal dairy farming technology under the EU milk quota system and organic subsidies. Food Policy 36, 223-229.

Croppenstedt, A., Demeke, M., Meschi, M.M., 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. Review of Development Economics 7(1), 58-70.

Endrizzi, I., Menichelli, E., Johansen, S.B., Olsen, N.V., Naes, T., 2011. Handling of individual differences in rating-based conjoint analysis. Food Quality and Preference 22, 241-254.

Fare, R., Primont, D., 1995. Multi-Output Production and Duality: Theory and Applications. Boston, Kluwer Academic Publishers.

Foster, A.D., Rosenzweig, M.R., 2010. Micro-economics of technology adoption. Annual Review of Economics 2, 395-424.

Fuglie, K.O., 2004. Challenging Bennet’s law: the new economics of starchy staples in Asia. Food Policy 29, 187-202.

Gladwin, C.H., Thomson, A.M., Peterson, J.S., Anderson, A.S., 2001. Addressing food security in Africa via multiple livelihood strategies of women farmers. Food Policy 26, 177-207.

Gildemacher, P., Demo, P., Barker, I., Kaguongo, W., Gebremedhin, W., Wagoire, W., Wakahiu, M., Leeuwis, C., Struik, P.C., 2009. A description of seed potato systems in Kenya, Uganda and Ethiopia. American Journal of Potato Research 86, 373-382.

Gildemacher, P., Schulte-Geldermann, E., Borus, D., Demo, P., Kinyae, P., Mundia, P., Struik, P.C., 2011. Seed potato quality improvement through positive selection by smallholder farmers in Kenya. Potato Research 54, 253-266.

Green, P.E, Rao, V.R., 1971. Conjoint measure for quantifying judgment data. Journal of Marketing Research 8, 355-363.

Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E., Tatham, R.L., 2006. Multivariate Data Analysis, 6th edition. Pearson Education, New Jersey.

Hirpa, A., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Oude Lansink, A.G.J.M., Tsegaye, A., Struik, P.C., 2010. Analysis of seed potato systems in Ethiopia. American Journal of Potato Research 87, 537-552.

Hirpa, A., Meuwissen, M.P.M., Ivo, V.L., Lommen, W.J.M., Oude Lansink, A.G.J.M., Tsegaye, A., Struik, P.C., 2012. Farmers' opinion on seed potato management attributes in Ethiopia: a conjoint analysis. Agronomy Journal 104, 1413-1423.

Huirne, R.B.M., Dijkhuizen, A.A., 1997. Basic methods of economic analysis. In A.A. Dijkhuizen and R.S. Morris (eds), Animal health economics: principles and applications. Sydney: Post Graduate Foundation in veterinary Science, University of Sydney.

International Potato Center (CIP), 2011. Roadmap for investment in the seed potato value chain in eastern Africa. Lima, Peru. 27 pp.

Juster, F.T., 1966. Consumer buying intentions and purchase probabilities: An experiment in survey design. Journal of American Statistical Association 61(315), 658-696.

Langyintuo, A.S., Mungoma, C., 2008. The effect of household wealth on the adoption of improved maize varieties in Zambia. Food Policy 33, 550-559.

Mulatu, E., Osman, E. I., Etenesh, B., 2005. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. Journal of New Seeds 7(3), 31-56.

Murty, K.G., 2010. Optimization for decision making: Linear and quadratic models. International Series in Operations Research and Management Science 137, 1-38. doi 10.1007/978-1-4419-1291-6_2.

Rao, V.H., 2008. Development in conjoint analysis. Handbook of marketing models, International Series in Operations Research and Management Sciences 121, part 2, 23-53.

Valeeva, N.I., Huirne, R.V.M., Meuwissen, M.P.M., Oude Lansink, A.G.J.M., 2007. Modelling farm-level strategies for improving food safety in the dairy chain. Agricultural systems 94, 528-540.

Yesuf, M., Bluffstone, R., 2007. Risk aversion in low-income countries: Experimental evidence from Ethiopia. International Food Policy Research Institute (IFPRI) discussion paper No. 715, Washington D.C., 36 pp.

Yu, B., Nin-Pratt, A., Funes, J., Gemessa, S.A., 2011. Cereal production and technology adoption in Ethiopia. International Food Policy Research Institute (IFPRI).Working paper 31. Accessed February 2012, available at http://www.ifpri.org/publication/cereal-production-and-technology-adoption-ethiopia-0.

Appendices

Appendix Table 1. Mean values of seed potato prices, rent, proportion of seed, seed rates, amount of labour, and cost of labour in two districts

Item	Jeldu			Welmera		
	N	Mean	Std. dev.	N	Mean	Std. dev.
Price (ETB[a]/Mg[b]) of medium size seed potato	130	3211	1041.5	141	3723	936.1
Land rent (ETB/ha)	81	2019.0	1131.5	88	1430.5	835.8
% seed potato from total tubers harvested from seed potato plot	147	70.0	18	155	78.6	15
Seed rate when planting small seed size (Mg/ha)	54	1.7	0.61	83	1.5	0.57
Seed rate when planting medium seed size (Mg/ha)	55	2.4	0.97	84	2.0	0.72
Seed rate when planting mixed seed size (Mg/ha)	54	3.1	1.20	82	2.6	0.94
Below recommended DAP rate (kg/ha)	85	101.6	37.72	112	96.2	40.0
Recommended DAP rate (kg/ha)	3	195	0	1	195	0
Above recommended DAP rate (kg/ha)	74	215.2	40.29	49	222.5	45.12
Below recommended urea rate (kg/ha)	140	73.5	38.35	134	82.0	37.41
Recommended urea rate (kg/ha)	3	165	0	1	165	0
Above recommended urea rate (kg/ha)	19	211.4	34.27	27	199.0	22.29
Bullock and operator labour required to plough 1 ha and lift tubers produced on 1 ha (ox days (OD) [c])						
1st tillage	10	7.2	1.03	10	7.0	1.83
2nd tillage	10	5.3	0.48	10	6.2	2.10
3rd tillage	10	4.9	0.57	10	5.3	1.70
4th tillage	10	4.6	0.63	10	5.0	1.15
Lifting tubers	10	9.0	1.05	10	9.1	1.10
Human labour (in man-day (MD) [d]) required for 1 ha						
Planting	10	22.0	3.90	10	17.9	2.60
1st hoeing	10	28.0	4.90	10	24.8	1.40
2nd hoeing plus hilling [e]	10	48.0	5.10	10	49.5	7.20
Harvesting	10	42.4	4.80	10	45.2	5.67
Grading (sorting) and store loading of 1 Mg tubers	10	2.0	0.47	10	1.5	0.33
Anticipated maximum yield (Mg/ha)	162	33.3	9.3	162	25.3	9.6
Yield (Mg/ha) of progeny of small size seed	10	16	1.23	10	18	1.08
Yield (Mg/ha) of progeny of medium-size seed	10	35	3.02	10	27	2.30
Yield (Mg/ha) of progeny of mixed size seed	10	27	1.89	10	22	1.70
Prices [f] of 1 Mg market seed of different sizes						
Small seed size	10	1000	233.33	10	1300	163.30
Medium seed size	10	1500	313.30	10	2000	266.67
Mixed seed size	10	1200	253.33	10	1800	230.94
Prices of 1 Mg of improved seed of different sizes						
Small seed size	10	2000	356.34	10	2500	278.89
Medium seed size	10	3300	924.42	10	3760	620.39
Mixed seed size	10	2500	444.36	10	2800	301.84
Price of 1 Mg of tuber (unfit for seed) sold as ware potato	10	800	105.41	10	1000	124.72
Cost of labour (ETB) for de-sprouting of 1 Mg seed	10	12	2.05	10	15	2.36
Cost of labour (ETB) sprouting under special condition of 1 Mg seed	10	120	14.91	10	170	18.86
			Unit costs (ETB)			
Cost of transportation of 100 kg seed from home to the field	-	6	-	-	3	-
Ox day (wage) rate	-	50	-	-	70	-
Wage rate (1 MD)	-	20	-	-	25	-
Cost fungicide application (1 MD)	-	50	-	-	60	-
Price of 100 kg fertilizer-DAP	-	1055	-	-	1052	-
Price of 100 kg fertilizer-Urea	-	888	-	-	886	-
Price of 1 kg fungicide (Ridomil MZ 63.5% WP)	-	420	-	-	420	-
Cost of transportation of 100 kg tubers from field to home	-	7	-	-	3	-
Guarding potato plant and tubers on the field (1 ha for 1 month)	-	400	-	-	400	-

[a] ETB represents Ethiopian Birr (USD 1 equivalent to ETB 17 on August 15, 2011).
[b] Mg represents mega gram.
[c] OD represents ox day (1 ox day in Jeldu and Welmera was plowing of land for 5 hours with a pair of oxen).
[d] MD represents man-day.

[e] 1st hoeing and 2nd hoeing were assumed to consume the same amount of labour and 20 MD (48-28) is the amount of labour used for hilling.
[f] Prices of market seed were prices averaged over five years for seed potatoes sold in the open market

Appendix Table 2. Cost[a] (in ETB[b]) required to produce and store own seed that could be produced on 0.5 ha in two districts.

Items	Jeldu			Welmera		
	Quantity	Unit cost	Total cost	Quantity	Unit cost	Total cost
A. Own small-size seed potato						
1. Rental value of land	0.5 ha	2019	1010	0.5 ha	1431	716
2. Seed (seed @ 1.7 Mg[c] /ha in Jeldu and 1.5 Mg/ha in Welmera) for 0.5 ha	0.85 Mg	2000	1700	0.75 Mg	2500	1875
3. Cost of 1 Mg of seed transportation to the field (ETB)	0.85 Mg	60	51	0.75 Mg	30	23
4. 1st tillage (bullock labour + operator)	3.65 OD[d]	50	175	3.5 OD	70	245
5. 2nd tillage (bullock labour + operator)	2.65 OD	50	125	3.0 OD	70	210
6. 3rd tillage (bullock labour + operator)	2.45 OD	50	125	2.5 OD	70	175
7. 4th tillage (bullock labour + operator)	2.3 OD	50	100	2.5 OD	70	175
8. Labour for planting	11 MD	20	220	9 MD	25	225
9. Labour for 1st hoeing	14.0 MD	20	280	12.4 MD	25	310
10. Labour for 2nd hoeing plus hilling	24.0 MD	20	480	24.75 MD	25	619
11. Labour for fungicide application	1.5 MD	50	75	1.5 MD	60	90
12. Guarding potato (plant and tubers) on the field	2 months	200	400	2 months	200	400
13. Amount of fertilizers – DAP	100 kg	10.55	1055	100 kg	10.52	1052
14. Amount of fertilizers – urea	75 kg	8.88	666	75 kg	8.86	665
15. Fungicide application frequency [e] (on 0.5 ha)	3 times	630	1890	3 times	630	1890
16. Lifting tubers (bullock labour + operator)	4.5 OD	50	225	4.55	70	319
17. Labour for harvesting [f]	10.19 MD	20	204	16.08 MD	25	402
18. Transport cost of potato produced on 0.5 ha	8 Mg	70	560	9 Mg	30	270
19. Cost of grading and store loading [g]	8 Mg	20	160	9 Mg	15	135
20. Storage cost ETB/Mg (net seed (@ 100% [h])	8 Mg	200	1600	9 Mg	178	1600
21. Total cost of own-small seed potato [1 + 2 + ... + 20]	8 Mg	-	11101	-	-	11396
22. **Cost of own-small sized seed (ETB/Mg)**	**-**	**1388**	**-**	**-**	**1266**	
B. Own-mixed sized seed potato						
23. Seed (seed @ 3.1 Mg/ha in Jeldu and 2.6 Mg/ha in Welmera) for 0.5 ha	1.55 Mg	2500	3875	1.3 Mg	2800	3640
24. Cost of Mg of seed transportation to the field (ETB)	1.55 Mg	60	93	1.3 Mg	30	39
25. Labour for harvesting[f]	17 MD	20	340	18 MD	25	450
26. Cost of transport	13.5 Mg	70	945	11.0 Mg	30	330
27. Cost of grading and store loading	13.5 Mg	20	270	11.0 Mg	15	165
28. Storage cost, in ETB/Mg (net seed (@ 100%)	13.5 Mg	118.5	1600	11.0 Mg	145.5	1600
29. Total cost of own mixed-sized seed [1 + (4 to 16) + (23 to 28)]			13949			13315
30**. Cost of own mixed-sized seed (ETB/Mg)**	**-**	**1033**	**-**	**-**	**1210**	**-**
C. Own-medium sized seed potato						
31. Seed (seed @ 2.4 Mg/ha in Jeldu and 2.0 Mg/ha in Welmera) for 0.5 ha	1.2 Mg	3211	3853	1.0 Mg	3723	3723
32. Transportation of seed to the field (ETB)	1.2 Mg	60	72	1.0 Mg	30	30
33. Labour for harvesting	21.2 MD	20	424	22.6 MD	25	565
34. Transport produce	16.65 Mg	70	1166	12.65 Mg	30	380
35. Cost of grading and store loading	16.65 Mg	20	333	12.65 Mg	15	190
36. Storage cost ETB/Mg (net seed (@ 70.0% for Jeldu and 78.6% for Welmera)	11.66 Mg	137	1600	9.94 Mg	161	1600
37. Value of tuber not used as seed (ETB 800 per Mg in Jeldu and ETB 1000 per Mg in Welmera)	4.99 Mg	-	-3992	2.71 Mg		-2710
38. Total cost of own medium-sized seed [1 + (4 to 16) + (31 to 37)]	-	-	10282	-	-	10869
39. **Cost of own-medium sized seed (ETB/Mg)**	**-**	**882**	**-**	**-**	**1093**	**-**

[a] Cost of capital is not included because bank interest rate (3% per annum) was lower than the inflation rate (> 20%).
[b] ETB represents Ethiopian Birr (USD 1 was equivalent to ETB 17 on August 15, 2011).
[c] Mg represents mega gram.
[d] OD represents ox day (1 ox day in Jeldu and Welmera was ploughing of land for 5 hours with a pair of oxen).
[e] One fungicide application comprised 1.50 kg Ridomil MZ 63.5% WP (factory recommendation is 3 kg/ha per application).
[f] Labour data required for harvest were based on the labour data for medium sized seed and adjusted for the lower yields.
[g] Grading and store loading in this case is not sorting but differentiating the good tuber from bad tubers and loading store.
[h] Seed growers of small sized seed potato were expected to use the whole produce for seed, and same held true for seed growers of mixed seed size potato.

Appendix Table 3. Cost[a] (in ETB[b]) of production and postharvest management of seed potato that could be produced on 0.5 ha in two districts.

Attributes	Jeldu[c] Quantity	Jeldu[c] Unit cost	Jeldu[c] Total Cost	Welmera[c] Quantity	Welmera[c] Unit cost	Welmera[c] Total cost
Seed source and seed size (amount of seed in Mg[d])						
Own-small	0.85 Mg	1388	1180	0.75 Mg	1266	950
Own-mixed	1.55 Mg	1033	1601	1.30 Mg	1210	1573
Own-medium	1.20 Mg	882	1058	1.00 Mg	1093	1093
Market-small	0.85 Mg	1000	850	0.75 Mg	1300	975
Market-mixed	1.55 Mg	1200	1860	1.30 Mg	1800	2340
Market-medium	1.20 Mg	1500	1800	1.00 Mg	2000	2000
Institution-small	0.85 Mg	2000	1700	0.75 Mg	2500	1875
Institution-mixed	1.55 Mg	2500	3875	1.30 Mg	2800	3640
Institution-medium	1.20 Mg	3300	3960	1.00 Mg	3760	3760
Storage method (capacity in Mg)						
Local	-	0	0	-	0	0
DLS[e]	1	16000	16000	1	16000	16000
Sprouting method						
De-sprouted	1.2 Mg	12	14.4	1.0 Mg	15	15.0
Special action	1.2 Mg	120	144	1.0 Mg	170	170
In store	1.2 Mg	0	0	1.0 Mg	0	0
Tillage frequency for 0.5 ha						
Three	8.7 MD[f]	50	435	9.25 MD	70	648
Four	10.8 MD	50	540	11.75 MD	70	823
Five	12.9 MD	50	645	14.25 MD	70	998
Planting date						
Labour required for hoeing/hilling in earlier than recommended period (a)	38.0 MD	20	760.0	37.5 MD	25	937.5
Fungicide applications frequency in earlier than recommended period (b)	2 times	630	1260	2 times	630	1260
Cost of earlier than recommended period (a+b)	-	2020	-	-	2197.5	-
Labour for hoeing combined with making hills in recommended period (c)[g]	57 MD	20	1140	56.25 MD	25	1406.25
FA[h] frequency in recommended period (d)[i]	3 times	630	1890	3 times	630	1890
Cost of recommended period (c+d)	-	3030	-	-	3296.25	-
Hoeing frequency and hill size						
Once and small	19 MD	20	380.0	18.58 MD	25	464.5
Twice and small	33 MD	20	660.0	30.98 MD	25	774.5
Twice and big	38.00 MD	20	760.00	37.15 MD	25	928.75
Interaction between FR[j] and FA						
Below recommended – DAP (e)	51.00 kg	10.55	538.05	48.10 kg	10.52	506.02
Below recommended – Urea (f)	36.75 kg	8.88	326.34	41.00 kg	8.86	363.26
Once fungicide application (g)	1 time	630	630	1 time	630	630
Labour for fungicide application (h)	0.5 MD	50	25	0.5 MD	60	30
Labour for fertilizer application (i)	0.5 MD	20	10.0	0.5 MD	25	12.5
Below recommended FR and once FA (e+f+g+h+i)	-	-	1529.39	-	-	1541.78
Below recommended FR and twice FA (e+f+2g+2h+i)	-	-	2184.39	-	-	2201.78
Below recommended FR and thrice FA (e+f+3g+3h+i)	-	-	2839.39	-	-	2861.78
Recommended – DAP (j)	97.5 kg	10.55	1028.63	97.5 kg	10.52	1025.70
Recommended – Urea (k)	82.5 kg	8.88	732.60	82.5 kg	8.86	730.95
Recommended FR and once FA (j+k+g+h+1.5i)	-	-	2431.23	-	-	2435.40
Recommended FR and twice FA (j+k+2g+2h+1.5i)	-	-	3086.23	-	-	3095.40
Recommended FR and thrice FA (j+k+3g+3h+1.5i)	-	-	3741.23	-	-	3755.40
Above recommended – DAP (m)	107.60	10.55	1135.18	111.25	10.52	1170.35
Above recommended – Urea (n)	105.70	8.88	938.62	99.50	8.86	881.57
Above recommended FR and once FA (m+n+g+h+1.5i)	-	-	2743.80	-	-	2730.67
Above recommended FR and twice FA (m+n+2g+2h+1.5i)	-	-	3398.80	-	-	3390.67
Above recommended FR and thrice FA (m+n+3g+3h+1.5i)	-	-	4053.80	-	-	4050.67

[a] Cost of capital is not included because bank interest rate (3% per annum) was lower than the inflation rate (> 20%).
[b] ETB represents Ethiopian Birr (USD 1 was equivalent to ETB 17 on August 15, 2011).
[c] In both districts seed potato is produced only once in a year and costs are pertinent to the single season in 2010.
[d] Mg represents mega gram.
[e] DLS represents diffused-light storage.
[f] MD represents man-day.
[g] Labour required for hoeing combined with making hill for recommended planting period are higher by 50% than the labour required for earlier than recommended period.
[h] FA represents fungicide application.
[i] FA frequency for recommended planting period are higher by 50% than FA frequency for earlier than recommended period.
[j] FR represents fertilizer rate.

Chapter 5

Performance of seed potato supply chains in Ethiopia

Adane Hirpa[1, 2], Miranda P.M. Meuwissen[1], Willemien J.M. Lommen[2], Alfons G.J.M. Oude Lansink[1], Admasu Tsegaye[3], and Paul C. Struik[2]

[1]Business Economics, Wageningen University, the Netherlands
[2]Centre for Crop Systems Analysis, Wageningen University, the Netherlands
[3]Addis Ababa University, Ethiopia

Submitted to: Supply Chain Management: An International Journal

Abstract

In Ethiopia, seed potatoes are required for production of ware and seed in different seasons, under different production conditions and for different production purposes. To satisfy the diversity of demands, different seed potato supply chains are required. Currently, knowledge on management and performance of existing Ethiopian seed potato supply chains and the impact of improvement options on performance is lacking. The objectives of this study were to describe existing and potential seed potato supply chains, and to evaluate their performance. The results showed that seed quality is a more important seed supply chain performance indicator than costs, flexibility and responsiveness, for improving overall performance of seed potato supply chains. Sub-indicators to evaluate seed supply chain performance, i.e. production costs, seed purity, seed genetic quality, seed health, appropriateness of potato seed size, seed physical damage, appropriateness in physiological age, mix flexibility, volume flexibility and lead time, can be better improved by seed potato supply chains that supply seed tubers of improved varieties than by a chain supplying seed tubers of local varieties. The results also showed that actors in a seed potato supply chain differed in their relative contributions to the performance sub-indicators, implying that a larger improvement in a seed potato supply chain with respect to a specific sub-indicator can be achieved by improving that sub-indicator at the actor level that has a larger relative contribution.

Key words: seed potato, supply chain, performance, Ethiopia

5.1. Introduction

Food security and cash income are major constraints for smallholder farmers in Ethiopia. Potato (*Solanum tuberosum* L.) is an important food and cash crop for farmers in the highlands of Ethiopia. However, farmers are not optimally benefiting from potato production because of low productivity caused by yield-limiting factors such as poor seed quality and lack of seed tubers of improved varieties which are in turn caused by absence of a well-functioning seed system (Hirpa et al., 2010; International Potato Center, 2011).

Three seed potato systems can be identified in Ethiopia: the informal, alternative and the formal seed systems. None of these systems is functioning efficiently (Hirpa et al., 2010). The informal seed potato system supplies the major portion (98.7%) of seed potatoes used in the country (Gildemacher et al., 2009a). However, the seed tubers supplied by the informal seed system are poor in health, unsuitable in physiological age, poor in genetic quality, impure (varietal mix-up), physically damaged and inappropriate in size (Lemaga et al., 1994; Mulatu et al., 2005; Gildemacher et al., 2009b; Hirpa et al., 2010). The alternative seed potato system is a seed potato system that supplies seed tubers produced by local farmers with financial and technical support from NGOs and breeding centres (Hirpa et al., 2010). The alternative seed potato system supplies a small fraction (1.3%) of the seed potatoes used in the country (Gildemacher et al., 2009a) and the formal seed system is in its incipient stage (Hirpa et al., 2010). To improve quality and availability of seed potato, co-existence and linkage of the three systems are important (Hirpa et al., 2010). According to Hirpa et al. (2010), the three seed potato systems can be improved especially through increasing awareness and skills of farmers, improving seed tuber quality and market access, availing new varieties, designing quality control methods, and reducing cost of seed production.

Potato is grown in Ethiopia by more than one million farmers that are mainly located in the central (10%), eastern (3%), north-western (40%), and southern (30%) areas of the country (CSA, 2009). In all areas, many farmers grow local varieties and some farmers grow improved potato varieties (Hirpa et al., 2010). Many farmers grow potato for multiple purposes, i.e. ware and seed and for own use and/or sale. However, some farmers grow potato mainly to sell as seed (e.g., some farmers in the central and eastern parts), and other farmers grow potato only to sell as ware potato (e.g., most of the farmers in the southern part). Farmers also produce potatoes in different seasons and production conditions. For instance, farmers in the central and north-western parts produce potatoes three times per year (*meher* - long rain season; June to October, *belg* - short rain season; February to May, and off-season through irrigation - October to January). Farmers may grow different varieties for different purposes in different seasons. For example, farmers in the central area grow improved varieties in the *meher* for seed, local varieties in *belg* for home consumption and small cash, and local varieties off-season under irrigation for commercial ware potato production. There are also differences in demand for different varieties among the end users. According to key informants, farmers in the central area demand improved varieties because these varieties are high-yielding and disease-tolerant, i.e. from a small plot they can harvest tubers that they use for home consumption and sell surplus at local markets. The local varieties produced by farmers in the southern part of the country have long shelf life and good cooking quality; therefore they are demanded by commercial ware growers. Thus many different chains are required to satisfy the demands of the various end users.

According to Van Roekel et al. (2002), a well-designed supply chain benefits the actors by enabling them to produce products required by end users, enables chains to innovate, improves demand forecasting, distributes risk among chain actors based on their capacity to manage specific risks, and helps to adapt to changing circumstances. In Ethiopia, seed potato supply chains for all three seed potato systems are underdeveloped and actors along the chain are not well-coordinated (Abebe et al., 2012). In order to compare existing Ethiopian seed potato supply chains and suggest options for improvement, knowledge on management and performance of existing supply chains is essential. Also, it is essential to be able to evaluate the impact of supply chain improvements on the supply chain performance. Supply chain performance is defined as the extent to which a supply chain satisfies requirements of end users and stakeholders with respect to relevant performance indicators at any point in time (Van der Vorst, 2006). Performance indicators are criteria or operationalized process characteristics with which products, services, and production processes can be evaluated against their normal or target values (Van der Vorst, 2006; Aramyan et al., 2007). Currently, knowledge on management and performance of existing Ethiopian seed potato supply chains and the impact of improvement options on performance is lacking. Therefore, the objectives of this study were to describe existing and potential seed potato supply chains, and to evaluate the performance of chains.

5.2. Research framework

Two frameworks were integrated and used to describe existing and to design potential seed potato supply chains, and to evaluate the performance of selected chains (Figure 5.1). The first framework was the supply chain management (SCM) framework developed by Lambert and Cooper (2000) and adapted by Van der Vorst et al. (2005). The second framework was the supply chain performance framework developed by Aramyan et al. (2007). The first framework comprises four elements that can be used to describe, design, analyse or develop a food supply chain network. These elements are: network structure, chain business processes, chain management, and chain resources (Van der Vorst et al., 2005). When these elements function in a proper manner they help a supply chain to achieve its objective(s) as measured by a set of performance indicators. The second framework comprises four elements that can be used to assess the performance of a supply chain. These elements are: efficiency, flexibility, responsiveness, and food quality. In this study, the two frameworks were integrated into one framework with eight elements that was suitable for analysing seed potato production chains (Figure 5.1). Details of the elements of the framework are provided below, following the terminology provided in Figure 5.1.

Supply chain network structure

Supply chain network structure is the structure that comprises supply chain members, their networks and process links (Lambert and Cooper, 2000). Description of the supply network structure helps to identify key-links in the supply chain that should be closely coordinated and integrated (Van der Vorst et al., 2005). In this study, the seed potato supply chain network comprised only those actors that directly took part in potato breeding, seed distribution or seed production. The descriptions comprised the key actors and their roles in the chain and the interrelation between actors.

Supply chain business processes

Supply chain business processes are sets of business activities designed to produce a specific output for a particular customer or market (Lambert and Cooper, 2000; Van der Vorst et al., 2005). The business processes considered in the seed potato supply chains were the existing and possible agreements that specify the level of performance (e.g., amount, type of variety and quality of seed) between seed growers and ware growers, and existing and possible information exchange mechanisms among the actors in the seed potato supply chain.

Supply chain management

According to Lambert and Cooper (2000) a successful supply chain management (SCM) has nine components: 1) planning and control (e.g., push or pull control), 2) work flow/activity structure (indicates how a firm performs its tasks and activities), 3) organization structure (indicates who performs the tasks and activities), 4) product flow facility structure (source, production, and distribution), 5) information flow facility structure (kind of information passed among channel member and frequency of information update), 6) management methods (i.e. firm philosophy and management techniques), 7) power and leadership structure, 8) risk and reward structure, and 9) culture and attitude. In this study, planning and information flow facility structure were considered because of their relevance to the chains under study.

Chain resources

Chain resources are supply chain enablers (people, storage and transportation facilities) used to produce a product and to deliver it to the customer or end user. In this study, all enablers that help ensure production, storage, and transportation of seed potatoes were considered.

Supply chain costs

Efficiency is one of the key performance indicators that measures how well chain resources are utilized (Lai et al., 2002; Aramyan et al., 2007). It includes production costs, profit, and return on investment (Aramyan et al., 2007). In this study, only costs of production/distribution and transaction incurred along the seed potato supply chains were considered. Production/distribution costs include costs of inputs and services incurred for production/distribution (i.e. inputs costs, labour costs, transportation costs, storage, and maintenance costs of seed store and equipment). Transaction costs include costs of contact (costs of searching partner or product), costs of negotiation (making agreement), and costs of safeguarding the agreement (enforcing/monitoring). The costs in this study were costs per unit (e.g., kg or ton) of seed potato.

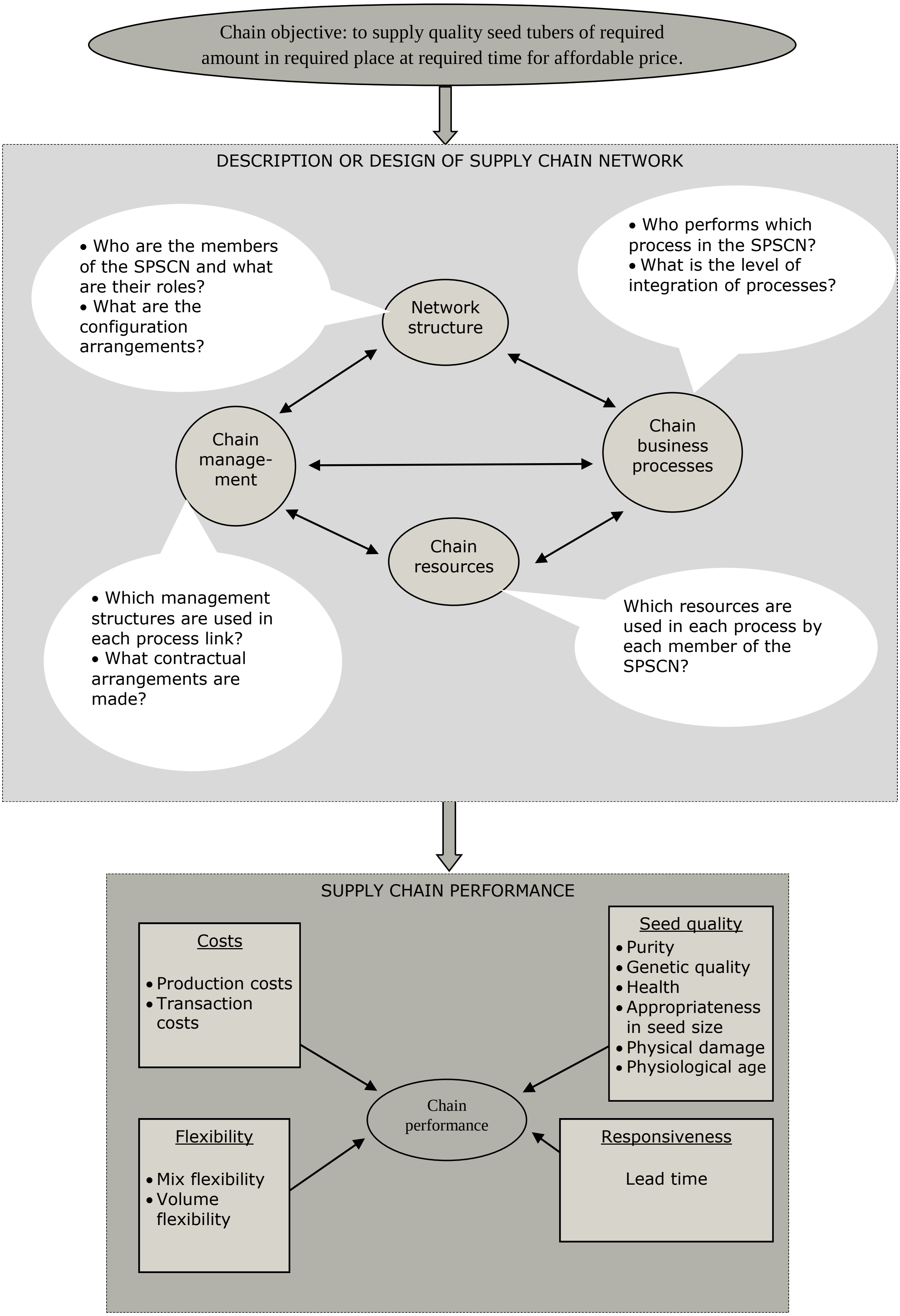


Figure 5.1. An integrated framework used to design seed potato supply chains [adapted by Van der Vorst et al. (2005) from Lambert and Cooper (2000)] and to evaluate their performances (Aramyan et al. (2007).

Supply chain flexibility

Flexibility is the degree to which the supply chain can respond to changing environments and customer requests (Aramyan et al., 2007). It includes mix flexibility and volume flexibility. Mix flexibility is the ability to change the variety of products produced based on the customer's request. In our study, flexibility is the ability of a seed potato supply chain to respond to changing market demands. Mix flexibility refers to the ability (number of varieties) of a supply chain to supply seed tubers of different varieties in different lots to satisfy the demand of customers. Volume flexibility is the ability of a supply chain to change the level of seed potato production (amount of seed) in order to deliver the volumes demanded.

Supply chain responsiveness

Responsiveness reflects the capacity of the chain to provide requested products with a short lead time. In our study, responsiveness refers to the ability of the supply chain actors to supply seed potato to customers in time (within agreed moment). Lead time is the total amount of time required to produce a seed potato lot, i.e. the time required for acquiring necessary resources and using them and produce seed potatoes.

Quality

According to Aramyan et al. (2007) quality can include product quality and process quality. Product quality comprises product safety and health, sensory properties and shelf life, and product reliability and convenience. Process quality comprises the production system characteristics (e.g. pesticide used), environmental aspects (e.g. waste management), and marketing. In our study, quality was defined as seed potato quality. The seed potato quality aspects considered were seed purity, genetic quality, health, size, physical damage, and physiological age (Hirpa et al., 2010). Seed quality as a supply chain performance indicator refers to the ability of a seed supply chain to supply seed potato that is pure (no mixture of varieties within a seed lot), genetically superior in quality (variety that is high-yielding, late-blight resistant, widely adaptable, has high food and/or processing quality), healthy (free from late blight, viruses, bacterial wilt, nematodes, and Potato Tuber Moth), appropriate in seed potato size, has minimal physical damage (cuts, bruises and holes, inflicted on tubers during harvesting, storage, packaging and transportation), and is appropriate in physiological age (in terms of dormancy, number and morphology of sprouts, and growth vigour).

5.3. Methods

The methodology used in this study consisted of three steps. The first step was the identification and description of existing and potential seed potato supply chains. Nine seed potato supply chains (Figure 5.2), five existing and four potential ones, were identified based on literature review and authors' experiences. The chains were described in line with the supply framework comprising the four components: network structure, chain management, chain business processes, and chain resources based on information obtained from literature and authors' experiences.

The second step was the selection of promising seed potato supply chains for in-depth performance evaluation. A list of the nine seed potato supply chains was prepared and sent to 15 (seven Ethiopians and eight foreign) potato experts through e-mail, individually. The foreign experts also had experience with potato research and development in Ethiopia. The experts were asked 1) to deselect the seed potato supply chains that were not realistic, if any, from the list of the nine seed potato supply chains, and 2) to rank the remaining chains in a way they expected them to perform best in Ethiopia based on four performance criteria: costs, flexibility, responsiveness and quality. Four chains were selected for further analysis, based on 1) ranks allotted to them by experts with respect to their perceived performance, and 2) dissimilarity among the selected chains.

The third step was an in-depth performance evaluation of the four selected seed potato supply chains and the default chain, i.e. the predominant chain. A questionnaire to be filled out by experts was developed, with detailed explanation of elements of performance indicators (costs, flexibility, responsiveness and quality), and a description of the default and selected chains. The questionnaire had three parts. Part 1 contained questions about the relative contribution of the individual groups of actors within the chains to the performance indicators. Experts were asked to divide 100 points among the actors within a chain, based on the contribution actors were perceived to have to sub-indicators of the four performance indicators. Part 2 contained questions to evaluate the extent of improvement of the performance sub-indicators in the four selected chains compared with the default chain. In this part, a Likert scale was used to obtain a score for each indicator. Experts were asked to give a score on a 1 to 5 scale for improvements in sub-indicators in the selected chains if the chains were performing according to their best practice compared to the state in default chain.

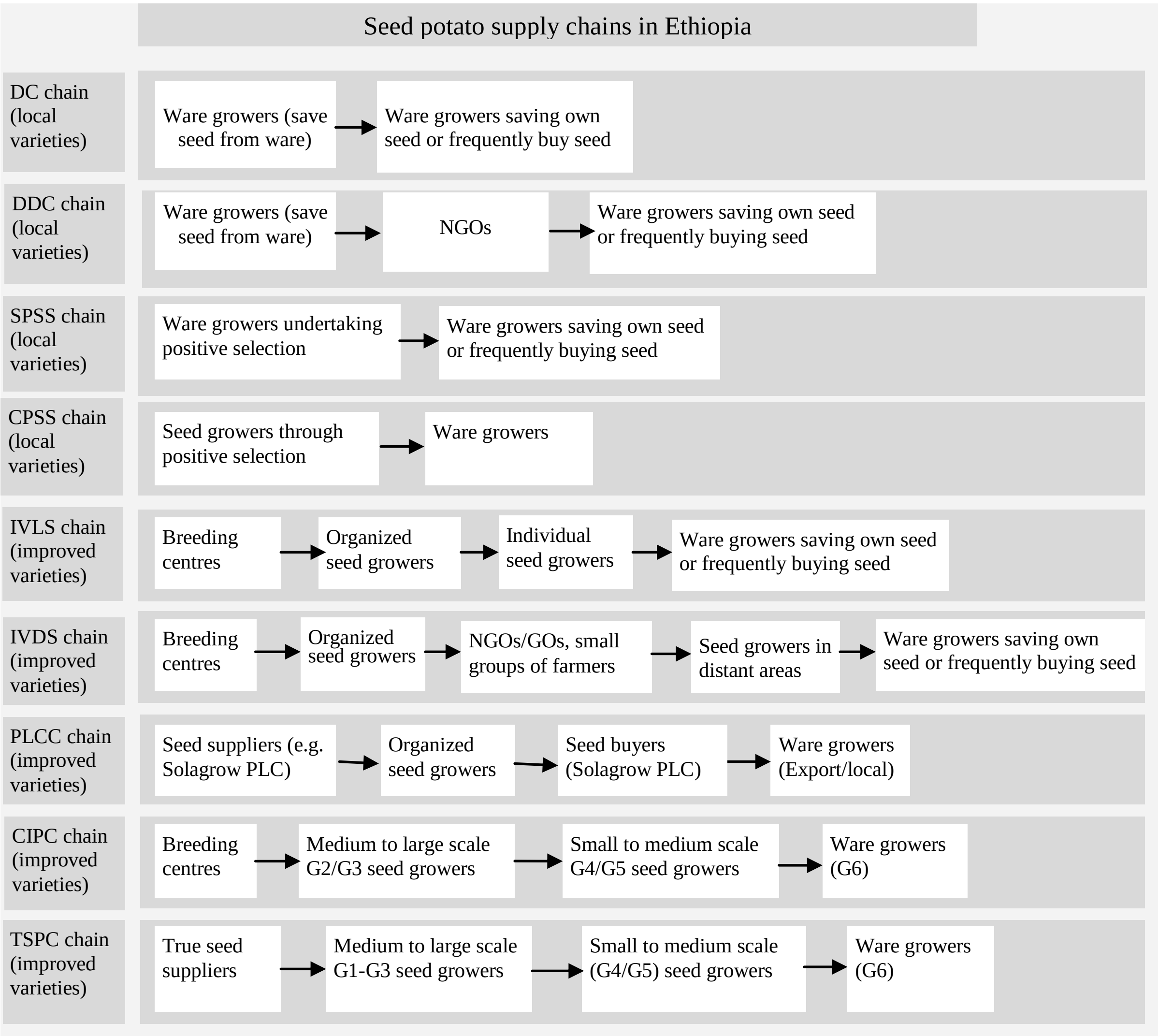


Figure 5.2. Structures of existing and possible seed potato supply chains in Ethiopia.

CIP represents International Potato Center.
PLC represents private limited company.
G1 represents first generation ... G6 represents sixth generation.
DC represents default chain.
DDC represents default distant chain.
SPSS represents subsistent positive seed selection.
CPSS represents commercial positive seed selection.
IVLS represents improved varieties for local supply.
IVDS represents improved varieties for distant supply.
PLCC represents private limited company chain.
CIPC represents International Potato Center (CIP) chain.
TSPC represents true seed potato chain.

For example, if experts thought it was possible to reduce production costs at the maximum possible by implementing Chain 4 instead of Chain 1, the score for production cost in Chain 4 would be ‘5’; if it was not possible to reduce production costs compared to the default chain the score would be ‘1’. Part 3 was assessing the perceived importance of four performance indicators (costs, flexibility, responsiveness and quality) to the overall performance of seed potato supply chains. In this part, experts were asked to divide 100 points to the four performance indicators based on the importance of these indicators to the overall performance of the seed potato supply chains. In this step 35 individuals’ experts were invited based on their experience in seed potato research and development and a total of 21 experts, 16 Ethiopian and 5 foreign experts participated. The foreign experts had experience in potato research and development in Ethiopia (seed or ware production, postharvest management and marketing). The Ethiopian experts were from all seed potato growing areas of Ethiopia (central, eastern, north-western and southern) (Hirpa et al., 2010). The questionnaire was administered individually through e-mail.

Descriptive statistics were used to analyse the data. Non-parametric independent sample tests, i.e. Wilcoxon rank-sum test and Mann-Whitney test, were used to test for differences between the scores given by Ethiopian and foreign experts. Non-parametric related sample tests known as the Wilcoxon signed rank test (for chains with two actors) and the Friedman test (for chains with more than two actors) were used to test for 1) differences between chain actors in their relative contribution to performance sub-indicators, 2) differences between the four selected chains in their scores for improvement of performance sub-indicators compared with the default chain, and 3) differences between the four supply chain performance indictors in their contributions to the overall performance of a seed potato supply chain. For those chains with significant Friedman test statistics, a Wilcoxon signed rank test was used to examine the differences between contributions of actors. This is because a Friedman test only evaluates overall differences, not specific differences between two actors.

5.4. Results

5.4.1. Description and design of seed potato supply chains

Among the nine seed potato supply chains, Chains 1 through 4 were based on local potato varieties and Chains 5 through 9 were based on improved potato varieties. Chains 1, 2, 3, 5, 6, and 7 existed in Ethiopia but Chains 4, 8, and 9 did not. Descriptions of the existing chains and designs of potential chains are provided below. Descriptions and designs are in line with the supply chain framework given in Figure 5.1.

Chain 1 – default chain (DC)

Chain DC is the dominant chain in Ethiopia. In this chain, potato is produced for ware (home consumption and sale) and seed (own use and sale).

Seed potato supply chains network structure

The key members of Chain DC seed potato supply chain network (SPSCN) are first ware growers saving seed for sale and own use, and second ware growers who buy seed tubers to renew their seed stock or buy seed tubers every season**.** Both types of actors are mostly smallholder farmers producing potato for home consumption and cash. There were about 1.13 million smallholder potato producers in Ethiopia in 2010 (CSA, 2011).

Seed potato chain business processes

Ware growers obtain agrochemicals from district bureaus of agriculture and rural development (DBARD) and traders in the vicinity, in order of importance. The major types of agrochemicals used in potato production are fertilizers (di-ammonium phosphate and urea) and fungicide (Ridomil MZ 63.5% wettable powder). Seed potato was usually self-supplied.

Ware grower saving own seed and ware growers frequently buying seed_buy seed from local markets to renew part of their seed stock. According to Gildemacher et al. (2009a), only 15% of seed stock of potato growers in the central and north-western areas of Ethiopia was renewed each season. There are also potato growers who frequently bought seed potato. For example, in the southern area, 100% of potato growers in district Arsi Negelle, 50% of potato growers in district Kofelle district, and 32% of potato growers in district Shashamene frequently bought seed potato from nearby highland areas. The input suppliers of agrochemicals were not regarded accountable for any problem in the described chains related to quality or efficacy of inputs. Farmers sold the seed/ware in the open market of a nearby town.

Seed potato chain management

Seed potato management comprised planning and information flow structure. Ware growers (ware growers who save seed from the ware production) plan their tasks and activities of seed potato production in a traditional way, i.e. they have no written plan and use memory. Thus their plans could be inaccurate. Farmers do not keep farm records about what has been done, bought, and sold. Farmers obtain information for potato production and marketing decisions from a variety of sources among which own experience is the main one. According to Gildemacher et al. (2009b), most potato growers in Ethiopia used own experience to select seed potato (57.3%), to enrich their soils (63.7%), to undertake general crop husbandry (59.2%), postharvest handling (62.9%), and marketing (70.4%). These authors also reported that farmers' own communities were the major sources of information about potato varieties (58.7%) and crop protection (33.7%). In this chain, there is no contractual agreement between chain actors.

Seed potato chain resources

Seed potato chain resources comprised people involved in seed production, and facilities used to store and transport seed potatoes. Farmers have little knowledge about efficient use of agricultural inputs. According to Haji and Andersson (2006) the average economic efficiency of vegetable farmers in Ethiopia was 43% and low literacy level of farmers was one of the causes of this low efficiency. The technical support farmers could obtain from the agricultural development agents is limited because 1) development agents are involved more in input supply and collecting tax and loan repayment than in providing technical support to farmers (Belay, undated), 2) the development agents do not have sufficient technical knowledge of agriculture (Belay and Degnet, 2004; Davis et al., 2010; Gebru et al., 2012).

Farmers in this chain used local storage methods such as leaving in the soil (postponed harvesting), local granary, jute sacks, and bed-like structure to store seed potatoes (Gildemacher et al., 2009; Hirpa et al., 2010). Local storage methods are largely sub-optimal because seed potatoes stored in local storage have fewer, longer and weaker sprouts that have low vigour at planting (Gildemacher, 2012). According to Hirpa et al. (2012), use of DLS was perceived by seed growers in districts of Jeldu and Welmera to have significant higher effect on seed yield compared to use of local storage methods. Also seed transportation facilities in

Ethiopia are poor. According to Hirpa et al. (2010), seed potatoes are usually transported by pack animals, tied by ropes on their backs, which could cause bruising.

Chain 2 – distant default chain (DDC)

Chain DDC is used to supply seed potato as seed assistance to farmers who do not have seed tubers of their own or who do not have sufficient resources to acquire seed tubers locally. In this chain, potato is produced for ware (home consumption and sale) and seed tubers (own use and sale).

Seed potato supply chains network structure

The key actors of Chain DDC are ware growers saving seed tubers for sale and own use, NGOs and ware growers that receive the seed lots for free or against subsidized prices to grow ware/seed. Ware growers in both stages are the same as in Chain DC. The NGOs involved in this chain are humanitarian and assisted farmers during seed crises. The NGOs include FAO, World Vision, VITA, VOCA-Ethiopia, and Self Help Africa.

Seed potato chain business processes

The ware growers saving seed tubers for sale and own use in this chain are similar to those in Chain DC and thus they have the same business processes as described for Chain DC. NGOs buy seed potatoes from anywhere they are and distributed to farmers who needed seed assistance. Some NGOs did the seed distribution through traders (Emana and Nigussie, 2011).

Seed potato chain management

The ware growers saving seed tubers for sale and own use in the Chain DDC are similar to those in Chain DC and thus they have the same plan and information flow structure. NGOs usually announce bids or use other mechanisms to approach traders who can supply seed potato to target farmers. Formal agreements on the amount of seed tubers and prices can be made between NGOs and traders. After supplying the stated amount of seed tubers to target farmers, traders receive agreed payment from the NGOs.

Seed potato chain resources

Ware growers in Chain DDC are similar to those in Chain DC and their chain resources are also the same.

Chain 3 – subsistence positive seed selection (SPSS) chain

Chain SPSS was praised to improve seed quality of local potato varies. In Kenya this chain proved to increase yield by 34% compared to a default chain (Gildemacher et al., 2011).

Seed potato supply chains network structure

In Chain SPSS, the key actors of SPSCN were ware growers producing seed tubers through positive selection, and buyers of seed tubers produced through positive selection. The members of both actors were smallholder farmers producing potato of local varieties used for home consumption and cash. According to Hirpa et al. (2010), in 2007, 13% of the farmers in the district Degem and 15% of the farmers in the district Jeldu in the central area of Ethiopia and 8% of the farmers in the district Banja in the north-western area of Ethiopia produced seed potatoes through positive selection.

Seed potato chain business processes

Ware growers undertaking positive selection used fertilizers (di-ammonium phosphate and urea) and fungicide (Ridomil) they obtained from DBARD and traders in the vicinity. The ware growers would need training or advice on the technique of positive selection as was done in Kenya (Gildemacher et al., 2007). In Kenya, the International Potato Center (CIP) in collaboration with the Kenyan Agricultural Research Institute (KARI) and the Kenyan Ministry of Agriculture trained extension agents and farmer-trainers on aspects of positive selection; subsequently, the extension agents and farmer-trainers trained other farmers (Gildemacher et al., 2007). The success of positive selection in Kenya was the result of trainings on positive selection that used the field as classroom, with sessions spread over seasons, and employed learning by doing through farmer managed field experiments (Gildemacher et al., 2012).

Seed potato chain management

The ware growers undertaking positive selection would plan when to peg healthy looking potato plants. According to Gildemacher et al. (2011), Kenyan potato growers pegged healthy looking potato plants roughly 10 weeks after planting (just before flowering); and two weeks after pegging they inspected the potato field and removed pegs from plants with newly developed disease symptoms.

Seed potato chain resources

In this chain, ware growers who produced seed potatoes through positive selection were similar to those in Chain DC and thus they had similar resources as described under Chain DC, except that additional resources were required for pegging of healthy looking potato plants.

Chain 4 – Commercial positive seed selection (CPSS) chain

Chain CPSS did not exist in Ethiopia but has a potential to improve quality of seed potatoes of local varieties. This chain is the commercial version of Chain SPSS. In Chain CPSS, there would be commercial seed growers of local potato varieties specialized in positive selection.

Seed potato supply chains network structure

In Chain CPSS, the key actors of the SPSCN would be seed growers growing seed potato through positive selection and ware growers who buy this seed. The seed growers through positive selection could be medium to large scale ware growers of local potato varieties smallholders specialized in seed potato production of local varieties through positive selection. Medium and large scale farmers who grow ware potato from local varieties could incorporate in their business plan production of seed potatoes through positive selection from ware potato production.

Seed potato chain business processes

Seed growers through positive selection used fertilizers (di-ammonium phosphate and urea) and fungicide (Ridomil) they obtained from DBARD and traders in the vicinity. Seed potatoes produced through positive selection would have a label that differentiates them from seed potatoes of local varieties produced in other ways. According to Guenthner (2006), labelling of seed potato helps to preserve the identity of high-quality seed potatoes and without an identification system, high-quality seed potatoes could get confused with ordinary or low-quality seed. Training on positive selection would be essential. Ware growers would buy seed potato from the seed growers and agrochemicals from DBARD to grow ware potatoes. Seed growers would sell seed tubers to ware growers.

Seed potato chain management

Like in Chain SPSS, seed growers in Chain CPSS would plan when to peg healthy looking plants and remove pegs from the pegged plants that show new disease symptoms. Seed growers would get training in positive selection techniques liked the ones done in Kenya, Malawi, Rwanda and Uganda (Gildemacher, 2012). The seed growers in this chain would be specialized seed growers through positive selection. Contractual agreement between the seed growers and ware growers (buyers of seed tubers produced through positive selection) could be very important.

Seed potato chain resources

In Chain CPSS, important chain resources would be trained seed growers, diffused light store (DLS) storage facilities and an institution that could regulate quality and give labels for seed potato produced through positive selection to differentiate it from other seed potatoes.

Chain 5 – improved variety for local supply (IVLS) chain

Chain IVLS is an existing chain that supplies seed potatoes of improved varieties in Ethiopia. It exists mainly in the central potato growing area of the country.

Seed potato supply chain network structure

In Chain IVLS, the key actors of the SPSCN are breeding centres, organized seed growers, individual seed growers, and ware growers saving own seed residing in the vicinities of seed production. Four agricultural research centres (Adet, Awassa, Holetta, Sheno) and Haramaya University are involved in potato variety development and supply of seed potatoes. Among these institutions, Holetta Agricultural Research Centre is the major actor involved in developing potato varieties and supplying basic seed of improved varieties, followed by Haramaya University.

In the second stage of Chain IVLS, seed tubers are grown by organized seed growers [farmer research groups (FRG) or farmers' field school (FFS)]. At present, most of the FRG and FFS are transformed into seed producers' cooperatives. There are more seed potato producers' cooperatives in the central and southern potato producing areas than in the eastern and north-western areas. The cooperatives in the central areas have more experience than the cooperatives in the southern areas. In the central potato producing area, there were four cooperatives in Jeldu (Abebe et al., 2010; LSB, 2010) and twelve in Welmera (Abebe et al., 2010). The cooperatives in Jeldu comprised 444 members while those in Welmera comprised about 300 members. In the eastern potato growing area, there was only one seed potato producers' cooperatives involved in seed potato production (LSB, 2011). The seed potato producers' cooperative is located in Haramaya district near Haramaya University. This cooperative had about 40 members and 70 out-growers (out-growers are farmers who are not member of the cooperative but sell their seed tuber to the cooperative). In the north-western region, there was one FRG with about 30 member farmers (LSB, 2009). There was also one cooperative (Felegewoyni in Atsibi-Wemberta) with 34 members in Tigray (in northern Ethiopia) (LSB, 2010). In the southern potato growing area there are about 15 seed potato cooperatives, all formed with the assistance of CIP-USAID funded project. The total number of members of these cooperatives is about 300. The actors in stage 3 of Chain IVLS are the individual seed grower (non-members of a cooperative). The number of individual seed growers is small.

Seed potato chain business processes

In Chain IVLS, like in other chains, DBARD supplies agrochemicals (fertilizers and fungicide), and technical advice. There are also private traders that supply agrochemicals.

The breeding centres 1) develop potato varieties that are high-yielding and tolerant to diseases, from the clones they obtain from CIP, 2) demonstrate the best performing varieties on farmers' fields and release them to farmers, and 3) form farmer research groups (FRG) and use these groups to popularize released potato varieties. The breeding centres provide basic seed of improved potato varieties and training on seed potato production to the organised seed growers. Some of the breeding centres are also involved in seed quality control and marketing. For example, potato researchers in Holetta Agricultural Research Centre have been supervising seed potato fields of cooperative members to examine the level of late blight and bacterial wilt infestations.

The organised seed growers produce seed potatoes from the basic seed they obtain from the breeding centres. They obtain agrochemicals from DBARD and traders. The members of FRGs/cooperatives produce seed potato on their own individual plots and store the seed tubers in their own DLS. Only few members use common stores.

According to key informants, in Welmera district, cooperatives have committee members who supervise seed potato fields of member farmers for disease infestation (especially for Bacterial wilt) in different stages of crop growth. The committees advise seed growers to improve the management practices and use the produce for seed in case of low infestation. In cases of high infestation the seed growers are advised to use the produce for ware. For example, in 2010 seed growers were advised to use produce for seed when the number of plants infected per ha was 40 or less; and for ware when the number of plants infected was above 40. There is no quality control in Jeldu district. The implementation of quality control in Welmera and absence of quality control in Jeldu could be because of prevalence of Bacterial wilt in Welmera and absence of Bacterial wilt in Jeldu (Hirpa et al., 2012). Bacterial wilt is both seed-borne and soil-borne and planting infested tubers will render the land unsuitable for seed production for a long time.

In all seed growing areas, the benefit for a seed grower of being member of a cooperative is to get access to a seed tuber market. The cooperative committee members seek markets for seed tubers and apportion the amount of seed potato a member could sell to the available market.

The actors in the third stage of Chain IVLS are other seed growers. These seed growers are not cooperative members but grow seed potatoes for commercial purposes. The sources of seed for these seed growers are cooperative members. They get agrochemicals from DBARD. According to key informants, in Welmera district, the seed potato fields of some of individual seed growers were supervised by the cooperative quality control committee and their produces were also sold through the cooperative but after the cooperative members seed potatoes were sold. There are also cooperative members who buy seed potato from the individual seed growers (not necessarily from supervised seed growers) and sell the tubers for some profits.

Seed potato chain management

Breeding centres usually plan research and extension activities they would be undertaking on an annual basis. They also have medium term (5 years) research plans. Grouped and individual seed growers plan amounts of seed potato to be produced in the next year and such a plan is based on prices of seed potatoes in the current year. It is a cobweb - high prices followed by a large harvest and low prices followed by a small harvest. There is no market contract between seed potato growers and seed buyers.

Seed potato chain resources

Most of the breeding centres use shared human resources and facilities with other divisions within a research centre. Holetta Agricultural Research has more staff members and research facilities than other breeding centres. Some members of grouped seed potato growers have better training and storage facilities than individual seed growers (Hirpa et al., 2010). Ware growers saving own seed are similar to those described in Chain DC and thus have similar resources as described in Chain DC.

Chain 6 – improved variety for distant supply chain (IVDS)

Chain IVDS is an existing chain in Ethiopia, in which seed potato of improved varieties is distributed mostly from seed growers in Degem, Jeldu, and Welmera in the central area to farmers in distant areas in north, south and west directions of Ethiopia.

Seed potato supply chains network structure

In Chain IVDS, the key actors of the SPSCN are breeding centre, grouped seed growers, NGOs/GOs/small seed potato buyer groups, seed growers in distant areas, and ware growers saving own seed tubers. The breeding centres and organized seed growers are those described in Chain IVLS. The major NGOs/GOs are CIP in the south and north, VITA in the south, FAO and Self Help Africa (SHA) in the east, World Vision and Tigray Development Association (TDA) in the north, and the DBARDs in all areas. Small seed potato buyer groups are ware/seed producers residing in areas that are distant from the main seed growing districts. Within a group, seed buyers pool resources and buy seed from the main seed growing areas (e.g., central areas) for themselves. For example, during our field survey in 2010, a group of potato growers in Shashamene district (in the southern area) pooled finances and sent two representatives to buy seed potato for them from the central potato growing area. Ware growers saving own seed are similar to those described in Chain DC and thus have similar chain network structure as described in Chain DC.

Seed potato chain business processes

The breeding centres and seed growers are similar to those given in Chain IVLS and thus their business processes are the same as expressed under Chain IVLS. The GOs and NGOs bought seed tubers from cooperatives and distributed them to farmers in distant districts/areas. NGOs that are recently involved in seed potato distribution in the southern area of Ethiopia are funded by USAID and worked together. For example, there is a consortium of eight NGOs (CRS, FAO Ethiopia, FHE, GOAL Ethiopia, World Vision Ethiopia, ChildFund, Concern Worldwide and IMC). The consortium is organized and established by FAO and aimed at implementing a project titled “Disaster Risk Management - Root and Tuber Crops Response Intervention in SNNP Region” (G. Solomon, CIP-Addis Ababa, personal communication). The NGOs planned to distribute about 800 Mg of seed potatoes. The NGOs distribute seed tubers to cooperatives or individual farmers. For example, the CIP-USAID-funded project distributes seed potato to cooperatives in the Southern area of Ethiopia. World vision and VITA had been distributing seed potato to cooperatives as well as individual farmers in southern Ethiopia. FAO also bought seed potatoes from cooperatives in the eastern area and distributed them to distant farmers in the same area. Some NGOs provided training and assisted growers in seed potato marketing. The seed tubers bought by the small seed potato buyer groups are distributed among the ware growers saving own seed who contributed finance. Ware growers saving own seed are similar to those described in Chain DC and thus have similar chain business processes as described in Chain DC.

Seed potato chain management

The breeding centres in this chain are similar to those in Chain IVLS and their plans and information flow structure are as given under Chain IVLS. The NGOs involved in this chain perform their activities under a project with a clear planning. The GOs have plans to distribute seed potatoes. However, the amount of seed potato that could be distributed by GOs could be small because of budget limitations.

Seed potato chain resources

The resources of breeding centre and grouped seed growers are described under Chain IVLS. GO/NGOs usually have some basic facilities and trained staff, and information infrastructure like telephone through which they could exchange information. Small groups of seed buyers used hired trucks to transport seed potatoes. These seed growers at distant areas lack necessary knowledge and skill of seed potato production and postharvest handling. They also lack necessary financial resources to buy inputs. Ware growers saving own seed also lack knowledge and skills required to produce ware/seed from improved varieties.

Chain 7 – private limited company chain (PLCC)

This is the only seed potato chain that supplied certified seed potato to seed potato growers in some areas in Ethiopia.

Seed potato supply chains network structure

The key actors in the Chain PLCC are seed suppliers, seed growers, seed buyers and ware growers. In this chain, Solagrow PLC is the only seed potato supplier. The PLC supplied seed potatoes to two seed potato grower cooperatives in the districts of Ambo and Doba. The cooperative in Ambo had 30 members (LSB, 2011). These cooperatives outgrew seed potato for Solagrow PLC, i.e. Solagrow PLC was the seed supplier and the seed buyer. The PLC also plans to export seed potatoes. Ware growers will be domestic farmers or farmers in the importing countries.

Seed potato chain business processes

Seed supplier Solagrow PLC obtained basic seed from the Dutch seed potato company HZPC Holland BV. The PLC does at least two multiplications of the basic seed on its farms at Haro Wonchi in West Shewa and at Doba in Arsi. The PLC then supplies the seed potatoes to seed growers organized in the cooperatives. The cooperative members get technical assistance from the employees of the PLC on seed potato production. They sell their produce (seed potato) back to the PLC. The company grades and certifies seed, and sells it to ware growers.

Seed potato chain management

Solagrow PLC is the only modern and licensed seed potato growing PLC in Ethiopia. The PLC has modern methods of planning and execution of activities. There is a contract between the seed supplier and the seed growers (LSB, 2011). Based on the contractual agreement, the PLC paid different prices for different grades of seed potatoes.

Seed potato chain resources

This chain has qualified human power and facilities to run its seed business. It has two large seed storage facilities located at Hidi and Wonchi. It has its own plant and molecular laboratory (ELISA and qPCR) important to certify phytosanitary qualities of seed potatoes (Solagrow PLC, 2011). The company also has a seed tuber grading facility and modern information facilities (internet, website, telephone lines, and cell phones) to communicate with its customers.

Chain 8 – International Potato Center chain (CIPC)

Chain CIPC, a seed supply chain that starts with the production of healthy minitubers. It does not exist in Ethiopia and other east African countries. This chain is adapted (only part of the seed supply chain is taken) from a chain developed by CIP in consultation with seed potato experts, value chain specialists, and various private and public sector actors (International Potato Center, 2011).

Seed potato supply chains network structure

In Chain CIPC, the key actors of the SPSCN are breeding centres producing G1 seed, medium to large scale G2/G3 seed growers, small to medium scale G4/G5 seed growers, and G6 ware growers. G1 is first generation seed or minitubers, G2 is second generation seed that is produced from the G1, G3 is the third generation seed produced from G2. G2 and G3 are basic seed. Details of breeding centres are given under Chain IVLS. Medium to large scale

G2/G3 seed growers, in this study, are those who would grow seed potato on more than 5 ha (medium scale - 5 to 10 ha, and large scale - more than 10 ha); and small to medium scale generations 4 and 5 (G4/G5) seed growers means those who would grow seed potato on 0.25 to 10 ha. Medium to large scale seed growers grow seed tubers of many clones or genotypes. Generation 6 (G6) ware growers could be commercial, semi-commercial or subsistence.

Seed potato chain business processes

In Chain CIPC, breeding centres produce plantlets in tissue culture laboratories. The breeding centres produce minitubers (G1) from in vitro plantlets through rapid multiplication techniques, such as aeroponics. Medium to large scale seed growers would buy G1 (pre-basic) seed and produce G2/G3 (basic seed). Decentralized small to medium seed growers would buy G2/G3 and produce G4/G5 (certified or quality-declared seed). According to CIP (2011), decentralized field multiplication is crucial to lower the costs of seed tubers and to improve seed potato availability to a large number of small-scale ware producers. The ware growers would buy G5 and produce G6.

Seed potato chain management

The breeding centres in this chain are similar to those described in Chain IVLS. The success of medium to large seed growers would depend on the robustness of their plans, information flow systems, and governance structures they would use (e.g., market contracts for seed potato).

Seed potato chain resources

The seed growers (small to large scale) will have all necessary resources in terms of skilled personnel, farm stead structures, and information infrastructure. A modern farm record keeping system is also essential.

Chain 9 – true seed potato chain (TPSC)

Chain TPSC is a chain that uses botanical seed as starting material. It does not exist in Ethiopia but was deemed to be an important alternative to conventional methods of potato production in Ethiopia (Tuku, 1994; Lemaga et al., 1994).

Seed potato supply chains network structure

The key actors in this SPSCN are true potato seed suppliers, medium to large scale G1 to G3 tuber seed growers (G1 from the true potato seed, and G2/G3 seed tubers), small to medium scale G4/G5 seed tuber growers, ware (G6) growers. True potato seed suppliers could be foreign companies involved in seed business. Small, medium and large scale seed potato growers are as defined under Chain CIPC.

Seed potato chain business processes

Seed supplier (could be a foreign company, for example, HZPC BV of the Netherlands) would supply true potato seed to medium to large scale foreign or domestic seed growers. The medium to large scale domestic seed growers would grow seed tubers for three generations (G1 to G3). The medium to large scale seed growers would access agrochemicals from big traders in cities in Ethiopia or import by themselves. Small to medium scale seed growers would obtain seed tubers of G3 from medium to large scale seed growers and would produce seed tubers of two generations (G4 and G5). The small to medium seed potato growers would access agrochemicals from DBARD and agricultural inputs traders. Ware growers would obtain seed potatoes of G5 from small to medium scale seed potato growers and would grow ware (G6). The ware potato would be sold to ware consumers in nearby rural areas, and big cities and towns. The ware growers would access agrochemicals from DBARD and agricultural input traders.

Seed potato chain management

Seed potato management in Chain TSPC is similar to the ones given in Chain IVLS.

Seed potato chain resources

Seed potato resources in this chain are similar to the ones described in Chain IVLS.

5.4.2. Seed potato supply chains performance analysis

Table 5.1 presents the number of experts that gave specific ranks to seed potato supply chains based on their performance with respect to costs, flexibility, responsiveness and quality. The five top chains based on the result of ranking by the potato experts were CPSS, IVLS, IVDS, PLCC and CIPC. Many experts (10 out of 15) perceived Chain TSPC to be unrealistic under Ethiopian conditions. Based on ranks allotted to them by experts and dissimilarities among them Chains CPSS, IVLS, PLCC and CIPC were selected for further in-depth analysis and compared to the most common present chain, Chain DC.

Table 5.2 shows the relative contributions of the different actors to the individual performance sub-indicators of Chains DC, CPSS, IVLS, PLCC and CIPC. Wilcoxon rank-sum tests showed that there were no differences ($p \leq 0.05$) between the scores given by Ethiopian and foreign experts in almost all contributions of the actors to sub-indicators, and extent of improvement of sub-indicators in the selected chains compared to Chain DC. The only significant difference ($p \leq 0.05$) between the two types of experts occurred in the scores for the contribution of 'responsiveness' to the overall performance of seed potato supply chains. Therefore, no distinction was made between the experts in data analysis.

In Chain DC, ware growers that sold own seed were scored to have larger contribution than ware growers buying the seed on the performance of the chain with respect to production costs, volume flexibility and lead time (Table 5.2). There were no significant differences between the producing ware growers and seed buyers with respect to their contributions to transaction costs, seed purity, seed health, appropriateness in seed size, seed physical damage, appropriateness in seed physiological age and mix flexibility.

In Chain CPSS, seed growers growing seed through positive selection were regarded to have significantly larger contributions than their buyers on the overall chain performance with regards to transaction costs, seed health, appropriateness of seed size, seed physical damage, and appropriateness in seed physiological age than ware growers using seed of positive selection.

In Chain IVLS, the contributions of breeding centre, organized seed growers, and individual seed growers were not different from each other for production costs, appropriateness of seed size, and appropriateness in seed physiological age, but they were higher than the contributions of the last actor group, the ware growers. All actors differed with respect to their contributions to seed purity, seed genetic quality, and seed health with larger scores allotted to actor groups earlier in the chain. The contributions of organized seed growers with respect to transaction costs, volume flexibility and lead time were regarded larger than those of other actors. The contribution of organized seed growers, individual seed growers and ware growers were not different from each other for physical damage, but they were higher than the contributions breeding centre.

Table 5.1. Ranking of nine seed potato supply chains in Ethiopia on costs, quality, flexibility and responsiveness. (n=15).

	Chain								
Rank	**DC**	**DDC**	**SPSS**	**CPSS**	**IVLS**	**IVDS**	**PLCC**	**CIPC**	**TPSC**
1	3	0	0	4	3	2	1	1	0
2	0	0	2	0	4	3	4	2	0
3	0	0	1	2	5	2	1	6	1
4	0	2	1	1	1	2	4	1	1
5	0	1	3	2	1	1	1	1	3
6	2	1	5	3	0	2	1	0	0
7	5	2	1	0	1	1	1	1	0
8	3	4	0	0	0	0	0	0	0
9	0	1	0	0	0	0	0	0	0
Number of experts who deselected	2	4	2	3	0	2	2	3	10

Note: The rows do not always add up to 15, because some experts gave similar ranks to more than one chain, started ranking from third rank, and deselected chains.
DC represents default chain.
DDC represents default distant chain.
SPSS represents subsistent positive seed selection.
CPSS represents commercial positive seed selection.
IVLS represents improved varieties for local supply.
IVDS represents improved varieties for distant supply.
PLCC represents private limited company chain.
CIPC represents International Potato Center (CIP) chain.
TSPC represents true seed potato chain.

In Chain PLCC, seed suppliers were perceived to contribute more to seed purity, seed genetic quality, and mix flexibility than other actors ($p \leq 0.05$); they were equally important when compared to seed growers with respect to their contribution to production costs, seed health, appropriateness in seed size, appropriateness in seed physiological age, volume flexibility, and lead time. The contributions of ware growers to all performance sub-indicators were the smallest and different ($p \leq 0.05$) from the contributions of other actors except for seed physical damage. The contributions of seed suppliers and seed buyers were not different from each other for appropriateness of seed size, seed physical damage, appropriateness in seed physiological age.

In Chain CIPC, the contribution of breeding centres, G2/G3 seed growers, G4/G5 seed growers and ware growers to seed purity, seed genetic quality and seed health were different at $p \leq 0.05$ and the scores were largest for breeding centre followed by G2/G3 seed growers.

The experts gave largest and different ($p \leq 0.05$) scores to the small to medium scale seed growers with respect to their contributions to appropriateness in seed physiological age.

Table 5.3 presents the average scores of the extent of improvement in performance sub-indicators in Chains CPSS, IVLS, PLCC and CIPC compared to Chain DC, when Chains CPSS, IVLS, PLCC and CIPC perform according to best practice. The scores allotted to Chains CPSS and IVLS were different ($p \leq 0.05$) with respect to the extent of improvement in all performance sub-indicators except transaction costs, for which no differences were found between any of the chains. The scores for Chains PLCC and CIPC were higher than those for Chains CPSS and IVLS; Chain PLCC and CIPC were not significantly different in the extent of improvement (lowering cost) in production costs, seed purity, seed genetic quality seed health, appropriateness of seed size, appropriateness in seed physiological age, mix flexibility and volume flexibility whereas Chain PLCC even scored better than Chain CIPC in improvement of physical seed damage and lead time. In sum these results show that Chain PLCC was perceived to be the best performing chain.

Experts also expressed their opinion on the relative importance of different performance indicators for the entire performance of a seed potato supply chain. Experts gave the highest score (42%) to seed quality followed by seed costs (28%) (Figure 5.3). Flexibility (15%) and responsiveness (15%) together comprised about one third of the total.

Table 5.2. Mean per cent contributions (standard deviations) of individual actor groups to the different performance sub-indicators in five selected seed potato supply chains (total contributions equal 100 per chain for one sub-indicator).

Chain	Production costs†	Transaction costs†	Seed purity†	Seed genetic quality†	Seed health†	Appropriateness of seed size†	Seed physical damage†	Appropriateness in physiological age†	Mix flexibility†	Volume flexibility†	Lead time†
DC											
Ware growers (save seed from ware production)	73 a (24.5)	52 (21.6)	60 (26.8)	np	59 (25.4)	58 (26.6)	59 (24.8)	59 (24.4)	64 (29.7)	69 a (24.1)	75 a (27.5)
Ware growers (farmers who want to renew their seed/frequent buyers)	27 b (24.5)	48 (21.6)	40 (26.8)	np	41 (25.4)	42 (26.6)	41 (24.8)	41 (24.4)	36 (29.7)	31 b (24.1)	25 b (27.5)
n	20	20	20		19	21	21	19	17	19	19
CPSS											
Seed growers through positive selection	100	63 a (22.6)	100	100	81 a (14.4)	71 a (22.5)	70 a (21.8)	73 a 17.3)	100	100	100
Ware growers using seed of positive selection	np	37 b (22.6)	np	np	19 b (14.4)	29 b (22.5)	30 b (21.8)	27 b (17.3)	np	np	np
n	18	17	18	15	18	20	19	18	19	18	19
IVLS											
Breeding centres	22 a (18.1)	20 b (18.4)	50 a (25.3)	75 a (21.3)	50 a (24.5)	38 a (28.0)	12 b (11.2)	25 a (23.9)	43 a (29.9)	21 b (19.6)	27 b (23.8)
Organized seed growers	32 a (14.4)	39 a (18.4)	25 b (11.1)	15 b (14.4)	26 b (12.8)	24 a (16.2)	27 a (19.6)	25 a (16.2)	27 ab (15.0)	43 a (16.9)	39 a (17.2)
Individual seed growers in the vicinity	31 a (23.1)	26 b (15.6)	17 c (14.3)	7 c (8.5)	17 c (13.4)	28 a (25.3)	33 a (19.7)	34 a (25.4)	24 b (23.3)	28 b (22.4)	28 b (24.4)
Ware growers saving own seed	15 b (13.2)	16 b (13.0)	8 d (7.1)	3 d (6.1)	7 d (6.4)	10 b (10.6)	28 a (21.9)	16 b (16.9)	6 c (6.4)	8 c (5.4)	6 c (5.3)
n	20	20	21	21	20	20	20	20	19	19	19
PLCC											
Seed suppliers	42 a (20.5)	40 a (24.8)	51 a (25.0)	70 a (27.3)	41 a (22.3)	34 a (24.1)	19 b (15.9)	29 a (24.8)	57 a (26.1)	44 (25.8)	40 a (23.6)
Seed growers	35 ab (20.5)	17 b (11.7)	25 b (14.8)	15 b (15.7)	33 a (23.1)	30 a (20.4)	41 a (19.0)	30 a (19.7)	24 b (18.2)	31 (17.0)	37 a (17.1)
Seed buyers (e.g. seed suppliers or other buyers)	23 b (21.9)	37 a (28.4)	24 b (21.8)	15 b (22.9)	20 b (20.4)	31 a (22.2)	26 ab (12.5)	33 a (23.5)	19 b (24.4)	25 (25.6)	23 b (23.5)
Ware growers	np	6 c (7.4)	np	np	6 c (5.8)	5 b (5.5)	14 b (21.2)	8 b (8.7)	np	np	np
n	19	19	19	19	18	19	19	19	19	19	19

Table 5.2. (continued)

Chain	Production costs†	Transaction costs†	Seed purity†	Seed genetic quality†	Seed health†	Appropriateness of seed size†	Seed physical damage†	Appropriateness in physiological age†	Mix flexibility†	Volume flexibility†	Lead time†
CIPC											
Breeding centre	30	18 b	46 a	70 a	42 a	30 a	12 b	23 b	42	23 b	24 b
	(18.6)	(16.2)	(23.5)	(24.4)	(20.2)	(26.0)	(13.9)	(23.5)	(26.0)	(17.7)	(19.3)
Medium to large scale G2/G3 seed growers	37	33 a	26 b	17 b	28 b	27 a	25 a	25 b	32	42 a	41 a
	(11.8)	(16.1)	(13.6)	(13.4)	(9.7)	(15.5)	(18.7)	(17.1)	(18.5)	(16.5)	(19.5)
Small to medium scale seed growers	33	33 a	20 c	9 c	22 b	34 a	40 a	37 a	26	35 ab	35 ab
	(14.0)	(13.8)	(13.4)	(10.5)	(13.3)	(25.1)	(21.6)	(27.0)	(21.9)	(20.8)	(24.6)
Ware growers	np	15 b	8 d	3 d	8 c	9 b	23 ab	15 c	np	np	np
		(12.2)	(9.0)	(3.9)	(5.8)	(13.3)	(18.8)	(15.8)			
n	19	19	19	19	18	19	19	19	19	19	19

np represents not possible according to authors.
† Similar letters within a chain and a performance sub-indicator indicate that contributions do not differ significantly according to Wilcoxon signed Rank test ($p \leq 0.05$).
G1 represents first generation ... G6 represents sixth generation.
DC represents default chain.
CPSS represents commercial positive seed selection.
IVLS represents improved varieties for local supply.
PLCC represents private limited company chain.
CIPC represents International Potato Center (CIP) chain.

Table 5.3. Average (standard deviation) score of the extent of improvement in performance sub-indicators in Chains CPSS, IVLS, PLC and CIP compared to Chain DC†, when they perform according to their best practice. Data collected in 5 points scale.

Chain	Production costs††	Transaction costs††	Seed purity††	Seed genetic quality††	Seed health††	Appropriateness of potato seed size††	Seed physical damage††	Appropriateness in physiological age††	Mix flexibility††	Volume flexibility ††	Lead time††
CPSS‡	1.67 b (0.913)	1.90 (1.044)	2.80 c (1.005)	2.50 c (1.051)	2.95 c (0.944)	2.60 c (0.994)	2.70 c (0.978)	2.55 c (0.945)	1.95 c (1.161)	1.95 c (1.161)	2.10 c (1.210)
IVLS§	2.29 a (1.521)	2.24 (1.300)	3.80 b (0.894)	3.75 b (1.164)	3.80 b (0.894)	3.50 b (1.051)	3.25 b (1.118)	3.10 b (1.165)	3.29 b (0.956)	3.33 b (1.110)	3.15 b (1.226)
PLCC¶	2.60 a (1.729)	2.60 (1.729)	4.70 a (0.470)	4.37 a (0.761)	4.68 a (0.477)	4.32a (0.885)	4.16 a (0.958)	4.32 a (0.885)	4.20 a (0.833)	4.15 a (0.745)	4.21 a (0.976)
CIPC#	2.38 a (1.564)	2.43 (1.363)	4.45 a (0.759)	4.45 a (0.605)	4.35 a (0.671)	4.10 a (0.912)	3.65 b (1.040)	3.85 a (0.988)	3.81 ab (0.981)	3.81 ab (0.928)	3.45 b (1.317)
n‡‡	21	21	20	20	20	20	20	20	21	21	20

DC represents default chain.
CPSS represents commercial positive seed selection.
IVLS represents improved varieties for local supply.
PLCC represents private limited company chain.
CIPC represents International Potato Center (CIP) chain.
† Key actors considered were ware growers saving seed from ware production and ware growers who want to renew part of their seed stock or frequent buyers.
‡ Key actors considered were seed growers from positive selection and ware growers who use seed of positive selection.
§ Key actors considered were breeding centres, grouped seed growers, individual seed growers and ware growers saving own seed.
¶ Key actors considered were seed suppliers, seed growers, seed buyers, and ware growers.
# Key actors considered were breeding centres, medium to large scale Generations 2 and 3 seed growers, small to medium scale Generations 4 and 5 seed growers, and ware growers.
†† Similar letters within a performance sub-indicator indicate that contributions do not differ significantly according to Wilcoxon Singed Rank test ($p \leq 0.05$).
‡‡ for PLCC chain n=19.

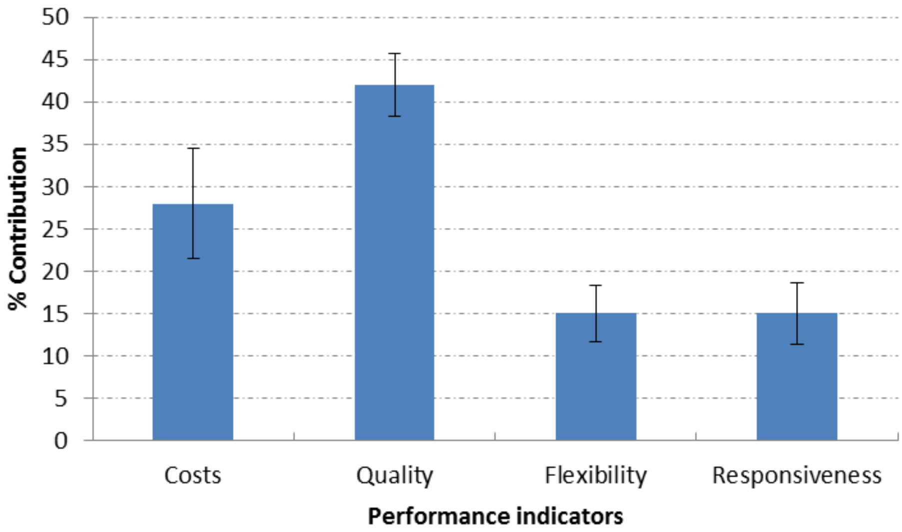


Figure 5.3. Relative importance of different types of performance indicators for the overall performance of a seed potato supply chain in Ethiopia, as perceived by experts (n=19). Contributions indicated by bars add to 100.

5.5. Discussion

The objectives of this study were to describe existing and to design potential seed potato supply chains, and to evaluate perceived performances of selected chains.

Description and design of chains

Chain DC was an existing chain in which the key actors were ware growers (saving seed for sale and own use), and seed buyers (those who bought seed to renew part of their seed stock and those who regular bought seed). The ware growers usually sold seed at local markets and the price was the main determinant of final transaction (Abebe et al., 2012). Ware growers accomplished all activities such as production postharvest management and transportation. Ware growers had little knowledge and skill in seed potato production, and used poor storage facilities (Hirpa et al., 2010). As a result the seed quality supplied by the ware growers was poor (Mulatu et al., 2005). The same was true for seed potato supplied by Chain DDC. NGOs in Chain DDC could distribute potato diseases with seed tubers they transported to new areas with a high potential for potato production. For that reason, Chain DDC was undesirable.

Chain SPSS was an existing chain in Kenya but not in Ethiopia. In this chain the key actors were ware growers undertaking positive selection, and buyers of seed potato produced through positive selection. Implementation of positive selection improved the quality of seed potato managed by ware growers in Kenya as compared to the DC (Gildemacher et al., 2011). Implementing this chain Ethiopia can also increase supply of quality seed potato if farmers will be trained in the techniques of positive selection. In Ethiopia, no training was given to potato growers on positive selection.

Chain CPSS did not exist in Ethiopia. This chain is a commercial version of Chain SPSS. Key actors in this chain will be seed potato growers through positive selection and ware growers. The members of the key actors of this chain could be small scale seed growers (growing seed from local varieties) or medium to large scale ware growers (growing local varieties) having seed production through positive selection as a component their ware business. The challenge of seed potato production through positive selection by smallholder farmers could be infeasibility of the business due to small scale. To this end the minimum size of plot to be allotted for commercial seed potato production through positive selection has to be investigated. Ware growers (buyers of seed potato produced through positive selection) have to be informed about merits of using seed potatoes produced through positive selection. This can be done through field demonstrations. The seed growers need training, and should have necessary facilities (e.g., store) and market for their seed.

Chain IVLS was an existing chain in which the key actors were breeding centres, organized seed growers, individual seed growers, and ware/seed growers. Breeding centres do adaptation trials and release potato varieties that are adaptable to diverse agro-ecologies, resistant to diseases, and high-yielding. Two potato varieties (Jalene - released in 2002 and Gudene - released in 2006) are under production by farmers that have access to seed tubers of new varieties. One variety (called Belete) has been released recently. The breeding centres have made no effort to improve productivity of local varieties, although these varieties are grown by the majority of smallholder potato growers and some commercial ware growers. Lack of emphasis on local varieties by the breeding centres could be attributed to low expectations of researchers of the benefits from improving local varieties. Another reason could be that the breeders are not aware of the criteria farmers have for a good variety (Asfaw et al., 2012).

In Chains IVDS (existing chains), some organized seed growers had basic training on seed potato production and postharvest handling. Organized seed growers had committee members who search the market for seed. In areas where bacterial wilt existed (e.g., Welmera) committee members made on-farm inspection of quality of seed produced by the members. Use of DLS among the organized seed growers was common. Individual seed growers had no training in seed potato production and postharvest handling but produced seed tubers based on the experience they got from fellow, trained seed potato growers.

Seed growers had no institutions that guided them in planning the amount of seed potato to produce. According to key informants, they based their next year's production plans on this year's prices, resulting in oversupply and lower prices in the next year. In Chain IVDS, a large portion of the marketed seed potatoes was sold to institutions that donated seed tubers. According to Abebe et al. (2010), NGOs and government agencies bought seed tubers at high prices and distributed them to farmers in other regions at a discounted price or for free. The involvement of the institutions could create market distortions.

Chain PLCC was an existing chain in Ethiopia. It is an ideal seed potato supply chain to seed potato growers in Ethiopia because it avails a market for their seed potatoes. In this chain, seed growers made a forward contract with seed buyers. This contract assured farmers a market for their seed. The key actors in this chain were seed supplier, seed grower, seed buyer, and ware growers. In this chain, the seed growers had contract with the seed buyers. During this study, there was only one private company (Solagrow PLC) playing a major role in this seed supply chain. The government of Ethiopia has supported private companies of this type through provision of necessary services.

Chain CIPC did not exist in Ethiopia. It was suggested on paper to benefit its key actors (International Potato Center, 2011). The key actors in this chain were breeding centres, medium to large scale G2/G3 seed growers, small to medium scale G4/G5 seed growers, G6 ware growers. In this chain, the private sector was expected to play a major role in producing seed tubers of different generation with the guidance and support of formal institutions (GOs and NGOs) (International Potato Center, 2011).

Chain TSPC did not exist in Ethiopia. This chain aimed at supplying seed potatoes at low costs to potato growers living in remote areas of Ethiopia. A company would supply true seed potatoes to medium to large scale seed growers. The medium to large scale seed growers would produce tubers from true seed and multiply the tubers for two generations and would supply G3 to other small to medium scale seed growers who would produce seed potato that would be used for ware production.

Selected chains and their performance evaluation

Of the nine chains investigated, four chains, i.e. Chains CPSS, IVLS, PLCC, and CIPC, were selected for further study because 1) of the higher ranks allotted to them by many experts compared with other chains, and 2) they were distinctly different. The performances of the selected chains and Chain DC were further evaluated with performance criteria that comprised sub-indicators of the main indicators.

Chain CPSS was allotted the first rank by several (4 out of 15) experts (Table 5.1), indicating its potential for improving quality of local seed potato varieties. Improvement in the quality of local seed potato varieties is very important, because most of the potato growers in Ethiopia use seed potatoes of local origin and their quality is very low. This chain is new (its feasibility is not tested yet), but will have a potential to improve seed quality in Ethiopia (Table 5.3). The seed potato that could be produced through this chain could be low in quantity as indicated by some experts. The problem of low multiplication rate will be tackled by making seed potato production through positive selection part of medium to large scale ware production of the business. Smallholder seed growers can also multiply seed potatoes produced through positive selection for some generations before they commercialize it.

Chain IVLS was ranked first by 3 and second by 4 out of 15 experts for its performance with respect to costs, flexibility, responsiveness and quality indicating its substantial importance in improving seed potato supply systems in Ethiopia. It is the dominant chain in the alternative seed potato system in Ethiopia (Hirpa et al., 2010). It was designed by breeding centres with the involvement of DBARD to play some roles of formal seed system. In the present study, it was the main chain that supplied seed potatoes of improved varieties to seed growers found in the vicinities.

Chain IVDS had similar key actors compared with Chain IVLS except for the involvement of NGOs, GOs and small groups of seed buyers from districts far away from the place where seed of improved potato varieties were grown. The NGOs and GOs bought seed potatoes from grouped seed potato growers and sold them for a subsidized price or gave them away for free (Abebe et al., 2010). It seemed that NGOs and GOs had replaced missing but very important actors, i.e. seed potato traders in terms transporting to far areas. NGOs and GOs did not only transfer seed potatoes but also gave technical assistance and agricultural inputs to the target potato growers. However, involvement of NGOs and GOs could cause price distortion in the seed potato market and could also make the seed system unsustainable. Despite its high rank, this chain was not selected for further performance analysis because of its partial similarity to Chain IVLS.

Chain PLCC was the only formal commercial chain that existed in Ethiopia when this study was undertaken. It was ranked first by 1 and second by 4 out of 15 experts, indicating its importance. In this chain there was only one company that supplied seed potatoes to seed growers (Solagrow PLC, 2011). The company had a forward market contract with seed growers. The seed growers back sold seed potatoes they produced to the company for pre-agreed prices based on grades (LSB, 2011). This chain seems ideal to a situation in Ethiopia where the market for seed potatoes of improved varieties is a problem.

Chain CIPC ranked first by 1, second by 2, and third by 6 out of 15 experts, indicating its importance in improving seed potato systems in Ethiopia. During this study, this chain was new (probably non-existing in Eastern Africa), but tested on paper to be economically feasible for a private sector who wants to take it up as a business (International Potato Center, 2011) (Table 5.1).

Chain TSPC was ranked last among the nine chains and deselected by 10 out of 15 experts indicating its inapplicability under Ethiopian condition. This chain was based on true seed potatoes (TSP) which was praised to benefit smallholder potato growers in the 1990s (Tuku, 1994) but ignored later.

The results of the performance evaluation of the selected chain show that actors differ in their contributions to the performances of sub-indicators, as perceived by the experts. In Chain DC, the selling ware growers contributed more to production costs, volume flexibility and lead time than the seed buyers (Table 5.2). This implies that, in this chain a higher improvement can be made in production costs, volume flexibility and lead time by improving these performance sub-indicators at ware growers (saving seed for sell) than at ware growers buying seed for seed renewal.

In Chain CPSS, seed growers were found to be more important than ware growers using the seed of positive selection for improving transaction costs, seed health, appropriateness of seed size, seed physical damage, and appropriateness in seed physiological age. Except transaction costs, all are quality sub-indicators implying a high importance of the actor (seed grower through positive selection) for quality improvement in the chain. This result is in line with the purpose of the chain, i.e. it was designed to improve the quality of seed potatoes of local varieties.

Performance sub-indicators were perceived to be improved in all selected chains (Chains CPSS, IVLS, PLCC, and CIPC) compared to the default chain (Table 5.3). However, improvements in the sub-indicators varied among some chains and were similar in others. In Chain CPSS, the extent of improvement in the performance sub-indicators was lower than in other chains. This could be because of the nature of the actors, i.e. key actors are smallholders who have low level of knowledge in seed potato production and have low level of resources to invest on seed potato production and methods used to produce seed potato. In Chain IVLS, the extent of improvement in seed purity, seed genetic quality, seed health, appropriateness of seed size, and appropriateness in seed physiological age was lower than in Chains PLCC and CIP. This could be due to the involvement of smallholder seed growers who have a low level of knowledge and low resources in Chain IVLS (Abebe et al, 2010) compared to those in Chains PLCC and CIPC. Moreover, Chains PLCC and CIPC use better methods to produce seed tubers, seed tubers of lower number of generation, and involve actors with higher level of knowledge and resources compared to Chain IVLS (International Potato Center, 2011, Solagrow, 2011). Chain PLCC was better than Chain CIPC with respect to the extent of improvement in seed physical damage and lead time. Scores of Chain PLCC in most of the sub-indicators were larger than scores for Chain CIPC (also differences were not significant). As perceived by experts, the order of the chains with respect to the extent of improvement in sub-indicators compared to Chain DC, were Chains PLCC, CIPC, IVLS and CPSS. This indicates the order of importance in improving the seed potato system in Ethiopia.

From the result of the relative importance of performance indicators for the overall performance of a seed potato supply chain, seed quality was found to be more important than other indicators (Figure 5.3). This implies that, to improve seed potato systems in Ethiopia, a chain with larger scores with respect to improvements of quality sub-indicators would be more important than a chain with smaller scores. This result is in line with the finding of previous studies by Mulatu et al. (2005) and Hirpa et al. (2010). These authors reported that quality was the major constraint of informal seed potato system in Ethiopia.

5.6. Outlook

The integrated supply chain management and performance framework helped us to describe existing chains. More specifically the framework enabled us 1) to review current statuses of the existing and potential seed potato supply chains and 2) to evaluate the performances of all chains based on the perception of experts.

The new chains that were evaluated for their performance (Chains CPSS and CIPC) have a good potential for improving seed yield and quality, but need institutional support. Chain CPSS needs intensive training of seed growers on positive selection and seed quality control. Chain CIPC needs support through a strong private public partnership; the private sector needs to invest in the chain and public institutions have to render necessary supports like availing land and basic seed.

Existing chains also need improvement. For example, the chain that supplies seed potatoes of improved varieties (Chain IVLS) was constrained by lack of market (Abebe et al., 2010). This could be because of the lack of demand for the seed supplied by this chain from commercial/semi-commercial ware growers. According to Abebe et al. (2012), ware potato growers in the Upper Rift valley of Ethiopia preferred local potato varieties to their improved counterparts because 1) local varieties needed less intensive management than improved varieties, and 2) local varieties have better stew quality than improved varieties.

In this study, a considerably higher number of experts gave higher ranks (1-4) to chains that used improved potato varieties than to chains that used local potato varieties, indicating chains that use improved potato varieties were perceived to be more important for seed production than chains that use local potato varieties (Table 5.1). This result contradicts the findings of Abebe et al. (2012) who found local varieties were preferred over improved varieties by ware growers in the southern potato growing area. Experts saw yielding ability and disease resistance but farmers have some more additional criteria like stew quality and low input requirement. Therefore, improvement of seed potato supply chains needs alignment of interests of all actors along the chain.

References

Abebe, G.K., Bijman, J., Pascucci, S., Omta, O., Admasu T., 2012. Analysis of the causes of low adoption in less developed agri-food chains: the case of potato supply chain in the

Upper Rift Valley region of Ethiopia. 10th Wageningen International Conference on Chain and Network Management (WICaNeM), 23-25 May 2012, Wageningen, The Netherlands.

Aramyan, L.H., Oude Lansink, A.G.J.M., van der Vorst, J.G.A.J., van Kooten, O., 2007. Performance measurement in agri-food supply chains: a case study. Supply Chain Management: An International Journal 12(4), 304-315.

Asfaw, A., Almekinders, C.J.M., Blair, M.W., Struik, P.C., 2012. Participatory approach in common bean (*Phaseolus vulgaris* L.) breeding for drought tolerance for southern Ethiopia. Plant Breeding 131, 125-134.

CSA (Central Statistical Agency of Ethiopia). 2011. Agricultural sample survey: Report on area and production of crops, Addis Abeba, Ethiopia, p. 128.

Davis, K., Swanson, B., Amudavi, D., Mekonnen, D.A., Flohrs, A., Riese, J., Lamb, C., Zerfu, E., 2010. In-depth assessment of the public agricultural extension system of Ethiopia and recommendations for improvement. IFPRI discussion paper 01041, available at http://www.ifpri.org/sites/default/files/publications/ifpridp01041.pdf and accessed 22 December 2012.

Emana, B., Nigussie, M., 2011. Potato Value Chain Analysis and Development in Ethiopia: Case of Tigray and SNNP regions. Accessed 4 October 2012 and available at http://sweetpotatoknowledge.org/projects-initiatives/better-potato-for-a-better-life/resources/potato-value-chain-analysis-and-development-in-ethiopia.pdf

Gebru, G.W., Asayehegn, K., Kaske, D., 2012. Challenges of development agents' performance in technology dissemination: a case from Southern, Nation, Nationalities and Peoples regional State, Ethiopia. Scholar Journal of Agricultural Sciences 2(9), 208-216.

Gildemacher, P., Demo, P., Kinyae, P., Wakahiu, M., Nyongesa, M., Zschocke, T., 2007. Select the best; positive selection to improve farm save seed potatoes. Training manual. CIP, 108 pp.

Gildemacher, P., Demo, P., Barker, I., Kaguongo, W., Gebremedhin, W., Wagoire, W., Wakahiu, M., Leeuwis, C., Struik, P.C., 2009a. A description of seed potato systems in Kenya, Uganda and Ethiopia. Am. J. Pot. Res. 86, 373-382.

Gildemacher, P., Kaguongo, W., Ortiz, O. Tesfaye, A., Gebremedhin, W., Wagoire, W.W., Kakuhenzire, R., Kinyae, P., Nyongesa, M., Struik, P.C., Leewis, C., 2009b. Improving potato production in Kenya, Uganda and Ethiopia. Potato Research 52: 173–205.

Gildemacher, P., Schulte-Geldermann, E., Borus, D. Demo, P., Kinyae, P., Mundia, P., Struik, P.C., 2011. Seed potato quality improvement through positive selection by smallholder farmers in Kenya. Potato Res. 54, 253-266.

Gildemacher, P., 2012. Innovation in seed potato systems in Eastern Africa, PhD thesis, Wageningen University. KIT Publishers, Amsterdam, The Netherlands.

Gildemacher, P., Leewis, C., Demo, P., Borus, D., Schulte-GeldeRmann, E., Kinyae, P., Mundia P., Nyongesa M., Struik, P.C., 2012. Positive selection in seed potato production in Kenya as a case of successful research-led innovation process. International Journal of Technology Management and Sustainable Development 11(1), 67-92.

Haji, J., Andersson, H., 2006. Determinants of efficiency of vegetable production in smallholder farmers: The case of Ethiopia. Food Economics – Acta Agriculturae Scandinavica, Section C, 3(3-4), 125-137.

Hirpa, A., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Lansink, A.O., Tsegaye, A., Struik, P.C., 2010. Analysis of seed potato systems in Ethiopia. Am. J. Potato Res. 87, 537-552.

Hirpa, A., Meuwissen, M.P.M., Lommen, W.J.M., Struik, P.C., Tsegaye, A., Lansink, A.O., 2013. Cost effective seed potato production in Ethiopia. Submitted to Potato Research.

International Potato Center (CIP), 2011. Roadmap for investment in the seed potato value chain in eastern Africa. Lima, Peru. 27 p.

Kassa, B., (undated). Agricultural research and extension linkages in Ethiopia: a historical survey. https://docs.google.com/viewer?a=v&q=cache:AULyM2aJhy8J:www.oerafrica.org/FTPFolder/Website%2520Materials/Agriculture/haramaya/Perspective_Agricultural_Extension/AICM%2520Module%2520Final%2520Jan%252031,%25202012/Paper_on_research_extension_likage21_Share.doc+Belay+Kassa+dvelopemnt+agents+(DAs)+Ethiopia+tax+collection&hl=en&gl=nl&pid=bl&srcid=ADGEESgjU34ChTRoe2O8aGQXeNvhsHR2XrCdy-52_Lk0Mw9mfEizXvXjAyM4otOIkgAPdVF249Bp8-ye7XPvosKzWSY2RiXeLoSz7t01byy7FdwsDaZZJeBA99_5L5DUNyhYAIDImFt1&sig=AHIEtbSA-mtF3NZaUP2EO5LCRmTOXeULEA

Kassa, B. Degnet A., 2004. Challenges Facing Agricultural Extension Agents: A Case Study from South-western Ethiopia. African Development Bank, 139-168.

Lai, K., Ngai, E.W.T., Cheng, T.C.E., 2002. Measures for evaluation of supply chain performance in transport logistics. Transport Research Part E 38, 439-456.

Lambert D.M., Cooper C.M., 2000. Issues in supply chain management. Industrial Marketing Management 29, 65–83.

Lemaga, B., Hailemariam, G., Gebremedhin, W., 1994. Prospects of seed potato production in Ethiopia. In Proceedings of the second national horticultural workshop of Ethiopia, ed. E. Hareth and D. Lemma, 254-275. Addis Abeba: Institute of Agricultural Research and FAO.

LSB (Local Seed Business), 2009. Local seed business newsletter. Issue 0. Accessed November 10, 2012 and available on http://portals.wi.wur.nl/files/docs/LSB%20Newsletter%20August2009.pdf.

LSB, 2010. Local seed business newsletter. Issue 4. Accessed November 10, 2012 and available on www.wageningenur.nl/web/file?uuid=42f3fdcf-86c7-4fda.

LSB, 2011. Local seed business newsletter. Issue 8. November 10, 2012 available on www.wageningenur.nl/web/file?uuid=ffd38d0f-7f04-417b.

Mulatu, E., Osman, E.I., Etenesh, B., 2005. Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. J New Seeds 7(3): 31–56.

Schulte-Geldermann, E., Gildemacher, P. Struik, P.C., 2012. Improving seed health and seed performance by positive selection in three Kenyan potato varieties. Am. J. Potato Res. 89, 429–437.

SolagrowPLC, 2011. About Solagrow. Accessed 24 December 2012 and available at http://www.solagrowplc.com/about-solagrow.

Tuku, Bereke-Tsehai, 1994. The utilization of true seed potato as an alternative method of potato production. Ph.D. dissertation. Wageningen Agricultural University, The Netherlands. 129 p. Accessed on November 19, 2012 and available at http://edepot.wur.nl/206983

Van der Vorst, J.G.A.J., 2006. Performance measurement in agri-food supply-chain networks (Chapter 2), in *Quantifying the agri-food supply chain*, Ondersteijn, C.J.M., Wijnands, J.H.M., Huirne, R.B.M., van Kooten, O. (eds.). Springer, Dordrecht, pp 15-26.

Van der Vorst, J.G.A.J., Beulens, A.J.M., van Beek, P., 2005. Innovations in logistics and ICT in food supply chain networks (Chapter 10), in *Innovation in agri-food systems*, Jongen W.M., Meulenberg M.T.G. (eds.). Wageningen Academic Publishers, Wageningen, pp. 245-292.

Van Roekel, J., Kopicki, R., Broekmans, C.J.E, Boselie, D.M.,2002. Building Agri-Supply Chains: Issues and Guidelines. Accessed October 4, 2012 and available on http://siteresources.worldbank.org/INTARD/864438-1112682945622/20716483/AgriSupplyChains.pdf

Chapter 6

General discussion

6.1. Introduction

This chapter discusses the results of the thesis and their implications. The overall objective of this thesis was to study the economic and agronomic aspects that affect availability and quality of seed tubers in Ethiopia. The research was motivated by the fact that little knowledge exists on the strengths and weaknesses of the existing seed potato systems in general and specific seed potato supply chains in particular; and on opportunities to improve them. As presented in Chapter 1, the overall objective was split into four sub-objectives. First, the thesis aimed at describing and analysing the status and performance of currently operating seed potato systems in Ethiopia, and identifying and prioritizing improvement options. The performances of the three existing seed potato systems (the informal, alternative and formal ones) were evaluated with respect to their strengths and weaknesses in undertaking their functions as a seed system, and options for their improvement were identified and prioritized in Chapter 2. Second, the thesis aimed at eliciting farmers' opinions on the importance of seed potato management attributes with respect to their perceived effects on seed potato yield and quality and at quantifying these effects. To accomplish this target, perceived effects on seed yield and quality of the most important seed potato management attributes were quantified in Chapter 3. Third, the thesis aimed at developing cost-effective seed potato production plans. This was accomplished by developing several seed potato production plans in Chapter 4. Fourth, the thesis aimed at describing existing and designing potential seed potato supply chains, and evaluating the performance of those chains selected by experts as the most suitable or promising. To achieve this aim, seed potato supply chains were described or designed and the expected performance of selected chains was evaluated.

The next sections of this general discussion will present a synthesis of results, will discuss the scientific and practical implications of the results, and will provide a future outlook and the most salient conclusions.

6.2. Synthesis of the results

This section synthesises the results of the thesis presented in Chapters 2 to 5. In this synthesis, the outcomes of the potato stakeholders workshop held in Addis Ababa on February 5, 2013 in which the results of Chapter 2-5 were presented and discussed from a practical perspective are also included. Figure 6.1 presents the links among the results of the different research chapters.

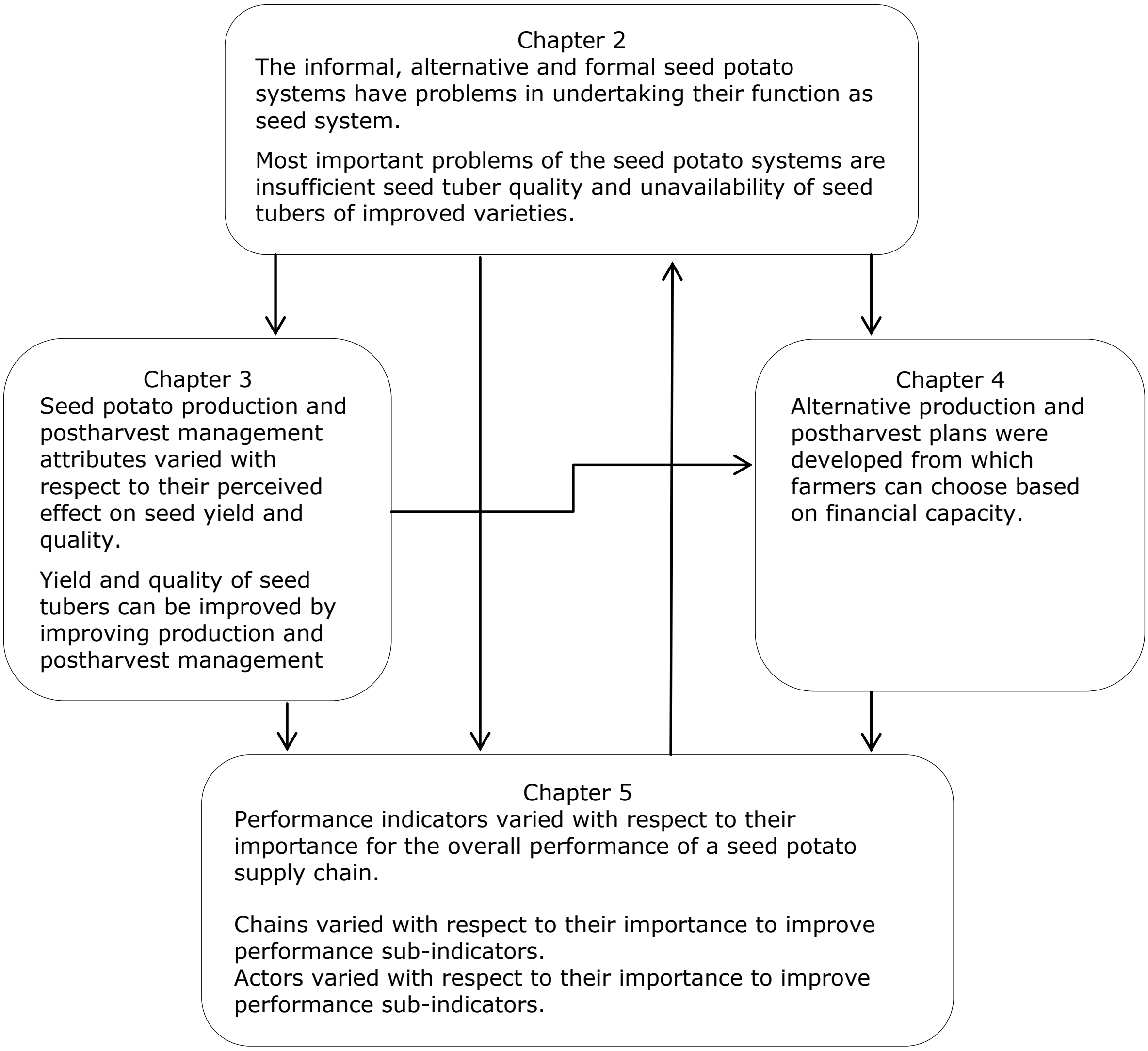


Figure 6.1. Links among results of Chapters 2-5.
Arrows show major flow of results in the synthesis.

6.2.1. Seed potato systems: current status and performance

Chapter two of this thesis considered the three seed potato systems, i.e. informal, alternative and formal seed systems, and the four major seed potato growing areas, i.e. central, eastern, north-western and southern Ethiopia. The results showed that all seed potato systems in all potato growing areas had problems in undertaking their functions as a seed system and needed to be improved. The informal seed system supplies the largest portion (98.7%) of the total seed potato used in the country. However, it supplies seed tubers that are poor in health, unsuitable in physiological age, poor in genetic quality, impure (mixed during production and trade), physically damaged and inappropriate in size. The alternative and formal seed potato systems supply a good quality seed tubers compared to the informal seed system but a very small amount (1.3%). Chapter 2 concluded that overall seed supply can be improved if the three seed systems co-exist and are linked as also suggested by Almekinders et al. (1994), Almekinders and Louwaars (2002) and Louwaars and De Boef (2012) for a general seed system operating in developing countries. The seed supply chain named improved variety chain for local supply (IVLS) that is presented in Chapter 5 (Figure 5.2) links the alternative and informal seed systems. It supplies seed tubers of improved varieties to the informal seed system.

6.2.2. Improving seed quality seed tubers of local varieties at farm level

Within the existing systems, the quality of seed tubers can also be improved by improving production and postharvest management at the farmer level. A study on the perceived effects of production and postharvest management attributes presented in Chapter 3 showed that quality of seed tubers can be increased by using seed potato production and postharvest management attribute levels that have a higher relative contribution to seed yield and quality (Tables 3.9 and 3.10). Moreover, the study on performance of seed supply chains presented in Chapter 5 showed that a commercial positive seed potato selection chain has a potential to improve quality of seed tubers of local varieties compared to the predominant seed potato chain in the country.

6.2.3. Improving availability of seed tubers of improved varieties

Chapter 2 concluded that insufficient supply of seed tubers of improved varieties was among the major problems of seed potato systems in Ethiopia. This section will deal with the causes of the insufficient supply of seed tubers of improved potato varieties, namely, low uptake of improved varieties by farmers, lack of functional seed potato supply chains, and low current demand for improved potato varieties by commercial ware growers, traders and consumers.

In Chapter 3 it is assumed that a low adoption of recommended seed potato technologies by famers in Ethiopia could be due to lack of alternative seed potato production methods compatible with farmers' economic and conditions. To improve the low uptake of improved potato varieties by farmers, alternative low-cost production and postharvest management plans were developed in Chapter 4 that will be compatible to the financial capacity of farmers. Chapter 4 used the relative contributions of seed potato management attributes to seed yield and quality that were quantified in Chapter 3 and calculated the extra costs to develop alternative seed potato production and postharvest management plans. Plans that included diffused light storage (DLS) had significantly higher costs than those without DLS. This implies that under the existing prices of materials used to construct DLS, DLS seemed to be an expensive investment to the majority of seed growers. The amount of seed tubers produced by the majority of the seed growers was also too small to justify construction of a DLS. To lower cost of seed storage, seed growers could pool resources and construct a DLS that can be used together.

A functional seed supply chain is needed to supply quality seed tubers at a right amount, in a right place and time, and for an affordable price. The result of the seed potato supply chains management assessment presented in Chapter 5 showed that the main constraints of the existing chains were attributed to low levels of knowledge and skill in seed potato production and postharvest management, lack of market for high quality seed tubers, and poor resource endowments which are similar to the constraints of seed systems in Chapter 2. There is also lack of involvement of private sectors in the seed potato production and supply (International Potato Center, 2011).

The results of the performance evaluation presented in Chapter 5 also showed that performance indicators such as costs, seed quality, flexibility and responsiveness differ in their importance to the overall performance of an entire seed potato supply chain. Of the four performance indicators, seed quality was perceived to be more important than other performance indicators. This confirms the findings in Chapter 2; among the seed system components, seed quality was ranked first in its importance to be improved in the informal, alternative and formal cooperative seed potato systems (Table 2.2). The results of the in-depth performance evaluation presented in Chapter 5 showed that actors differed in their relative contribution to performance sub-indicators such as production costs, transaction costs, seed purity, seed genetic quality, seed health, appropriateness in seed size, seed physical damage, appropriateness in seed physiological age, mix flexibility, volume flexibility and lead time. This implies that a larger improvement in a seed supply chain with respect to a specific sub-indicator can be achieved by improving that sub-indicator at the actor level that has a larger relative contribution.

The current demand for seed tubers of improved varieties could be increased by creating markets for ware potatoes with a higher added value. This needs, among other aspects, creating a sustainable pull, thus adding value to the potato chain through advances in for instance potato processing like what was accomplished in India (Marwaha et al., 2010); and sharing added value across all links in the supply chain. Currently the main buyers of seed tubers of improved varieties are NGOs and GOs (Abebe et al., 2010). The demand for the seed tubers by the NGOs and GOs will depend on factors like availability of budget and their plans and programmes; their demand is irregular in time and amount. Moreover, demands for seed tubers by the NGOs and GOs are not communicated in advance to seed growers; seed growers simply grow seed without any knowledge about the market for their seed tubers. Thus, seed growers face uncertainty on markets for seed tubers.

Moreover, ware growers prefer to grow local varieties to improved varieties because they perceive that local varieties have better cultivation management and stew quality than improved varieties as shown by Abebe et al. (2012) in a study conducted in the southern potato producing area (the largest commercial ware producing area in the country). This implies that there is a need to demonstrate the agronomic advantages of improved seed to farmers and traders, and to convince consumers about the good (or at least comparable to local varieties) quality of improved varieties in terms of taste and cooking qualities.

A long distance between the source and destination areas could contribute to the low demand of improved varieties by the commercial ware growers. The distance between major improved seed growing areas (districts of Jeldu, Degem and Welmera) and major ware growing areas (districts of Shashamene, Koffel and Arsi Negelle) ranges from 300 to 400 km. According to commercial seed potato experts, transporting seed tubers over a distance of more than 150 km is not economically feasible because of high transportation cost. Moreover, because seed tubers are transported after they sprout, sprout damage during transportation could be very high, especially because most of the transporters do not use transportation facilities convenient for sprouted tubers (i.e. they use sacks instead of boxes to transport the tubers). Sprout damage will have a negative effect on the potential yield of improved varieties. This suggests a need for local potato seed production for local markets. Transport of seed over long distances also brings the danger of transferring seed-borne diseases from one region to the next.

6.3. Scientific innovation

The thesis used combinations of approaches that can also be used to study seed systems and seed supply chains of other agricultural products, more specifically crop products. The thesis began with a goal of discovering strengths and weaknesses of existing seed potato systems and identified improvement options. To that end, the conceptual framework developed from farmers' perspective by Weltzien and vom Brocke (2001) was adapted to systematically analyse the strengths and weaknesses of the seed potato systems. From the analysis we found that all seed systems had weaknesses but the weaknesses lie in different components of the seed systems implying that options to improve the seed systems vary. A workshop that involved national and international seed potato experts was organized to identify and prioritize improvement options of the seed potato systems. Because of the complex and dynamic nature of seed systems (Sperling and Cooper, 2003), we brought together experiences from various sources by involving seed potato experts such as Wageningen University professors, managers of Netherlands-based research and development projects, International Potato Center (CIP) staff and Ethiopian experts, to obtain the best possible results. Our results demonstrated that the use of combined approaches helps to undertake an in-depth analysis of the seed systems and to identify and prioritize improvement options.

In the second stage of the thesis, alternative seed potato production plans were developed. To that end, first, seed potato production and postharvest management attributes were identified and prioritized with respect to their importance to seed potato yield and quality using the Delphi technique; and second, effects of selected management attributes (from the result of the Delphi study) on seed yield and quality and relative contributions of each seed potato management attribute level were quantified using conjoint analysis. The combination of the Delphi technique and conjoint analysis in this thesis was an innovative substitution of a complex, costly and time taking field experimentation that could have been undertaken to achieve the same goal. More specifically, we applied social science concepts to find a solution for agronomic problems and obtained important quantities that could be used together with cost data to develop alternative seed potato production plans. Third, costs of management attributes were estimated and systematically combined by using integer linear programming to arrive at alternative plans for farmers in different scenarios. The package of approaches used in this thesis is a valuable methodological application that can be used to quantify effects and relative contributions of management variables in other agricultural products including crops or livestock.

In the third stage of the thesis, the performance of existing and potential seed potato supply chains was evaluated. Two frameworks, the supply chain management framework (Lambert and Cooper, 2000) and the supply chain performance framework (Aramyan et al., 2007) were integrated. The integrated framework helped us to simultaneously and systematically describe/design all seed potato supply chains, to identify their strengths and weakness, and to develop improvement options for selected chains.

6.4. Business and policy implications

In Chapter 5, four seed potato supply chains that were expected to perform best under Ethiopian conditions were selected from nine existing and potential seed potato supply chains. Because the market for seed tubers is problematic in Ethiopia, the successes of these chains depend on the pull mechanism, a result-based mechanism designed to overcome a market failure (McAdams, 2011). In a pull mechanism profit-oriented companies will take part in the chain by creating demand for ware potato, which in turn creates demand for the seed tubers. Even though a potentially large market for processed potatoes exists in Ethiopia, there was no enterprise or company engaged in processing, packaging and selling of ready-to-fry chilled or frozen chips (Tesfaye et al., 2010). Therefore, there is a need to establish potato processing factories that can create a sustainable pull thus adding value to the potato chain and to share this value added value across all actors.

The success of selected seed potato supply chains described in Chapter 5 requires involvement of the private sector as seed tuber producer, agrochemical supplier, machinery and equipment supplier, transporter, and credit supplier. There are huge opportunities for those who want to take part in the seed potato business. Currently, the supply of seed tubers of improved varieties is very small because of limited involvement of the private sector in seed production. With very modest assumptions on seed multiplication rate and price, the seed potato business that includes minituber production, specialized seed multiplication (Generations 2 and 3), and secondary seed multiplication (Generations 4 and 5), in Ethiopia is expected to be profitable (International Potato Center, 2011).

In Ethiopia, because of poorly developed input and output markets, development of functional seed potato supply chains needs involvement of the government in the creation and effective coordination of market linkages. Currently, in Ethiopia, value chains are developed for commodities such as honey, small ruminants, haricot beans, and cereals with involvement of the government and the Netherlands Development Organization (SNV) (Nyathi and Akele, 2012). Similar experience can be used in developing functional seed potato supply chains. More specifically, market problems can be solved by creating institutions that arrange the functionality of the seed potato market at the national level. To that end, policy makers can use the knowledge generated on seed potato supply chains in Chapter 5 in arranging functional seed markets. Networking among potato growers could also help to create a market for improved seed tubers as it is proven to work in other crops. However, there is a need to create awareness among potato growers about the added value of networking.

6.5. Future outlook

This thesis has generated and tested knowledge that can contribute to improving seed potato availability and quality in Ethiopia. However, there are areas that need attention in future research. Chapter 2 concluded that co-existence and a good linkage of informal, alternative and formal seed potato systems was necessary to improve the overall supply of seed potato in the country; and suggested improvement options for individual seed systems. However, a study is needed to investigate how an efficient linkage among the seed systems can be created and what the roles would be of each seed system to improve quality and amount seed potato supply. Currently, in Ethiopia, there is no institution that is mandated to control seed tuber quality. To improve seed quality, there is a high need to create a simple system, i.e. a system that does not need complex institutions that declares seed tuber quality. A study is needed to design a simple efficient system that declares seed quality.

Even though the yielding ability of a potato crop is higher in the *meher* than in the *belg* season, most potato crops (77% of the total area) are grown in *belg* because of a higher disease and pest incidence in *meher* than in *belg*. The main potato varieties grown in *belg* are local varieties. Improved potato varieties are mainly grown in *meher* season with an intensive use of crop protection chemicals which have negative cost, profit and environmental implications. There is a need to undertake a comparative economic analysis of growing improved potato varieties in *meher* and *belg*. Besides the low disease incidence, more labour and land are available in *belg* (only 10% of the cultivated land is covered by crops) than in *meher*.

Farmers obtain information on name, source, yielding ability, marketability and food quality of potatoes from various sources such as family members, extension workers, neighbouring farmers, NGO employees, researchers and potato traders. However, the sources can differ in the efficacy and quality of information they deliver and specific sources may also differ in its efficacy among districts. A study conducted in Kenya showed that the importance of agricultural information sources varied among districts and commodities (Rees et al., 2004). Therefore, there is a need to study the efficacy of the information delivered by different sources in order to recommend farmers about the most useful sources information. Chapter 2 concluded that awareness creation among the seed growers on production and postharvest management, and networking to access market information are important to improve seed potato systems. However, little information exists on how awareness creation can be made on an efficient manner.

The relative contributions of management attributes to seed yield and quality, quantified in Chapter 3, are based on perception data collected from seed growers. This result can be supported by field experiments. In Chapter 4, we used relative contributions of management attribute-levels and extra costs to develop alternative seed potato production plans. Follow-up research is important to analyse the profitability of the plans and also to verify acceptability of the plans by seed growers.

The description part of the chain (Chapter 5) depended entirely on literature and for some of the actors not enough information was available. Primary data on the seed supply chains could improve the description.

6.6. Conclusions

The main conclusions of the thesis are:

- The informal seed system supplies seed tubers that are poor in health, unsuitable in physiological age, poor in genetic quality, impure (varietal mix up), physically damaged and inappropriate in size. This seed system can be improved by prioritizing increasing awareness and skills of farmers, improving seed tuber quality and improving market access (Chapter 2).
- The alternative seed system supplies better quality tubers than the informal seed system but supplies very small amounts. The alternative and formal seed systems can be improved by availing new varieties, designing quality control methods and reducing cost of seed production (Chapter 2).
- To improve the overall seed supply in the country, coexistence and a good linkage of the three seed systems are important (Chapter 2).
- The most important seed potato production and postharvest management attributes for improving seed yield and quality as perceived by seed potato growers are storage method, hoeing frequency combined with hill size, fertilizer rate and fungicide application frequency (Chapter 3).
- If all seed growers adopt the best levels of seed potato production and postharvest management attributes, potato seed yield is expected to increase by about twofold compared with the actual yield reported for 2010. The best levels of the management attributes as perceived by seed potato growers were own or institutional seed tubers, medium size seed tubers, diffused light store, in store sprouting method, tilling land four times, planting at recommended date, hoeing twice combined with large hill size, and recommended fertilizer rate combined with two fungicide applications (Chapter 3).
- Substantial simultaneous improvements in expected yield and quality can be achieved at relatively low extra costs. Moreover, more than 80% of the improvements can already be achieved at less than 30% of the extra costs (Chapter 4).
- For improving overall performance of seed potato supply chains in Ethiopia, seed quality is perceived to be a more important seed supply chain performance indicator than costs, flexibility and responsiveness (Chapter 5).

- Sub-indicators to evaluate seed supply chain performance, i.e. production costs, seed purity, seed genetic quality, seed health, appropriateness of potato seed size, seed physical damage, appropriateness in physiological age, mix flexibility, volume flexibility and lead time, are perceived to be better improved by seed potato supply chains that supply seed tubers of improved varieties than by a chain supplying seed tubers of local varieties (Chapter 5).

References

Abebe, G.K., Bijman, J., Ruben, R., Omta, O., Admasu T., 2010. The role of agricultural public organizations in improving quality and reducing transaction costs in the Ethiopian potato chain. 9th Wageningen International Conference on Chain and Network Management (WICaNeM), 26-28 May 2010, Wageningen, The Netherlands.

Abebe, G.K., Bijman, J., Pascucci, S., Omta, O., Admasu T., 2012. Analysis of the causes of low adoption in less developed agri-food chains: the case of potato supply chain in the Upper Rift Valley region of Ethiopia. 10th Wageningen International Conference on Chain and Network Management (WICaNeM), 23-25 May 2012, Wageningen, The Netherlands.

Almekinders, C.J.M., Louwaars, N.P., Bruijn, G.H., 1994. Local seed systems and their importance for an improved seed supply in developing countries. Euphytica 78, 207-216.

Almekinders, C.J.M, Louwaars, N.P., 2002. The importance of the farmers' seed systems in a functional national seed sector. Journal of New Seeds 4(1-2), 15-33.

Aramyan, L.H., Oude Lansink, A.G.J.M., van der Vorst, J.G.A.J., van Kooten, O., 2007. Performance measurement in agri-food supply chains: a case study. Supply Chain Management: An International Journal 12(4), 304-315.

International Potato Center (CIP), 2011. Roadmap for investment in the seed potato value chain in eastern Africa. Lima, Peru. 27 p.

Lambert D.M., Cooper C.M., 2000. Issues in supply chain management. Industrial Marketing Management 29, 65–83.

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, 39-59.

Marwaha, R.S., Pandey, S. K., Kumar, D., Singh, S.V., Kumar, P., 2010. Potato processing scenario in India: Industrial constraints, future projections, challenges ahead and remedies – A review. Journal of Food Science and Technology 47(2), 137-156.

McAdams, S. 2011. The Agricultural Pull Mechanism Initiative. Accessed 18 February 2013 and available at http://www.agropolis.org/pdf/g20/session2/G20-AGPM-The-Agriculture-Pull-Mechanism-Initiative-S-McAdams.pdf

Nyathi, N., Akele, G., 2012. Adapting the value chain approach to reach the poorest rural households. In: Visser, P., Steen, M., Greiling, J., Hayesso, T., Neefjes, R., Greijn, H. (eds.) Pro-Poor Value Chain Development: Private Sector-Led Innovative Practices in Ethiopia, Netherlands Development Organisation (SNV), Addis Ababa, Ethiopia.

Rees, D., Momanyi, M., Wekundah, J., Ndungu, F., Odondi, J., Oyure, A.O., Andima, D., Kamau, M., Ndubi, J., Musembi, F., Mwaura, L., Joldersma, R., 2004. Agricultural knowledge and information systems in Kenya – implications for technology dissemination and development. Accessed 14 February 2013 and available at http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/5120.pdf

Sperling, L., Cooper, H.D., 2003. Understanding seed systems and seed security. In Improving the effectiveness and sustainability of seed relief. Proceedings of a stakeholders' workshop, Rome, 26-28 May 2003. Food and Agriculture Organization, Rome, Italy.

Tesfaye, A. Lemaga, B. Mwakasendo, J. A. Nzohabonayoz, Z., Mutware, J., Wanda, K.Y., Kinyae, P. M., Ortiz, O., Crissman, C., Thiele, G., 2010. Markets for fresh and frozen potato chips in the ASARECA region and the potential for regional trade: Ethiopia, Tanzania, Rwanda, Kenya, Burundi and Uganda. International Potato Center (CIP), Lima, Peru. Working Paper, 44 p.

Weltzien, E., vom Brocke, K., 2001. Seed systems and their potential for innovation: Conceptual framework for analysis. In: Sperling, L. (ed.), Targeted seed aid and seed system interventions: Strengthening small farmer seed systems in East and Central Africa. Proceedings of a workshop held from 21–24 June 2000 in Kampala, Uganda.

Summary

In Ethiopia, potato can substantially contribute to improving food security through increasing food availability and cash income of smallholder farmers because of its high yield potential, availability of suitable agro-ecology within the country and availability of labour to grow potato. There is also an increasing demand for ware potato. Potato gives the highest amount of energy per unit of land per day among the major arable crops including wheat, rice and maize; potato tubers are rich in vitamin C, a good source of vitamins B1, B2 and B6 and minerals such as potassium, phosphorous and magnesium, and a good source of high quality protein rich in S. In Ethiopia, potato can grow on 70% of the total arable land located in highland areas (from above 1500 to 3200 m above sea level with annual precipitation of 600 - 1200 mm), where about 90% of the Ethiopians live. Demand for potato is increasing because of urbanization and change in consumption patterns of the urban population towards processed products like chips. Moreover, potato is grown in *meher* (long rain season – June to October), *belg* (short rain season – February to May) and off-season under irrigation (October to January) which makes it a crop that supplies food and cash in all seasons and that assures staple food before grain crops can be harvested.

Currently, production and productivity of potato in Ethiopia are much below their potential. Only 2.3% of the total suitable land is cropped with potato and the average yield is very low at 10 Mg ha^{-1}. Low acreage and poor yields are attributed to many factors among which poor quality of seed tubers used by the majority of the farmers and unavailability of seed tubers of improved potato varieties are the major ones. These factors have economic and agronomic causes. The overall objective of this thesis was to study the technical and institutional aspects that affect quality and availability of seed tubers in Ethiopia.

In Chapter 2, the three seed potato systems, informal, alternative and formal, operating in the four major potato growing areas, central, eastern, north-western and southern Ethiopia, were described and their status and performance were analysed using literature, field surveys, expert elicitation, field observations and local knowledge. The results showed that all seed potato systems in all potato growing areas had problems in performing their role as a seed system and needed to be improved. The informal seed system supplied the largest portion (about 98.7%) of the total amount of seed potatoes used in the country, but supplied seed tubers which are poor in health, unsuitable in physiological age, poor in genetic quality,

impure (mixed during production and trade), physically damaged and inappropriate in size. The alternative and formal seed potato systems supplied better quality seed tubers compared with the informal seed system but in very small amounts.

In the informal potato seed system, poor production and postharvest management practices, poor genetic quality of seed tubers, and prevalence of diseases like late blight [causal agent *Phytophthora infestans* (Mont.) de Bary], viruses [e.g., *Potato leaf roll virus* (PLRV) and *Potato virus Y* (PVY)] and bacterial wilt (causal agent *Ralstonia solanacearum*) are the major factors that cause poor quality seed tubers. In this seed system, production and postharvest management practices that enhance quality of seed tubers (such as allotting separate plots to seed production, positive selection, haulm destruction, and use of diffused light storage) were not common among seed growers. Potato experts postulated that in order to improve informal seed systems awareness and skills of farmers needed to be increased and seed tuber quality and market access needed to be improved. To improve alternative and formal seed systems, experts indicated that availing new varieties, designing quality control methods and reducing cost of seed production were required. Chapter 2 concluded that to improve the overall seed potato supply in the country, the co-existence and a good linkage of the three seed systems, and development of self-regulation and self-certification in the informal, alternative and formal cooperative seed potato systems was needed.

In Chapter 3, (i) seed potato production and postharvest management attributes and their levels were identified based on literature and data collected from seed growers and potato experts, (ii) the management attributes were prioritized based on their importance to seed yield and quality using seed growers' and experts' elicitations; and (iii) perceived effects of selected management attributes and relative contribution of levels within the attribute were quantified using data collected from seed growers in the districts Jeldu and Welmera. The result showed that production and postharvest management attributes such as storage method, hoeing frequency combined with hill size, fertilizer rate and fungicide application frequency had a larger perceived effect on seed yield and quality than seed source, seed size, sprouting method, tillage frequency, and planting date. The result also showed that relative contributions of the production and postharvest management attribute levels within a management attribute also varied. Using diffused light storage; hoeing twice, combined with big hill; and using recommended fertilizer rate, combined with two fungicide applications had a significant perceived effect on yield and quality of seed potato. The results imply that seed potato yield and quality can be improved using those management attribute levels with higher relative contributions instead of those with lower relative contributions.

In Chapter 4, relative contributions of seed potato management attributes quantified in Chapter 3 and costs of the management attributes levels were used to develop alternative seed potato production and postharvest management plans by using an integer linear programming technique. Results showed that several alternative plans were developed from which farmers can choose an affordable plan that will enable them to produce seed potato with reasonable yield and quality levels. The result also showed that seed yield and quality levels could be simultaneously increased at relatively low extra costs. Most of the plans were also found to be robust at 50% increase in the rental value of land, price of seed, wage rates, and prices of agrochemicals.

In Chapter 5, seed potato supply chains were evaluated with respect to their performances based on supply chain performance indicators, i.e. costs, seed quality, flexibility and responsiveness using expert elicitation. The results show seed quality was perceived to be more important than costs, flexibility and responsiveness in all chains. Sub-indicators to evaluate seed supply chain performance, i.e. production costs, transaction costs, seed purity, seed genetic quality, seed health, appropriateness of potato seed size, seed physical damage, appropriateness in physiological age, mix flexibility, volume flexibility and lead time, can be better improved by seed potato supply chains that supply seed tubers of improved varieties than by a chain supplying seed tubers of local varieties. The results also showed that actors in a seed potato supply chain differed in their relative contributions to the performance sub-indicators implying that a larger improvement in a seed potato supply chain with respect to a specific sub-indicator can be achieved by improving that sub-indicator at the actor level that has a larger relative contribution.

In Chapter 6, the results of Chapters 2−5 were synthesised and scientific innovation, future outlook and business implications were discussed. An important scientific innovation of this thesis is that it used combinations of research approaches in Chapters 2−5 to attain its objectives. These combinations of approaches can also be used to study seed systems and seed supply chains of other agricultural products. The success of seed supply chains designed in Chapter 5 needs a pull in the supply chain strategy which requires the involvement of the private sector in different stage(s) of potato supply chains, especially of a processor to create a market for ware. Other stages of the potato supply chains also need private sector engagement as seed growers, input suppliers, potato traders, and transporters.

Based on the main results of the thesis in Chapters 2−5, the following conclusions were drawn.

- The informal seed system supplies seed tubers that are poor in health, unsuitable in physiological age, poor in genetic quality, impure (varietal mix up), physically damaged and inappropriate in size. This seed system can be improved by prioritizing increasing awareness and skills of farmers, improving seed tuber quality and improving market access (Chapter 2).
- The alternative seed system supplies better quality tubers than the informal seed system but supplies very small amounts. The alternative and formal seed systems can be improved by availing new varieties, designing quality control methods and reducing cost of seed production (Chapter 2).
- To improve the overall seed supply in the country, coexistence and a good linkage of the three seed systems are important (Chapter 2).
- The most important seed potato production and postharvest management attributes for improving seed yield and quality as perceived by seed potato growers are storage method, hoeing frequency combined with hill size, fertilizer rate and fungicide application frequency (Chapter 3).
- If all seed growers adopt the best levels of seed potato production and postharvest management attributes, potato seed yield is expected to increase by about twofold compared with the actual yield reported for 2010. The best levels of the management attributes as perceived by seed potato growers were own or institutional seed tubers, medium size seed tubers, diffused light store, in store sprouting method, tilling land four times, planting at recommended date, hoeing twice combined with large hill size, and recommended fertilizer rate combined with two fungicide applications (Chapter 3).
- Substantial simultaneous improvements in expected yield and quality can be achieved at relatively low extra costs. Moreover, more than 80% of the improvements can already be achieved at less than 30% of the extra costs (Chapter 4).

- For improving overall performance of seed potato supply chains in Ethiopia, seed quality is perceived to be a more important seed supply chain performance indicator than costs, flexibility and responsiveness (Chapter 5).
- Sub-indicators to evaluate seed supply chain performance, i.e. production costs, seed purity, seed genetic quality, seed health, appropriateness of potato seed size, seed physical damage, appropriateness in physiological age, mix flexibility, volume flexibility and lead time, are perceived to be better improved by seed potato supply chains that supply seed tubers of improved varieties than by a chain supplying seed tubers of local varieties (Chapter 5).

Samenvatting

Doordat de aardappel inkomen en voedsel kan verschaffen aan kleinschalige bedrijven, kan dit gewas een substantiële bijdrage leveren aan de voedselzekerheid in Ethiopië. Belangrijke factoren die hier aan bijdragen, zijn de hoge potentiële opbrengst van het gewas, de geschikte agro-ecologische omstandigheden ter plekke en de ruime beschikbaarheid van arbeid. Aardappelen leveren meer voedingsstoffen per land- en tijdseenheid op dan andere belangrijke akkerbouwgewassen, zoals tarwe, rijst en maïs. Ook zijn aardappelen rijk aan vitamine C, vitaminen B1, B2 en B6, en mineralen zoals kalium, fosfor en magnesium, en vormen ze een goede bron van eiwit. Door verstedelijking en toenemende vraag naar verwerkte producten neemt de vraag naar verse aardappelen de laatste jaren toe. In Ethiopië kan het aardappelgewas verbouwd worden op 70% van de totale oppervlakte aan bouwland in de hooglanden (1500 tot 3200 meter boven zeeniveau met jaarlijks 600-1200 mm neerslag). Hier woont ongeveer 90% van de Ethiopische bevolking. Door gunstige klimaatomstandigheden kan het aardappelgewas in Ethiopië in drie perioden van het jaar verbouwd worden: in het lange regenseizoen (de zogenaamde *meher*, van juni tot oktober), in het korte regenseizoen (*belg*, van februari tot mei) en, met irrigatie, buiten de normale teeltseizoenen van oktober tot januari. Hierdoor levert de aardappel het hele jaar door voedsel op, zelfs voordat graan geoogst kan worden.

De totale productie van aardappelen en de productiviteit per hectare zijn echter niet optimaal. Slechts 2,3% van het geschikte areaal wordt gebruikt en de opbrengst is gemiddeld 10 ton per ha. Lage opbrengsten worden mede veroorzaakt doordat de meeste telers pootgoed van slechte kwaliteit gebruiken en doordat er geen pootgoed van verbeterde rassen beschikbaar is. Het doel van dit proefschrift was het analyseren van de technische en institutionele aspecten die kwaliteit en beschikbaarheid van pootaardappelen in Ethiopië beïnvloeden.

In Hoofdstuk 2 zijn de drie productiesystemen van pootaardappelen (het informele, alternatieve en formele systeem) uit de vier belangrijke productiegebieden (centraal, oost, noord-west en zuid) vergeleken op stand van zaken en prestatie. Dit is gedaan aan de hand van literatuur, veldwerk, expert-kennis, veldobservaties en lokale kennis. Resultaten laten zien dat de systemen hun rol als pootgoedleverancier niet goed kunnen vervullen en dat er behoefte is aan verbetering. Het overgrote deel van het pootgoed komt uit het informele systeem (98,7%); dit pootgoed is veelal sterk verziekt, heeft niet de juiste fysiologische leeftijd, heeft een slechte genetische kwaliteit, en is door vermenging tijdens productie en handel tamelijk onzuiver; bovendien heeft het pootgoed vaak niet de juiste maat en zijn de meeste poters beschadigd. De andere twee systemen, het formele en alternatieve systeem, leveren pootgoed van betere kwaliteit, maar slechts in kleine hoeveelheden.

In het informele systeem wordt de slechte kwaliteit van de pootaardappelen met name veroorzaakt door gebrekkige teeltmaatregelen tijdens productie en opslag, en ziektes, zoals fytoftora, virussen en bruinrot. In dit systeem zijn productie- en opslagmethoden die de kwaliteit kunnen verbeteren, zoals positieve selectie, aparte percelen voor pootgoed, en opslag in diffuus licht (DLS), geen gemeengoed. Experts zijn van mening dat verbeteringen bereikt kunnen worden door meer bewustwording en kennis bij de telers en door het verbeteren van kwaliteit en toegang tot de markt. In de alternatieve en formele systemen hangen verbeteringen samen met het beschikbaar komen van nieuwe rassen, het ontwikkelen van een kwaliteitscontrolesysteem en het reduceren van kosten. Uit Hoofdstuk 2 blijkt ook dat voor een algehele verbetering van de aardappelpootgoedsector in Ethiopië het van belang is dat de drie systemen naast elkaar blijven bestaan, maar met goede onderlinge samenwerking. Ook het ontwikkelen van zelfregulatie en –certificering is van belang.

In Hoofdstuk 3 is aan de hand van literatuur, experts en telers een lijst samengesteld van relevante productie- en opslagmethoden voor pootaardappelen. Vervolgens is hier door experts een prioritering in aangebracht op basis van het te verwachten effect op opbrengst en kwaliteit. Daarna is voor elke methode de relatieve bijdrage aan opbrengst en kwaliteit gekwantificeerd. Hiervoor is gebruik gemaakt van conjointanalyse, die is uitgevoerd met pootaardappeltelers in Jeldu en Welmera. Resultaten geven aan dat de methode van opslag, frequentie van schoffelen en hoogte van de aardappelruggen in het veld, en de bemestingsgraad in combinatie met de frequentie van pesticidengebruik naar verwachting meer bijdragen aan opbrengst en kwaliteit dan de herkomst van het pootgoed, potergrootte, methode van ontspruiten, grondbewerking, en precieze datum van poten. Ook voor wat betreft de details per methode is duidelijk verschil zichtbaar. Zo is te verwachten dat pootaardappelen uit DLS, met twee keer schoffelen in combinatie met een hoge rug, en toepassing van de aanbevolen bemesting en twee maal pesticidengebruik leiden tot een significant betere opbrengst en kwaliteit van het pootgoed dan de andere combinaties van methoden. Resultaten impliceren dat bij het zoeken naar verbeteringen in de pootgoedsector het beste kan worden aangesloten bij de methoden met de grootste relatieve bijdrage aan opbrengst en kwaliteit.

Om te komen tot concrete pakketten van maatregelen voor productie en opslag van pootaardappelen is in Hoofdstuk 4 een lineair programmeringsmodel ontwikkeld. Voor elke methode vormden de relatieve bijdrage aan opbrengst of kwaliteit uit Hoofdstuk 3 en ingeschatte kosten de input. Resultaten laten alternatieve plannen zien waarmee telers, gegeven hun budget, opbrengst en kwaliteit kunnen optimaliseren. Resultaten geven ook aan dat de opbrengst en kwaliteit van pootaardappelen tezamen behoorlijk verbeterd kunnen worden tegen relatief lage extra kosten. Plannen zijn robuust voor een 50% toename van grondprijzen, pootgoedkosten, arbeidsloon en kosten van pesticiden.

In Hoofdstuk 5 is de prestatie van diverse aardappelpootgoedketens vergeleken voor de volgende indicatoren: kosten, kwaliteit van het pootgoed, flexibiliteit en mogelijkheid om te reageren op veranderingen in de markt (respons). Prestaties zijn gemeten met behulp van expertinschattingen. Voor alle ketens wordt pootgoedkwaliteit belangrijker gevonden dan respons, kosten en flexibiliteit. Resultaten geven ook aan dat subindicatoren voor het meten van prestaties, zoals productiekosten, transactiekosten, zuiverheid van het pootgoed, genetische kwaliteit, gezondheid, adequate potergrootte, mate van beschadiging, fysiologische leeftijd, keuzeflexibiliteit, volumeflexibiliteit en snelheid van respons, naar verwachting meer verbeterd kunnen worden in ketens met pootgoed van verbeterde rassen dan in ketens met pootgoed van lokale rassen. Ook blijkt de bijdrage per ketenactor in de verbetering van bepaalde subindicatoren duidelijk te verschillen. Voor verbeteringen in de keten kan dus het beste worden gestuurd op de actoren die relatief de grootste rol spelen.

Hoofdstuk 6 geeft een synthese van voorgaande hoofdstukken, en een duiding van de wetenschappelijke vernieuwing van het onderzoek en van de implicaties voor het bedrijfsleven. De wetenschappelijke vernieuwing zit met name in de combinatie van diverse onderzoeksmethoden. Deze aanpak kan ook gebruikt worden voor het bestuderen van pootgoedketens van andere agrarische producten. Voor wat betreft het bedrijfsleven komt een duidelijke rol naar voren voor de private sector als drijvende kracht, bijvoorbeeld een verwerkende industrie met vraag naar consumptie-aardappelen. Ook andere schakels in de keten hebben behoefte aan inmenging van de private sector, bijvoorbeeld via pootgoedtelers, leveranciers van input, handelaren en transporteurs.

Op basis van voorgaande bevindingen zijn de belangrijkste conclusies van dit onderzoek:

- Het informele systeem van pootaardappelen in Ethiopië levert pootgoed van matige gezondheid, niet-geschikte fysiologische leeftijd, matige genetische kwaliteit en onvoldoende zuiverheid. Ook zijn er te veel beschadigingen en zijn de poters niet aan de maat. Verbeteringen kunnen worden gerealiseerd door prioriteit te geven aan het verbeteren van bewustwording en kennis van pootgoedtelers, de kwaliteit van het pootgoedmateriaal en de toegang tot markten (Hoofdstuk 2).
- Pootaardappelen uit het alternatieve systeem zijn van betere kwaliteit, maar zijn slechts beperkt beschikbaar. De alternatieve en formele systemen kunnen worden verbeterd door het beschikbaar stellen van nieuwe rassen, het opzetten van kwaliteitscontrolesystemen en het terugdringen van de productiekosten (Hoofdstuk 2).
- Om de totale productie en levering van pootaardappelen in Ethiopië te verbeteren is het van belang dat de drie systemen naast elkaar blijven bestaan, maar wel met een goede onderlinge samenwerking (Hoofdstuk 2).
- Voor het verbeteren van opbrengst en kwaliteit van pootaardappelen zijn pootaardappeltelers van mening dat opslagmethode, frequentie van schoffelen in combinatie met de hoogte van de aardappelruggen, en bemesting in combinatie met frequentie van pesticidengebruik, de belangrijkste managementaspecten zijn op het gebied van productie en opslag (Hoofdstuk 3).
- Als alle pootgoedtelers de best mogelijke productie- en opslagmethoden gebruiken, kan de opbrengst van pootaardappelen naar verwachting bijna verdubbelen ten opzichte van de opbrengsten in 2010. De volgende methoden zijn dan van toepassing: pootgoed van eigen of institutionele herkomst, poters van gemiddelde grootte, opslag in diffuus licht, ontspruiting in opslag, het vier keer bewerken van de bodem, poten op de aanbevolen datum, twee keer schoffelen in combinatie met hoge aardappelruggen, en toepassen van de aanbevolen bemesting in combinatie met twee maal gebruik van pesticiden (Hoofdstuk 3).
- Kwaliteit en opbrengst van pootgoed kan substantieel verbeterd worden voor relatief weinig extra kosten. Tachtig procent van de potentiële verbetering is naar verwachting zelfs te realiseren voor 30% van de maximale extra kosten (Hoofdstuk 4).

- Bij het verbeteren van de prestatie van pootaardappelketens in Ethiopië wordt het belangrijker gevonden om te sturen op kwaliteit dan op prestatie-indicatoren op het gebied van kosten, flexibiliteit en mate waarmee op veranderingen in de markt kan worden ingespeeld (respons) (Hoofdstuk 5).
- Verbeteringen ten aanzien van prestatie-subindicatoren, zoals productiekosten, zuiverheid, genetische kwaliteit, gezondheid, potergrootte, mate van beschadiging, fysiologische leeftijd, flexibiliteit met betrekking tot variatie en volume, en snelheid van respons, kunnen naar verwachting beter gerealiseerd worden in ketens die werken met verbeterde rassen in plaats van lokale rassen (Hoofdstuk 5).

Biography

Adane Hirpa Tufa was born on September 20, 1974 in Shewa, Ethiopia. He graduated with a BSc degree in Animal Sciences in 1995 from Haramaya University, in Ethiopia, and an MSc degree in Agricultural Economics in 2002 from G.B. Pant University of Agriculture and Technology, in India. Adane started his professional career in 1996 in a collaborative project between Università degli Studi di Firenze and Addis Ababa University as a research assistant. In 1997, he joined Oromia Agricultural Research Institute as a junior researcher in animal feeds and nutrition at Bako Agricultural Research Centre. After his MSc, he worked in assistant researcher in the Socio-economics Research Division at Bako and Adami Tulu Agricultural Research Centres. In 2004, he joined Hawassa University as a lecture at Department of Agricultural Resource Economics and Management. He served as Head, department of Agricultural Resource Economics and Management from June 2007 to September 2008. Adane also served as a consultant for a project entitled Improving Productivity and Market Success of Ethiopian Farmers (IPMS) at ILRI in Addis Ababa. His areas of interest and experience are supply/value chain, agricultural economics, agri-business, agricultural marketing and production economics.

Publications

Journal articles

Hirpa, A., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Oude Lansink, A.G.J.M., Tsegaye, A. and Struik, P.C., 2010. Analysis of Seed Potato Systems in Ethiopia. American Journal of Potato Research 87, 537-552.

Hirpa, A., Meuwissen, M.P.M., Van der Lans, I.A., Lommen, W.J.M., Oude Lansink, A.G.J.M., Tsegaye, A. and Struik, P.C., 2012. Farmers' opinion on seed potato management attributes in Ethiopia: a conjoint analysis. Agronomy Journal 104(5), 1413-1424.

Hirpa, A., Meuwissen, M.P.M., Lommen, W.J.M., Tsegaye, A. and Struik, P.C., Oude Lansink, A.G.J.M., 2013. Cost-effective methods of seed potato production in Ethiopia. Submitted to Potato Research.

Hirpa, A., Meuwissen, M.P.M., Lommen, W.J.M., Oude Lansink, A.G.J.M., Tsegaye, A. and Struik, P.C., 2013. Performance of seed potato supply chains in Ethiopia. Submitted to Supply Chain Management: An International Journal.

Ashenafi Mengistu, Abule Ebro, Tadesse Assefa, **Adane Hirpa** and Belete Shenkute, 2007. Effect of supplementation of tef (*Eragrostis tef*) straw with different levels of noug (*Guizotia abyssinica*) meal on worked Arsi oxen (*Bos indicus*). *Trop. Sci.* 2007, **47(1)**, 49–51.

Lemma Gizachew, **Adane Hirpha**, Fikadu Jaleta and GN Smit, 2002. Mineral element status of soils, native pastures and cattle blood serum in the mid-altitude of western Ethiopia. African Journal of Range and Forage Science 2002, 19(3): 147-155

Diriba Geleti, Temesgen Diriba, Lemma Gizachew and **Adane Hirpa**, 2001. Effect of season and location on mineral concentration of natural pasture in Bako area, Western Ethiopia. Ethiopian Journal of Animal production, 1(1): 25-32.

Diriba Geleti, Temesgen Diriba, Lemma Gizachew and **Adane Hirpa**, 2001. Planting density and cutting and cutting interval effects on productivity of *callindra callothyrsus* (L.) Miessen. Ethiopian Journal of animal production, 1(1): 34-44.

Working papers

Berhanu Gebremedhin, **Adane Hirpa** and Kahsay Berhe, 2009. **Feed marketing in Ethiopia: Result of rapid market appraisal**. Improving Productivity and Market Success (IPMS) of Ethiopian Farmers working paper 15. ILRI (International Livestock Research Institute), Nairobi, Kenya. 64 p.

Proceedings

Adane Hirpa and Ashenafi Mengistu, 2004. Economics of different supplement options to teff straw for fattening Arsi oxen. Proceedings of the 12th annual conference of Ethiopian Society of Animal production (ESAP) held in Addis Ababa, Ethiopia, August 30-31, 2004.

Diriba Geleti, Lemma Gizachew and **Adane Hirpa**, 2001. Grain and forage yield responses of maize genotypes intercropped with *lablab purpureus* under Bako condition, Western Ethiopia. Livestock in food security: Roles and contributions. Proceedings of the 9th

annual conference of Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 30-31, 2001. pp. 247-258.

Melese Abdisa, Diriba Geleti, Lemma Gizachew, Temesgen Diriba and **Adane Hirpa**, 2001. The effect of improved forage and/or concentrate supplementation on live weight of Horro lambs and growing bulls. Livestock in food security Roles and contributions. Proceedings of the 9th annual conference of Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, August 30-31, 2001. pp. 259-266.

Lemma Gizachew, **Adane Hirpa**, Diriba Geleti and Abubeker Hassen, 2000. Seed and Herbage DM production yield performance of herbaceous forage legumes in sub-humid climate of Western Ethiopia. Pastoralism and Agro-pastoralism: which way forward? Proceedings of the 8th annual conference of ESAP, 24-26 August 2000, Addis Ababa, Ethiopia. pp. 252-257.

Diriba Geleti, Abubeker Hassen, Lemma Gizachew and **Adane Hirpa**, 1999. Evaluation of different accessions of Centrosema species for forage yield in sub humid climate of western Ethiopia. Proceedings of the 9th conference of crop science society of Ethiopia (CSSE), 22-23 June 1999. pp. 59-62.

Book chapters

Adane Hirpa, 2008. Sheep and goat economics of production and marketing. In: Alemu Yami and R.C. Markel (eds). Sheep and Goat Production Handbook for Ethiopia. ESGPIP (Ethiopia Sheep and Goats Productivity Improvement Program). 2008, Addis Ababa, Ethiopia. pp. 297-324.

Adane Hirpa and Girma Abebe 2008**.** Economic significance of sheep and goats. In: Alemu Yami and R.C. Markel (eds). Sheep and Goat Production Handbook for Ethiopia. ESGPIP (Ethiopia Sheep and Goats Productivity Improvement Program). 2008, Addis Ababa, Ethiopia. P. 2-4.

Michele Nori and **Adane Hirpa**, 1999. Complementary method to understand land use changes an example from the Ethiopian Rift valley in Marc p. lammeink and Dick de Jong (eds) participatory learning and Action (PLA) notes community water management IIED No 35, June 1999. pp. 16-20.

Adane Hirpa Tufa
Wageningen School of Social Sciences (WASS)
Completed Training and Supervision Plan

Name of the course	Department/Institute	Year	ECTS (=28 hrs)
I. General part			
Techniques for writing and presenting a Scientific paper	Wageningen Graduate Schools (WGS)	2012	1.2
Information Literacy for PhD including EndNote Introduction	WGS	2011	0.6
Voice matters	WGS	2011	0.3
II. Mansholt-specific part			
Mansholt Introduction course	Mansholt Graduate School	2009	1.5
"Analysis of seed potato systems in Ethiopia"	Mansholt Multidisciplinary Seminar	2009	1
"Effect of management attributes on seed potato yield and quality in Ethiopia"	Wageningen – WICaNeM conference	2012	1
III. Discipline-specific part			
Business Economics PhD meeting	Business Economics, Mansholt Graduate School	2008 - 2012	4
"Economic and agronomic analysis of seed potato supply chains in Ethiopia"	International CoQA Workshop, Wageningen, The Netherlands	2009	1
"Identification and evaluation of seed potato management variables using the Modified Delphi Technique"	International CoQA Workshop, Addis Ababa, Ethiopia	2010	1
"Elicitation of farmers' opinion on seed potato management attributes in Ethiopia"	International CoQA Workshop, Cotonou, Benin	2011	1
"Improvement of production and postharvest practices in seed potato supply chains"	CoQA Agri-ProFocus Stakeholder Workshop, Addis Ababa, Ethiopia	2013	1
PhD proposal writing	Mansholt Graduate School	2009	4
Organisation of Agribusiness (BEC 31306)	WUR	2008	6
Risk Management in Food Supply Chain (BEC 51306)	WUR	2009	6
Advanced Supply Chain Management (ORL 31306)	WUR	2009	6
Advanced Econometrics (AEP 60306)	WUR	2009	6
Economic Models (AEP 30806)	WUR	2009	6
IV. Teaching and supervising activities			
Supervising Tewodros Ayalew Dejene	CWE, WUR	2010 - 2011	1
TOTAL			**48.6**

Funding

The research described in this thesis was co-financed by the Interdisciplinary Research and Education Fund (INREF) of Wageningen University and the Netherlands Organization for International Cooperation in Higher Education (NUFFIC). Printing cost of this thesis was partly covered by Dr JA Zwartz Foundation.

Publisher

GVO drukkers and vormgevers B.V./Ponsen and Looijen