China Potato GAP 2013-2016

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Summary This report shows the results of the Topsector Agrifood Public Private Project on Good Agricultural Practices (GAP) in potato production in China. Public and private partners cooperate in order to develop test Dutch potato production innovations under Chinese growing conditions. The report contains information on soil tillage, crop protection, seed potato quality, crop care methods and storage methods in key potato production provinces in China (Heilongjiang and Hebei). Potato yields can be improved in China by implementation GAP innovations from the Netherlands.

Keywords: sustainable production, late blight, decision support, *Solanum tuberosum*

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Wageningen Plant Research Report

Photo cover: Corné Kempenaar

Parties below have contributed to the success of the PPS China Potato GAP:

Contents

Preface

The Agricultural Counsellor Mr. Henk van Duijn of the Netherlands Embassy in Beijing initiated a BOCI project 'China Netherlands IPM' in 2009. The project yielded a Sino-Dutch, Public-Private potato experts network on sustainable crop protection methods. A Pubic Private Partnership (PPP) on innovation of Good Agricultural Practices (GAP) in potato production and storage methods in China was established in 2012, with partners in China and The Netherlands. The scope of the R&D in the network was broadened from crop protection to crop production and storage technology, but still with potato as the crop of interest. The Agricultural counsellors in China between 2013 and 2016, Marinus Overheul and Martin Oldemonnikhof, sustained the PPP between 2013 and 2016.

In this report we describe all results of the R&D program of the China Potato GAP PPP. A part was already published in a mid-term report (chapters 2 – 5). The Dutch partners in the PPP are APH Group, Dacom, DLV Plant/Delphy, Syngenta and Wageningen Plant Research (PPOPRI). HAAS (Heilongjiang Agricultural Academy of Science, a WPR counterpart in potato research in China, committed herself to the PPP with a Memorandum of Understanding (MoU) on cooperation on specific potato R&D topics. SAITIP, the strategic Alliance for potato Industry in China, was linked to this planned R&D via HAAS). Snow Valley also committed herself to the PPP with an MoU.

The aim of the Potato GAP China PPP was to develop and demonstrate GAP innovations in potato production and storage in China. Dutch technologies and know how were calibrated under Chinese cropping conditions and demonstrated in field experiments on at least four locations in North East China. In this report, we describe the results of the experiments, investigations and communications carried out in the PPP in the period January 1, 2013 until December 31, 2016. The R&D topics addressed all aspects of GAP, from soil tillage to seed quality to crop care, with a focus on late blight control, to harvest and storage methods. Sustainability of production methods were evaluated. Research went hand in hand with demonstration and dissemination activities.

Most of the data in this report come from Heilongjiang province, an important potato producing province in China and home province of HAAS, with head office in the city of Harbin. Scientific interactions also took place with staff of research institutes and extension services in Beijing, Inner Mongolia, Ningxia, Guizhou, Yunnan and Sichuan. McCain Harbin provided valuable crop production data. From 2014 onwards, Snow Valley/Aviko in Hebei province also contributed to the results of the PPP.

The activities carried out by WPR were mainly financed by The Dutch Ministry of Economic Affairs, TKI-office Agrifood and the Dutch PPP partners. The activities carried out by the Chinese parties in the project were financed with Chinese budgets and resources. These parties provided a small but significant cash budget to WPR as well for research and knowledge transfer in the PPP. We acknowledge the support and contributions from the Dutch partners (Dutch Ministry of Economic Affairs, TKI AF, APH Group, Dacom, DLV Plant, Syngenta), the Chinese partners (HAAS, McCain, Snow Valley/Aviko), and the parties that provided contributions during the course of the project (B&E, Eurofins, Eijkelkamp, Mantis, NAFTC China plus members). We also acknowledge contributions and communications with CAAS, IMU, AUH, NAITS, YAAS and CIP Beijing during the course of the project.

Corné Kempenaar
Coordinator Wageningen Plant Research team

Executive summary

Good Agricultural Practices (GAP) are practices to apply for in on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability. Introduction of GAP will help Chinese agriculture to increase the yield and quality of potatoes grown in China. Increase of potato yields and quality is one of the food security priorities in the Chinese agricultural policy. The Netherlands has much experience with GAP in potato. Both countries have expressed interest to cooperate in the field of GAP potato with the aim to exchange knowledge and technology, and to jointly develop and adept innovations. In this report, we describe results of a Sino-Dutch Potato GAP project, with public private partners from both countries and running from 2013 to 2016.

The outline of the R&D program in China potato GAP project was developed in several meetings between Dutch and Chinese research institutes and companies before 2013. In 2013, a Memorandum of Understanding (MoU) was signed by Heilongjiang Academy of Agricultural Science (HAAS) and the Dutch Potato GAP consortium to cooperate on at least five topics between 2013 and 2016:

1. Seed potato quality, breeding technology, production and certification;
2. Good Agricultural Practices for water use, crop protection, weed control, fertilizer use, etc., with a focus on GAP late blight control and seed quality;
3. Potato production machinery, equipment and harvesting technology;
4. Storage technology;
5. Demonstration & know how transfer (training of extension and industry people.

The Dutch potato GAP consortium consists of APH group, Dacom, DLV Plant/Delphy, Syngenta and Wageningen UR. The research in China was coordinated by HAAS. During the course of the project, other parties joined the R&D: Snow Valley/Aviko, McCain, B&E, Eijkelkamp, Eurofins and Mantis. Parties who only participated in communications, workshops and/or trainings, were CAAS, YAAS (Yunnan), AUH (Hebei), IMU (Inner Mongolia), NAITS (Guizhou), CIP, ICAMA, NATESC and NAFTC China.

In this report results of the China potato GAP project are described. The program addressed issues related to late blight control and other crop protection topics, quality of seed potatoes and planting methods, soil tillage, fertilizer use and irrigation, application, harvest and storage technologies, and sustainability evaluation of potato production methods in different regions of China.

A major objective was to establish experimental fields and demonstration sites in China to develop, calibrate and demonstrate Dutch potato production technologies and know how under Chinese farming conditions. This objective was first met in 2015 and enlarged in 2016. Also in these two years, a first and second Sino-Dutch potato workshop was organized to support broad dissemination of the results.

Chapter 2. Potato late blight disease is probably the most important factor causing low yields and poor tuber quality in China's potato production. *Phytophthora infestans* population in Heilongjiang was characterized with different diagnostic methods. Several field experiments were carried out in 2014 on variety resistance and fungicide efficacy. Also, a decision support system for optimization of application of fungicides was tested (see Chapter 2). The late blight monitoring study confirmed that both A1 and A2 mating types of *P. infestans* are present in Heilongjiang. It also showed that most isolates have resistance against metalaxyl. The field experiments in potato crops were carried out according to international protocols. The field evaluation of variety resistance against late blight disease showed large differences in rate of disease development. Favorita was one of the least resistant varieties while Sarpo Mira showed only very little disease development. Chinese varieties such as Kexin18 and Kexin13 showed high and promising levels of resistance. The field evaluation of fungicide schemes against late blight disease showed large differences between fungicide products and combinations. The use of the decision support system reduced late blight disease development in potato significantly in 2014 in Heilongjiang, but the efficacy of the system was not good enough to keep crops free from late blight by far. There is a need for improvement of the system in order to protect potato crops in Heilongjiang against late blight disease.

Chapter 3. Seed quality is another important yield depressing factor in China's potato production. Seed tubers often have poor quality due to high incidence of virus or bacterial infections. Also, systemic *P. infestans* infections are often found in seed potatoes from China. Field experiments were carried out in 2014 to study performance of different seed potato lots from Heilongjiang province, and to study effect of potato haulm killing date on tuber yield and virus infection. Large differences were observed in the performance of seed lots of Keshan 13 variety from different origins of Heilongjiang produce. Yield differences of almost 50% and PVY incidence differences of almost 100% were observed. Aphids that can spread PVY virus, were detected in the experimental potato field in an aphid trap from mid-June onward during the season. Peak in aphid numbers was end of July. Yield of Favorita variety in this field experiment was higher than the yield of Atlantic variety. Harvest date affected yield and tuber size. Favorita is known to be more tolerant to PVY than Atlantic. PVY infection data of harvested tubers are not yet available, but will be added to the study results later on.

Chapter 4. More and more, consumers ask for safe sustainable food. Two studies were carried out with potato production data of farms in China. The first study focussed on data from five Chinese provinces and The Netherlands. The second studied used data of Heilongjiang province only. Yield gaps, carbon foot print, land and water use efficiencies and energy use, expressed in CO_2-equivalent per tonnes of potatoes, were calculated for the different cropping systems. Potato yields in different cropping systems varied between 20-50 tonnes. The yield gap analysis showed gaps of 10 to 25 tonnes compared with potential yields calculated with LINTUL potato growth model. The carbon foot print of the different potato cropping systems in the national study showed a smaller CO_2 load for the production of potatoes during the winter period as for the summer period, except for Keshan. Within Heilongjiang, also differences in CO2 load were calculated. The CO2 load for production and storage of potatoes varied between 58 and 291 kg CO_2-equivalent per tonnes of potatoes. Fertilizer use and irrigation are main factors determining this carbon food print. The Carbon footprints reported are low compared to other Asian production regions (India) as storage energy use is low. Transport of yield to the final destination or transport of potato seed for planting can contribute considerable to the CO_2-eq load.

Chapter 5. Total Heilongjiang potato production amounts to 8.3 million tonnes per year. Accurate statistics on the storage capacity of Heilongjiang are lacking. However, this capacity should be over 7 M tons if more than 80% of the produce is stored. We estimate that 5 - 10% of the Heilongjiang annual potato production is stored in modern stores with air ventilation and climate control to keep the potato quality at the required level. This figure could be underestimated knowing the fast increase in starch and flakes factories in the province. These factories have own modern stores. A large part of the Heilongjiang potato produce is stored in traditional stores at town and city levels, may be up to 80% of the Heilongjiang produce. The traditional stores lack ventilation and air circulation systems and rely upon cool air within the stores.

Chapter 6. Four years of aphids trap data from two locations in Heilongjiang were analysed in order to understand population dynamics of these virus transmitting insects. *Myzus persicae* was one of several aphid species detected and the most efficient potato virus transmitting aphid. The first serious peek in aphid numbers in potato crops as end of July early/early August. This peek is main responsible for transmission of potato viruses and should be controlled in seed potato crops to safeguard good quality seed potato produce.

Chapter 7. Two field experiments were carried out in 2015 in Heilongjiang province. Different GAP technologies and decision support were tested under practical potato cropping conditions near Minzhu and Keshan. Methods included soil tillage, planting methods, fertilizer use and crop protection, weed control and irrigation. The importance of good soil tillage and seed bed preparation in combination with use of good quality seeds and planting methods was demonstrated. Yield effects GAP fertilizer use and crop protection could not be demonstrated due to seed quality effects in the different objects. Decision support on late blight control reduced the development of this disease in the potato crops.

Chapter 8. Four field experiments were carried out in 2016 in Heilongjiang and Hebei provinces. Different GAP technologies and decision support were further tested under practical potato cropping conditions. Experimental designs, protocols, arrangements and observations were based on lessons learnt from 2015. The experiments show that (1) uncut good quality seeds in combination with tailored soil tillage and planting methods result in better emergence and early crop development, (2) fertilizer use can be optimized using soil analysis data, crop protection can be improved using early warning system and decision support, and yields are higher when GAPs are applied in potato crop production. Recommendations for further improvement of yields of potato crops in Heilongjhiang are provided, such as use of power rotary harrow, optimization of planting methods, use of uncut seeds and application of decision support for fertilizer use, irrigation and crop protection. A GIS platform can be used to apply the decision support. The high level of PVY infection of tubers observed in 2016 harvest is point of attention for 2017.

Chapter 9. The evaluation of use of weather stations and pesticides application technology was evaluated on farms in Hebei and Heilongjiang. The importance of regular calibration and control of the technology was discussed.

Chapter 10. Knowledge dissemination is a major topic within the China potato Gap project. In the years 2012 to 2014, 5 missions from Dutch experts to China and 3 missions from Chinese experts to The Netherlands took place. In 2015 and 2016 the number of missions increased. All knowledge dissemination activities are listed, including two successful Sino-Dutch GAP potato workshops in 2015 and 2016, with each over 300 participants from China, The Netherlands and few other countries.

Besides the large amount of technical information the PPP provided, the Sino – Dutch potato network was strengthened, with the ambition to continue cooperation in 2017 and further on. The cooperation leads to better understanding of both interests and challenges, and supports adoption and implementation of Dutch potato technology and know-how in China, while Dutch partners gain knowledge on performance of their products, models and decision support under specific and important conditions.

1. Introduction

Globally, potato is one of the top five of most important food crops. It provides billions of people with a healthy (staple) food source. China is the biggest producer of potatoes in the world, with 70 to 80 million tonnes per year in recent years, grown on about 5 million hectares (www.potatopro.com; personal communications HAAS and YAAS). Second and third in this ranking are India and the Russian Federation. The Netherlands only ranks number 10, with a volume of around 8 million tonnes per year grown on about 175.000 ha. It has a total farm gate value of about 800 million euro per year. Where the average production per ha is in China is around 20 tonnes per ha, it is in The Netherlands over 45 tonnes per ha. China can increase her potato production by introducing Good Agricultural Practices (GAP) and quality control and extension systems as applied in The Netherlands. For a geographical representation of potato production area in China, see Figure 1.1. In Figure 1.2, the main potato provinces of China and their contribution to the total potato production are shown.

Good Agricultural Practices (GAP) refer to any collection of principles to apply for in on-farm production and post-production processes, resulting in safe and healthy food and non-food agricultural products, while taking into account economic, social and environmental sustainability. Today, GAP are incorporated in certification schemes as to warrant, benchmark and promote sustainability of agricultural products. Unsafe practices in crop production and operation seriously harm the environment, leading to soil compaction, soil fertility decline, underground water pollution and environmental pollution. Integrated pest management (IPM) is a frame for GAP in crop protection.

The Chinese and Dutch Ministries of Agriculture have expressed in meetings in 2008 the intention to set up specific cooperation projects on GAP in sustainable crop protection (also referred to as integrated pest management (IPM), integrated weed management (IWM) or integrated crop management (ICM)). The Netherlands has developed many relevant technologies and decision support systems for sustainable crop protection during the past 30 years. China is interested to introduce these methods in her agricultural system, to improve yields, financial results and sustainability and to meet international GAP-standards. In 2009, preparatory activities were started to enlarge cooperation between the two countries on the exchange of potato GAP technologies and know how. This has lead BOCI-projects, the Orange potato project and the Potato GAP China project, financially supported by the Dutch government and companies. And to funding of several Sino potato R&D projects by Chinese government and industries between 2009 and now. In this report, we describe the mid-term results of this Sino-Dutch Potato GAP China project, which started in 2013.

The outline of the R&D program was developed in several meetings between Dutch and Chinese research institutes and companies between 2009 and 2013. HAAS explained that the use of seed potatoes with suboptimal quality (virus and bacterial infections) and severe damage by potato late blight disease are main causes of low potato yields in China. In 2013, a Memorandum of Understanding was signed by HAAS and the Dutch Potato GAP consortium to cooperate on at least five topics (details on MoU, see chapter 6):

1. Seed potato quality, breeding technology, production and certification;
2. Good Agricultural Practices (GAP) for potato cultivation (water use, crop protection, weed control, fertilizers, etc.), with a focus on late blight control;
3. Machinery, equipment and harvesting technology. Modern equipment for customized soil tillage, planting depth and rate, ridging, plant protection, weed control and harvest are crucial for a good production;
4. Storage technology;
5. Demonstration & know how transfer (training of extension and industry people.

In chapter 2 of this report, we describe results on potato late blight studies. In chapter 3, results of seed quality studies are described. In chapter 4, an evaluation of the sustainability of potato production in China is presented. Chapter 5 shows information on potato storage facilities in Heilongjiang province. Chapter 6 contains new information on aphid population dynamics in potato crops in Heilongjiang. Chapters 7 and 8 contain the results of experiments on GAP on different locations in two provinces in North East China. These experiments includes studies on effects of GAP soil tillage, seed quality and planting methods, crop protection, fertilizer use and harvest methods. Chapter 10 summarizes all communication activities in the Potato GAP project, including two Sino-Dutch potato GAP workshops.

Most of the studies described in the chapters 2 to 9 were done in Heilongjiang province within the strategic cooperation between HAAS and the Potato GAP consortium. Heilongjiang is an important potato producing province with an annual potato production of about 8 million tonnes, comparable to the total annual potato production of the Netherlands. In 2015 and 2016, study area was extended towards Hebei and Inner Mongolia, where potato production is also developing very fast.

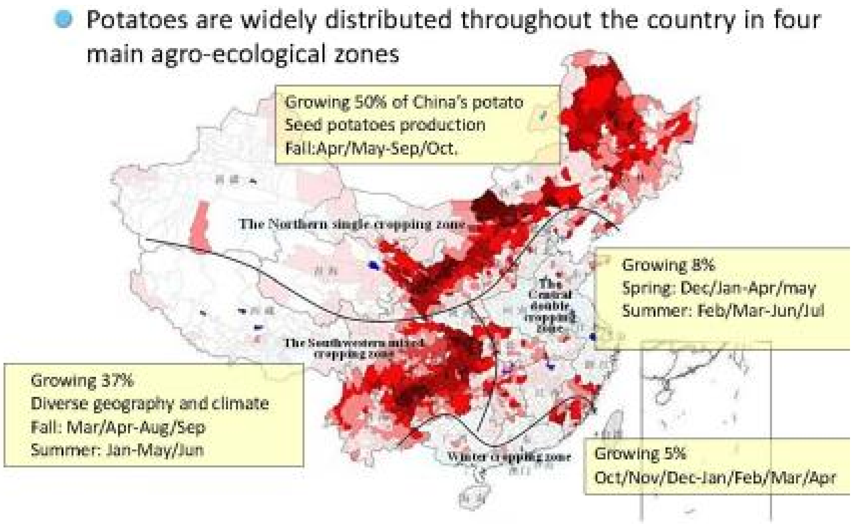

Figure 1.1 *Overview of potato producing regions in China (Source: YAAS, 2015).*

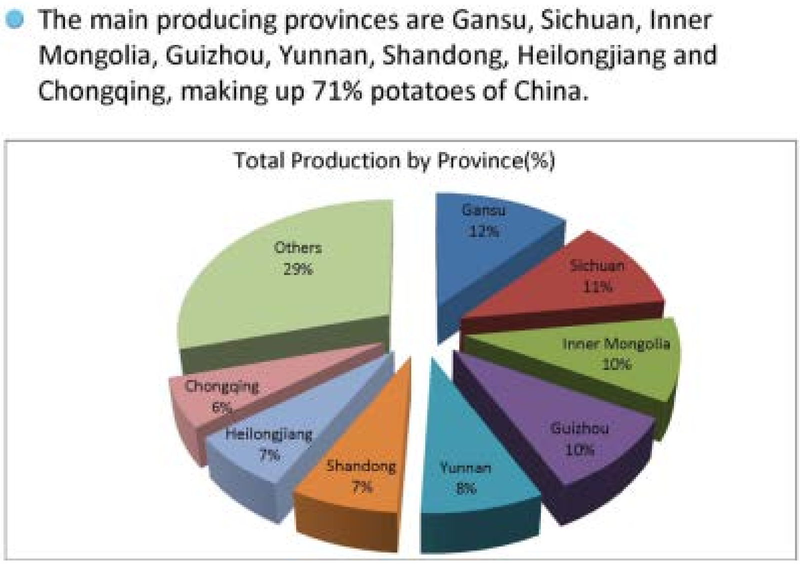

Figure 1.2 *Overview of potato production in China per province (Source: YAAS, 2015). See also Table 4.1.*

2. Late blight monitoring and control

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2.1 Abstract

Phytophthora infestans causes late blight disease in potato and is one of the biggest problems in potato production in China. Following exchange of protocols, joint experiments were carried out with respect to characterisation of the Heilongjiang *P. infestans* population, evaluation of potato variety resistance, evaluation of fungicide efficacy against *P. infestans*, and support for further development of the HAAS decision support system.
The monitoring study confirmed that both A1 and A2 mating types of *P. infestans* are present in Heilongjiang. It also showed that complex races are common and that most isolates are resistant to metalaxyl. This e.g. explains the poor performance of metalaxyl in the fungicide efficacy field test. The field evaluation of variety resistance against *P. infestans* showed large differences in rate of disease development for the reference varieties but, more importantly, also for locally bred Chinese varieties such as Kexin18 and Kexin13. Field evaluation of fungicide efficacy against *P. infestans* also showed large differences between fungicide performance. Unsurprisingly, metalaxyl sprayed at 25% only displayed a marginal effect against the fungus while propamocarb – HCL + fluopicolide and Macleaya-1 performed the best. The decision support system for late blight control developed by HAAS in cooperation with CRAW from Belgium, is operational in Heilongjiang. The system was effective in reducing disease development in potato, but the efficacy of the system should be improved in order to keep potato crops free from the disease during the largest part of the season. Achievement of a zero tolerance level of blight control requires major improvement of the system. It is recommend to further analyse the data of the experiments, to identify the white spots (e.g. for the HAAS DSS), to update the protocols with the 2014 experience and to repeat the field experiments in 2015.

2.2 Introduction

Within the framework of the Sino-Dutch Potato GAP it was agreed during a project meeting in April 2014 to carry out joint experiments on potato late blight (PLB) in Heilongjiang in, at least, 2014 and 2015. Selected topics included:

- **Monitoring of the Heilongjiang *Phytophthora infestans* population.**

Major P. *infestans* population changes frequently cause serious additional PLB control problems to farmers. The highly aggressive P. *infestans* genotype Blue13 (EU13-A2) was recently reported from China (Li *et al.* 2013). If aggressive genotypes like Blue13 become dominant in China, major additional control problems are anticipated.

- **Evaluation of potato varieties for late blight resistance in the field.**

Host resistance is an important part of an integrated (IPM) control strategy for potato late blight. The necessary fungicide input (and thus the environmental impact) on (more) resistant varieties is much lower than on susceptible varieties. Adoption of cultivation of resistant varieties allows for a more durable, future proof, cultivation of potato. To be able to use host resistance in the control strategy, reliable resistance ratings are imperative.

- **Field evaluation of fungicide efficacy with 10 fungicides**

Effective fungicide applications are a necessary part of the complete IPM control strategy for potato late blight. To be able to use fungicides effectively in an IPM control strategies, a reliable characterisation and rating of the various capabilities of the fungicides, e.g. foliar protection, tuber protection etc., is highly important.

- **Further development of a HAAS decision support system.**

Ideally fungicides are only used when necessary. Decision Support Systems (DSS's) can play a major role in advising on the most effective timing of fungicide applications. DSS's thus prevent over-use of fungicides and at the same time optimally protect the crop when it is most necessary. For these purposes, standardized protocols, as used within e.g. Euroblight, were discussed for adaptation to local circumstances and use in these experiments.

The following paragraphs report on the activities carried out by HAAS during the 2014 growing season.

2.3 Study description and results

2.3.1 Monitoring of the Heilongjiang *Phytophthora infestans* population

During the 2013 and 2014 growing seasons *P. infestans* isolates and *P. infestans* imprints on FTA cards (only DNA, experimental technology) were collected and analysed. They have been prepared for characterisation on virulence spectrum, physiological race, mating type, haplotype and SSR genetic fingerprint. Characterisation protocols have been exchanged between Wageningen Plant Research /Euroblight and HAAS. Main results are given hereafter.

In 2013, *P. infestans* in Heilongjiang was 66% A1 mating type and 34% A2 mating type. In Nehe and Suihua only A1 was found (Table 2.1). Metalaxyl sensitivity of *P. infestans* in Heilongjiang in 2013: 80% is resistant, 20% is intermediate resistant, 0% was found to be sensitive (Table 2.2). Physiological races of 16 *P. infestans* isolates were determined on the R1 – R11 differential set: r, R1, R2, R3, R4, R5, R6, R7, R8, R9, R10 and R11. The results show 12 races among 16 isolates. Race 1.3.4.7.10.11 was most common with a frequency of 31.52 %. It was found in two out of four areas. Meanwhile, the highly complex race 1.2.3.4.5.6.7.8.9.10.11 was also detected at a low frequency (Table 2.3 and Table 2.4).

Table 2.1 *Composition, Percentage and geographical distribution of mating type of P. infestans in Heilongjiang during 2013.*

			A1		A2	
Area	Site	Number of isolates	Number	Percentage	Number	Percentage
Heihe	Heihe	15	3	20.00%	12	80.00%
Qiqihar	Keshan	5	3	60.00%	2	40.00%
	Nehe	10	10	100.00%	0	0.00%
Suihua	Suihua	11	11	100.00%	0	0.00%
Total		41	27	65.85%	14	34.15%

Table 2.2 *Metalaxyl sensitivity of P. infestans in Heilongjiang during 2013.*

			Sensitive		Intermediate		Resistant	
Area	Site	Number of isolates	Number	Percentage	Number	Percentage	Number	Percentage
Heihe	Heihe	16	0	0.00%	6	37.50%	10	62.50%
Qiqihar	Keshan	4	0	0.00%	1	25.00%	3	75.00%
	Nehe	9	0	0.00%	1	11.11%	8	88.89%
Suihua	Suihua	11	0	0.00%	0	0.00%	11	100.00%
Total		40	0	0.00%	8	20.00%	32	80.00%

Table 2.3 *Identification of physiological races of P. infestans isolates collected from Heilongjiang in 2013 on the R1 – R11 differential set.*

Isolate code	Physiological race	Site	Area
13—1	1.2.3.4.5.6.7.8.10.11	Minzhu	Harbin
13—4	1.3.6.10.11	Minzhu	Harbin
13—5	1.3.4.5.6.7.8.9.10.11	Minzhu	Harbin
13—8	1.3.4.6.7.10.11	Minzhu	Harbin
13—10	1.2.3.4.5.6.7.8.9.10.11	Minzhu	Harbin
KS13-13	1.3.4.7.10.11	Keshan	Qiqihar
KS13-6	1.3.4.7.10.11	Keshan	Qiqihar
NH13-1	1.2.3.4.7.10.11	Nehe	Qiqihar
NH13-7	1.3.5.8.11	Nehe	Qiqihar
SH13-14	3.4.7.10.11	Suihua	Suihua
SH13-20	1.3.4.7.9.10.11	Suihua	Suihua
SH13-3	1.2.4.5.6.7.8.9.10.11	Suihua	Suihua
SH13-5	1.3.4.7.10.11	Suihua	Suihua
SH13-7	1.3.4.7.10.11	Suihua	Suihua
SH13-21	1.3.4.7.10.11	Suihua	Suihua
SH13-26	1.3.7.8.11	Suihua	Suihua

Table 2.4 *Frequency of P. infestans physiological races from different areas of Heilongjiang Province.*

No.	Physiological race	Number	Frequency (%)	Site
1	3.4.7.10.11	1	6.25	Suihua
2	1.3.7.8.11	1	6.25	Suihua
3	1.3.6.10.11	1	6.25	Minzhu
4	1.3.5.8.11	1	6.25	Nehe
5	1.3.4.7.9.10.11	1	6.25	Suihua
6	1.3.4.7.10.11	5	31.25	Suihua
				Keshan
7	1.3.4.6.7.10.11	1	6.25	Minzhu
8	1.3.4.5.6.7.8.9.10.11	1	6.25	Minzhu
9	1.2.4.5.6.7.8.9.10.11	1	6.25	Suihua
10	1.2.3.4.7.10.11	1	6.25	Nehe
11	1.2.3.4.5.6.7.8.9.10.11	1	6.25	Minzhu
12	1.2.3.4.5.6.7.8.10.11	1	6.25	Minzhu

2.3.2 Evaluation of potato varieties for late blight resistance in the field

Protocol for late blight resistance quantification under field conditions were exchanged between Wageningen Plant Research and HAAS (see Annex 1).

The two 2014 host resistance trials were located in Zhaodong city (Chernozem type soil) and at the Minzhu research station (black clay type soil) in Harbin. Planting dates were 28 April and 10 May respectively. Reference varieties included were Bintje (code 101), Markies (103), Sarpomira (102), Agria (104) and Gloria (105). Test varieties included Kexin13, Kexin18, Favorita, Zhaodabai, and Youjin 885. Both trials were setup as randomized block experiments with three replicates. The varieties were grown in plots, 2.6 m long and two rows wide. Spacing within the plots was 80cm between rows and 25cm within rows. Each plot contained 12 potato plants per row. Experiments were surrounded by maize. Spreader plants of the susceptible variety Favorita were used to separate plots to ensure a spatially homogeneous and reliable source of inoculum during the epidemic. These trials were not inoculated but depended on natural infection. No fungicides were applied during the season. The trials were harvested on 29th September 2014.

Under the mid hill conditions at Minzhu in 2014, Kexin18 and Kexin13 were found highly resistant to late blight, Youjin 885 was resistant to late blight, Zhaodabai was moderately resistant to late blight, Favorita was susceptible to late blight (Figure 2.1 and Figure 2.2 and Table 2.5).

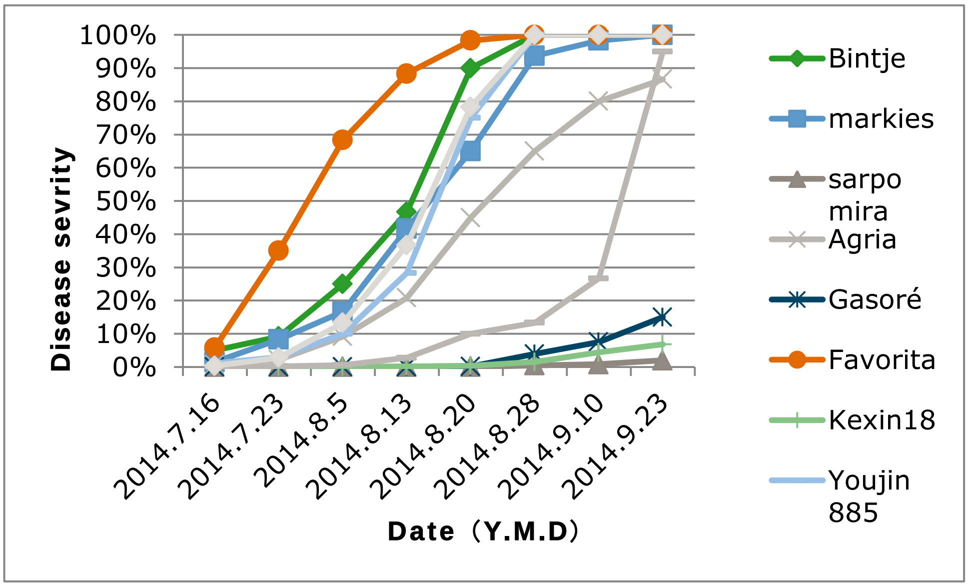


Figure 2.1. *Mean progression of foliage blight in trial of different potato varieties.*

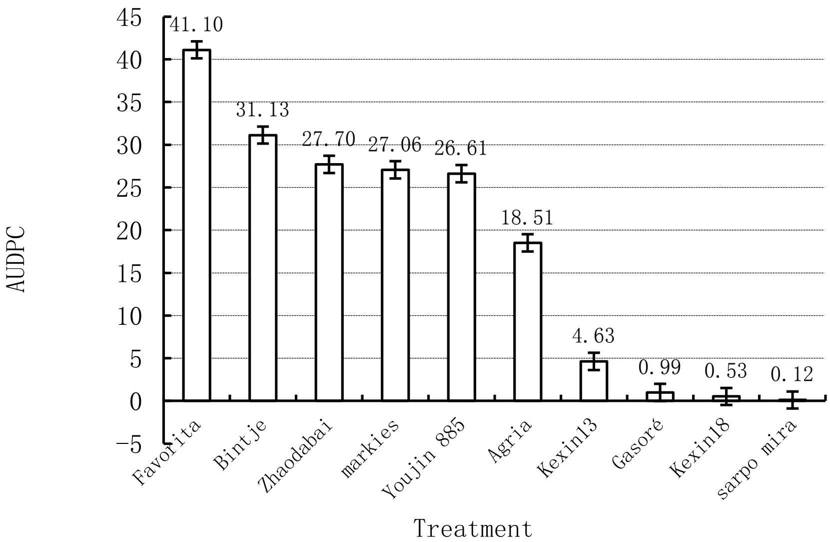


Figure 2.2 *AUDPC values in trial of different potato varieties.*

Table 2.5 *Reaction of potato varieties against late blight under field conditions.*

Varieties	AUDPC	RAUDPC	Range of score	Resistance category
Bintje	31.13	0.4716	2.4	MR
Sarpo mira	0.12	0.0018	8.9	HR
Markies	27.06	0.4099	3.4	MR
Agria	18.51	0.2805	4.8	R
Gasoré	0.99	0.01496	7.6	HR
Favorita	41.10	0.6227	1.7	S
Youjin 885	26.61	0.4032	4.1	R
Kexin18	0.53	0.008	8.2	HR
Kexin13	4.63	0.0707	7.6	HR
Zhaodabai	27.70	0.4196	3.9	MR

2.3.3 Field evaluation of fungicide efficacy with 10 fungicides

The 2014 fungicide efficacy trial was located at Minzhu Research Station in Harbin. Late blight occurs naturally in this area every year. Planting date was 10 May 2014. The variety of choice was the popular cultivar Favorita. The experiment was established as a randomized complete block design with four replicates. Plots were eight rows wide and 2m long with a spacing of 80cm between rows and 18cm within rows. The experiment was surrounded by a maize buffer. Fungicides were applied as stand-alone products for the duration of the season. Timing of the applications was calculated using the HAAS-CRAW version of the NegFry DSS.
Late blight first occurred at 18 July 2014 in the control and the 25% Metalaxyl plots, the other treatments remained healthy at this date. Late blight developed relatively slowly. On 13 August severity was at 48.75% for the Control followed by 25% Mancozeb (46.25%), the famoxadone + cymoxanil (12.5%), the Metalaxyl + Mancozeb (7.50%), the Macleaya-2 (6.19%), the Fluazinam (5.05%), the Mancozeb (2.00%), the Flumorph and the Macleaya-1(1.75%), the cymoxanil + mancozeb（1.19%), and the Propamocarb-HCl + Fluopicolide (0.27%). Following this observation, the disease developed rapidly, in only 15 days the disease severity reached 100% and 92.5% in the Control and the 25% Metalaxyl respectively. The other treatments were very effective in reducing late blight development.
The most effective fungicides were: Propamocarb-HCl + Fluopicolide, Followed by cymoxanil + mancozeb, Flumorph, Macleaya-1, Fluazinam, Mancozeb, Metalaxyl + mancozeb, Famoxadone + cymoxanil and the Macleaya-2 (Figure 2.3 and Figure 2.4).

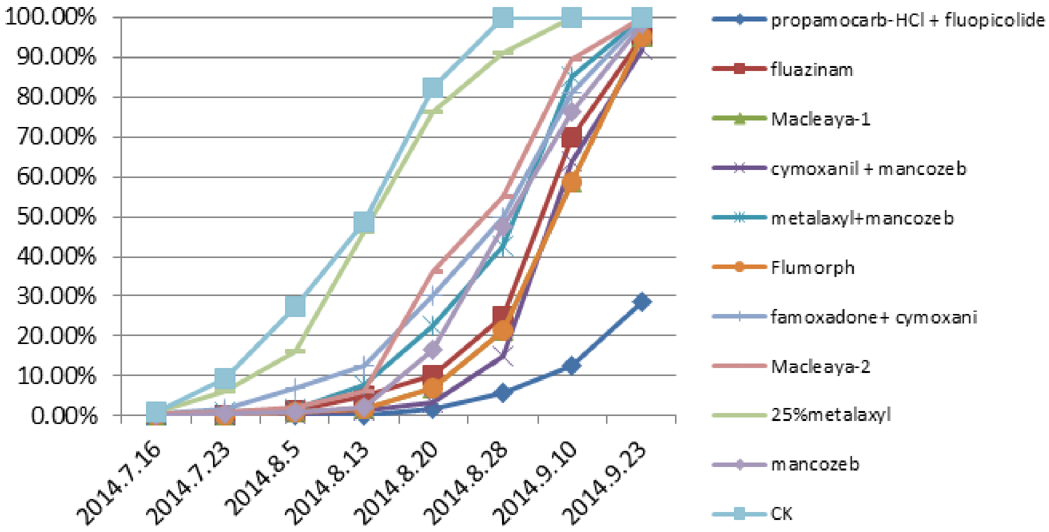


Figure 2.3 *Disease development curve of different treatments.*

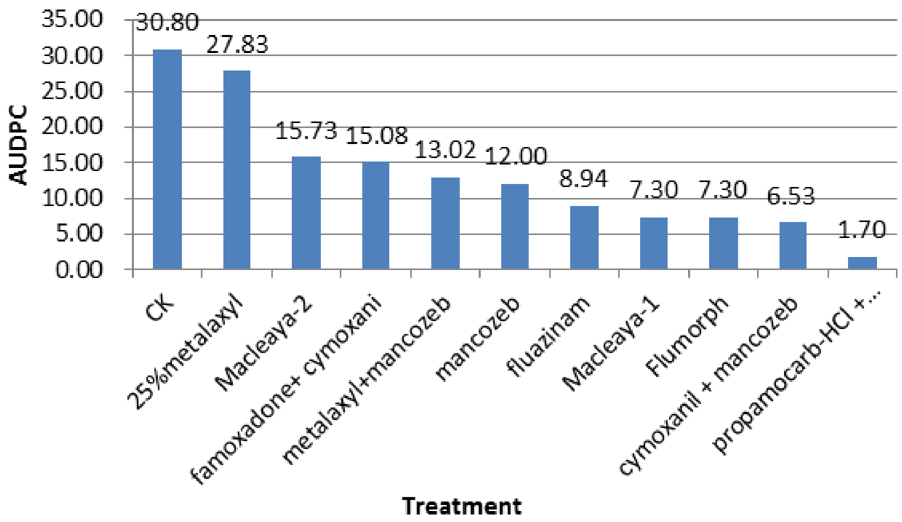


Figure 2.4 *AUDPC values in trial of different treatments.*

Figure 2.5 *Impression of the HAAS potato late blight resistance trial (right panel) and fungicide efficacy trials (left panel) in 2014.*

2.3.4 Further development of a HAAS decision support system

HAAS is developing a decision support system (DSS) for spray advice on late blight control. In 2014 a field evaluation of the late blight forecast software of HAAS-CRAW was carried out (Figure 2.6). The system uses four weather stations placed in main potato growing regions in Heilongjiang.

In 2014, the system showed promising results. Late blight control effect on test fields was 80%. Reduction of 15-20% fungicides spray. And reduction of fungicide costs of 20%. However, further development of the DSS is required to be able to advice better timing of fungicides and to keep crops free from disease up to end of growth season.

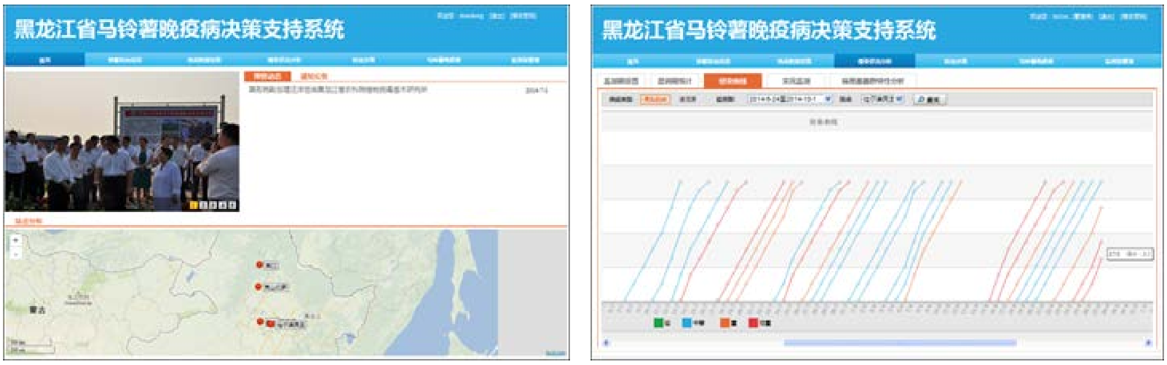


Figure 2.6 *Screenshots of application of the HAAS-CRAW.*

Figure 2.7. *Impressions of interaction and field visits staff DLV Plant, Wageningen Plant Research and HAAS.*

2.4 Conclusions and recommendations

We conclude and recommend the following points:

- The experiments in potato crops were carried out according to protocol.

- The monitoring study confirmed that both A1 and A2 mating types of *Phytophthora infestans* are present in Heilongjiang. It also showed that most isolates have resistance against metalaxyl.
- The field evaluation of variety resistance against *Phytophthora infestans* showed large differences in rate of disease development. Favorita was the least resistant while Sarpo Mira showed only very little disease development. Chinese varieties such as Kexin18 and Kexin13 showed high and promising levels of resistance.
- The field evaluation of fungicide schemes against *Phytophthora infestans* also showed large differences between fungicide products and combinations. Metalaxyl sprayed at 25% showed the smallest effect against the fungus while propamocarb-HCL + fluopicolide and Macleaya-1 performed the best.
- HAAS has developed a decision support system for late blight control in potato in cooperation with CRAW from Belgium. Though the system reduced disease development in potato significantly in 2014 in Heilongjiang, the efficacy of the system was not good enough to keep crops free from the disease. There is a need for improvement of the system in order to protect potato crops against late blight disease.
- We recommend further analysing the results, to identify the "room for improvement" of the HAAS DSS, to update the protocols with the 2014 experience and to repeat the field experiments in 2015.

3. Field experiments on seed quality

Romke Wustman & Corné Kempenaar, Wageningen Plant Research
Yanju Bai, Guoquan Fan, Shu Zhang, HAAS

3.1 Abstract

The seed potato field experiments in the 2014 growth season confirmed the importance of good quality seed potatoes. We observed large differences in growth and yield of crops from of 11 different seed potato lots of Keshan 13 variety grown in Heilongjiang in 2013. Yield differences were about 50%, and PVY incidence difference almost 100%. In another experiment, yield of variety Favorita was higher than that of variety Atlantic. Favorita is more tolerant to PVY infection than Atlantic. Aphid monitoring on the experimental field showed that aphids were present in from mid-June onward during the remaining part of the season, with a peak in aphid numbers end of July. Data on tuber infection are not yet available.

3.2 Introduction

Seed potato quality is another theme in the Sino-Dutch potato GAP Project. It was decided in April 2014 to start a series of field experiments in which the performance of different seed potato lots from Heilongjiang are studied and the effects of harvest date on virus infection and yield. Two experiments were carried out in 2014:

- **Performance of different seed lots of the Keshan 13 variety.**

Samples from eleven 2013 Keshan seed potato crops were planted in a field experiment in 2014. The growth and yield of the seed lots were assessed.

- **Effect of haulm killing date on yield and PVY incidence of potato crops.**

In a field trial, two potato varieties were planted. The haulm of the crops was killed at different dates. Yield and disease incidence was assessed.

3.3 Study description and results

3.3.1 Performance of different seed lots

For the protocol agreed upon, see Annex 2 and 3. HAAS collected seed potato samples from 11 origins. The variety was Keshan 13. The seed potatoes were grown on different fields in 2013 in Heilongjiang.
In May 2014, the seed potatoes were planted on a field of the HAAS experimental farm near Harbin. The soil type was a sandy clay type soil. The experimental design was a randomized block design in three replicates. The experiment consisted of 11 treatments (seed origins). Three plots were planted per treatment. Gross plot size was 4 m by 4 m. Each plot consisted of six rows. Row width was 65 cm. Seed tuber distance in the row was 30 cm. The net plot size for yield assessment was 2 m^2 (3 rows, 1 m per row). Soil tillage, fertilizer use and crop protection was according to HAAS recommendation. The tubers were not treated with any chemical before planting.
After planting, the crops on the individual plots were assessed on emergence %, number of stems per row, mean plant height, virus incidence in the field, yield and tuber size of harvested product. The experiment yielded in this way six performance indicators.

Large differences were observed in the performance indicators. On June 5, emergence % ranged from 38% (seed lot # 2) to 93% (seed lot # 9). On June 13, this had increased to77% to 95%, respectively. On this date, number of stems per plant ranged from 2.2 (seed lot # 2) to 3.3 (seed lot

9), and mean plant height ranged from 24 to 40 cm (at unspecified days). Potato Virus Y (PVY) and *Rhizoctonia* symptoms were observed in the plots, see e.g. Figure 3.1. On some plots, all plants showed PVY symptoms while other plots were completely healthy (observation August 2014). PVY incidence on the plots is shown in Figure 3.2, ranging from almost zero (# 9) to almost 97% (# 7). The mean yield, assessed by harvesting the tubes of 3 central rows over a length of 1 m per row (unspecified days), 6.3 kg (# 11) to 10.3 kg (# 9) (see Figure 3.3). Net plot size was 1.95 per m^2. Some pictures of vigour of crops on plots which good and bad performing seed lots are shown in Figure 3.4 (unspecified dates). Lot # 6 had 58% of the harvested tuber heavier than 100 g, while lot # 1 had 75%. Lot 9 was also amongst the plots with the biggest individual harvested tubers (tubers > 100 g, in other experiment 40 g as threshold).
Overall, we can conclude that seed lot # 9 performed the best on all indicators while 2, 5, 6, 7 and 11 performed bad on several or all six indicators. A high PVY incidence did not automatically result in a poor yield. The difference in performance between the seed lots was striking.

Figure 3.1 *Reduced foliage development on the left of the figure and more vigorous foliage growth on the right on August 13 2014.*

Figure 3.2 *Mean PVY incidence on 24 plants per plot per seed lot (unspecified date).*

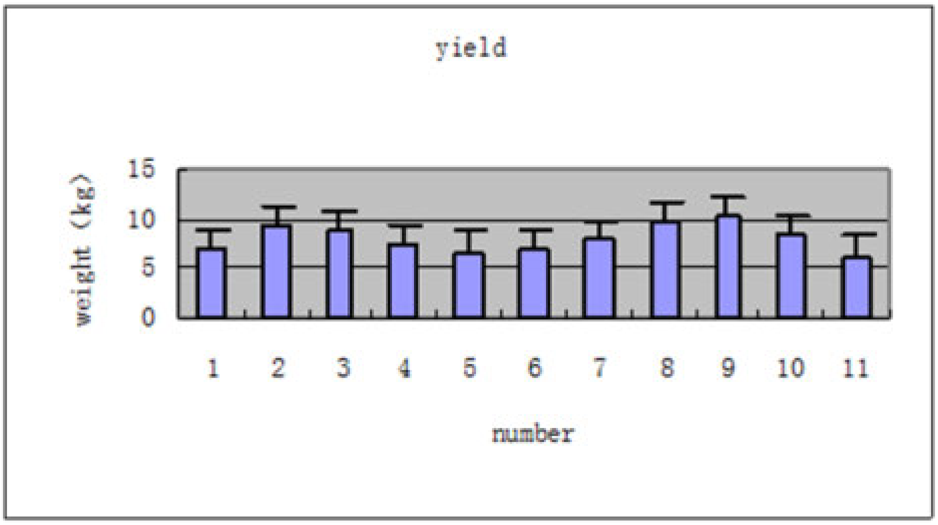


Figure 3.3 *Mean tuber yield (kg per 1.95 m²) per seed lot (unspecified date).*

Figure 3.4 *Pictures of plots of seed lot number 2 (left), 7 (middle) and 9 (right, unspecified date).*

3.3.2 Effect of harvest date on potato yield and quality

This experiment was also carried out at Minzhu Experimental station of HAAS in Harbin. Soil type is black clay soil. Small plots were laid out on a field where potatoes were grown in 2014. In the experiment, two varieties and 3 harvest dates. The varieties were Favorita (middle PVY resistant) and Atlantic (low PVY resistant). Harvest dates were August 1, August 20 and September 11, 2014. The experimental design was a randomized block design in 3 replicates. Plot size was 6 rows wide and 10 m long (11.7 m^2). In the experimental field an aphid trap was positioned (Figure 3.5, right). Aphid collection was carried out by HAAS.

Planting date and crop management was similar to that of the seed performance trial (see 3.3.1). Observations were counting of aphids in aphid trap between 3 June and 12 September about every 5 days., yield and tuber size assessment and PVY infection of harvested tubers. Per plot, an unspecified number of plants was harvested for yield and tuber size assessment.

Figure 3.5 shows some pictures of the experimental field. Already in third week of June, some aphids were caught and determined in the aphid trap. The peak in aphid counts was end of July; on 29 July 201 aphid heads were counted. The data on tuber infection by PVY are not yet available (December 2014). Preliminary data on yield show that Favorita had 2.3 kg per m^2 and Atlantic 1.5 kg per m^2 on last harvest date (unspecified). And for Favorita, 88% of tubers were larger than 40 g, while for

Atlantic 84%. On earlier harvest dates, yields and tuber size were smaller, as expected. The data on yield and PVY infection of the offspring will be added to the report later this year.

Figure 3.5 *An overview of the experimental layout of the field (left), an example of the haverst (middle) and an aphid trap (right).*

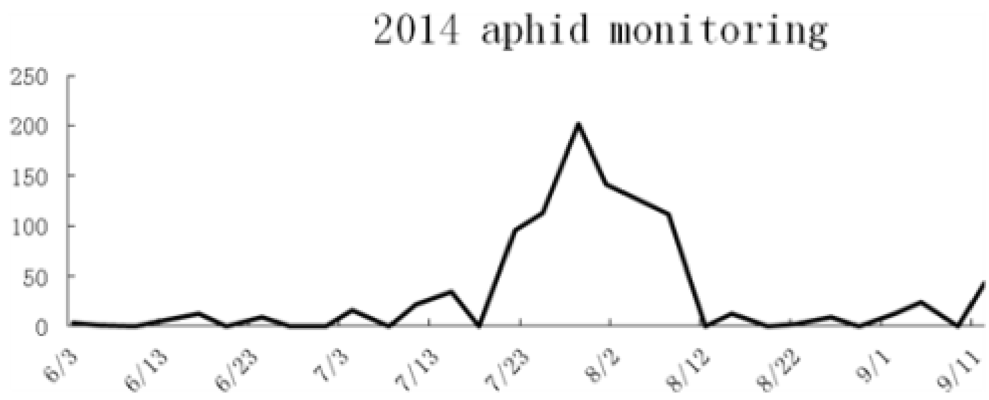


Figure 3.6 *Number of aphids in yellow aphid trap (see Figure 3.5, right) during the growth season of 2014.*

3.4 Conclusions and recommendations

We conclude and recommend the following points:

- The experiments were carried out according to protocol. The potato crops on the experimental plots grew and developed as expected under the Harbin growing conditions. Some parameters have to be checked for publication.
- Large differences were observed in the performance of seed lots of Keshan 13 from different origins of Heilongjiang produce. E.g., yield difference of almost 50% and PVY incidence difference of almost 100% were observed.
- Aphids that can spread PVY virus were detected from mid-June onward during the season. Peak in aphid numbers was end of July.
- Yield of Favorita was higher than yield of Atlantic. Harvest date affected yield and tuber size. Favorita is more tolerant to PVY than Atlantic.
- PVY infection data of tubers are to be added to the report to draw conclusions on this aspect.
- The data are in line with earlier seed potato tests in Ningxia province.

We recommend to repeat the experiments in 2015.

4. Optimal use of land and water, and foot printing of the potato production in China

Annette Pronk, Anton Haverkort, Corné Kempenaar & Frank de Ruijter, Wageningen Plant Research

4.1 Abstract

The total amount of potatoes produced in China is on the rise and the demand for high quality potatoes for the processing industry is growing. In the current situation there is a gap between the demand of the industry and the production of high quality potatoes by farmers. In this study a yield gap analysis was done and the Cool Farm Tool was used to. Both activities were used to evaluate local practices, conditions and performance of growers with respect to potato production and to identify the potentials of the investigated areas. This analysis was done for the major potato producing areas in China (Ningxia: Xiji and Yanchi, Inner Mongolia: Dalate, Heilongjiang: Keshan, Hebei: Chabei and Fujian: Yutian) as well as for four locations in the well-known potato producing Province Heilongjiang (Keshan, Zhaodong, Hulan and Minzhu).

Based on the results of this study it is concluded that:

- Model calculations on attainable yield show room for improvement of production.
- Irrigation needs to be investigated as this was identified as a major production limiting component and data provided was poor.
- The carbon footprint of potato producing specialized farms range between 55 and 282 CO_2-eq per tonnes potatoes (no storage, no transport). When storage and transport effects are added, carbon foot print is higher. It may well be possible that on non-specialised farms the CO_2-eq per tonnes potatoes is larger than the finding of this study.
- The Carbon footprints reported are low compared to other Asian production regions (India) as storage energy use is low.
- Transport of yield to the final destination or transport of potato seed for planting can contribute considerable to the CO_2-eq load.
- Improvements on fertilizer use may reduce costs. This needs to be investigated.

4.2 Introduction

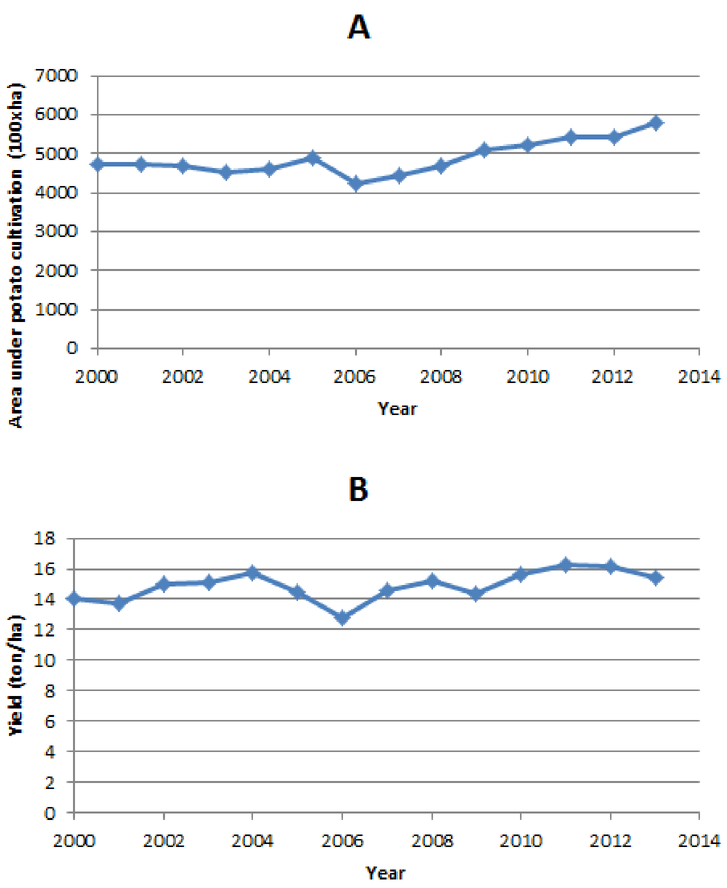
The potato industry is a fast growing sector in the Chines economy, certainly in the Northeast provinces Heilongjiang, Hebei and Inner Mongolia. The total amount of potatoes produced in China is on the rise (Figure 4.1, left) and the demand for a high quality potatoes for the processing industry is growing as well. In the current situation there is a gap between the demand of the industry and the production of high quality potatoes by farmers. The challenge for the complete potato chain is to significantly improve production. Modernization of potato cultivation is necessary to increase the low average yield (Figure 4.1, right) and so to meet the growing demand. McCain (pers. comm.) says yields as high as 40 tons/ha can be and are found at some farms. Relatively high yields were estimated, around 40 to 50 tons/ha, when fields were visited by the Dutch delegation (see chapter 6) and thus a yield gap analysis needs to identify room for improvement. Improvements need to be done to overcome the expected yield gap by modernization of the potato cultivation.

Modernizing potato cultivation is also an economically interesting challenge: up scaling production, better machinery and equipment for soil tillage, planting, ridging, crop protection, harvesting and storage are key elements.
To facilitate the potato modernization, the yield gap analysis is used. The attainable yield and irrigation need under optimal conditions serves as an ultimate goal to aim at. On the other side, aspects as energy consumption and carbon foot printing severely contribute to potato producers as well as processors awareness of the impact of potato production, handling and storage on the environment.

The objectives of this study were:

1. to identify the yield gap of potato production between attainable yields actual yields of several provinces or autonomous regions in China (Table 4.1) and for specific locations in the province Heilongjiang;
2. to identify energy costs (translated into CO_2) of the various parts of the production system till harvest, till the end of the storage period and till final destination has been reached for areas mentioned above.

From these analysis suggestions for adjustments can be made to make the potato production more competitive.



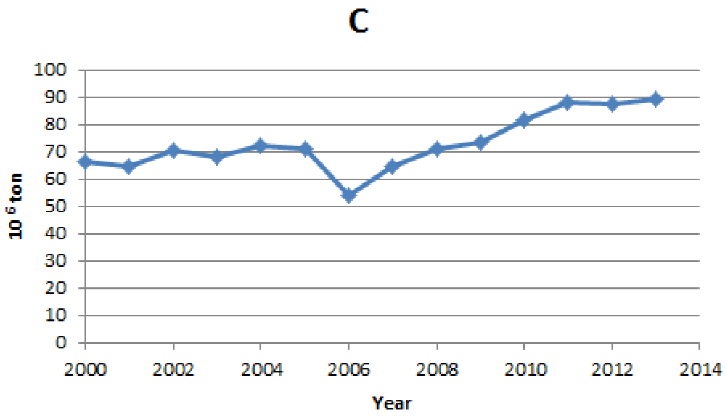


Figure 4.1 *The total area under potato cultivation (A), the average yield of potatoes (B) and the total amount of potatoes produced (C) in China for the past 13 years (FAO STAT).*

Table 4.1 *The top 10 potato producing provinces or regions in China in 2006 (Cao et al. 2009).*

Province/ autonomous region	Locations	Planting area (×1000 ha)	Production (million ton)	Average yield (ton/ha)
Sichuan	Southwest	632.0	9.48	15.0
Guizhou	Southwest	592.8	7.70	13.0
Inner Mongolia	North	589.1	8.80	14.9
Gansu	Northwest	567.8	9.40	16.6
Yunnan	Southwest	539.9	8.61	15.9
Chongqing	Southwest	347.4	4.71	13.5
Heilongjiang	Northeast	319.3	4.05	12.7
Shanxi	Northwest	299.2	2.42	8.1
Shaanxi	Northwest	252.0	2.55	10.1
Hebei	Central South	229.8	3.39	14.8

4.3 Materials and methods

4.3.1 Study areas

The study areas are located in major potato growing areas in China; Ningxia, Inner Mongolia, Hebei, Fujian and Heilongjiang. Not all of these provinces/regions are indicated as major potato growing area's in 2006 (Table 4.1), but between 2006 and 2013 the area under potato cultivation increased by more than 20% per year (Figure 4.1A).

Study area of the national study in 2012/3
The first analysis was done for six provinces/regions of China, Ningxia, Inner Mongolia, Hebei, Fujian and Heilongjiang (Figure 4.2, left).

Study area of the provincial study in 2013/4
The second analysis is done for four regions in the province Heilongjiang (Figure 4.2, right).

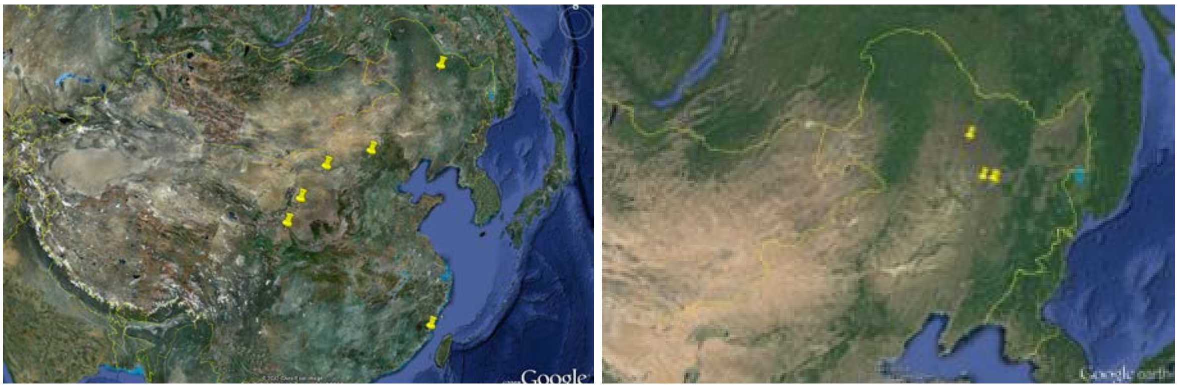


Figure 4.2 *An overview of the study areas of the national study of China (left) and of the provincial study of Heilongjiang (right).*

4.3.2 Data collection

Data were collected for the yield gap analysis and the carbon foot printing by email after sending a questionnaire (Annex 4) to different contact persons in the specified areas. Mr. Chen Lan from Syngenta provided the information on the production of potatoes in the Provinces Inner Mongolia (Dalate), Heilongjiang (Keshan) and Hebei (Chabei). Ms. Cui provided the information for Ningxia (Xiji and Yanchi county) and Mr. Zhaonian Yuan for Fujian (Yutian).
For the provincial study in Heilongjiang, the information was provided by Mr. Yu of McCain and HAAS. In case information was not complete, the contact persons were asked and in case information was not available assumptions were made or other sources were used.

4.3.3 Yield gap analysis

The attainable yield and irrigation need were calculated with the crop growth model LINTUL-potato (Kooman & Haverkort 1995). This model calculates dry mass production through the interception of radiation by green leaves. Sprout growth (0.7 mm/°C day) and canopy closure (650°C day after emergence) are temperature driven and when the canopy is closed maximum radiation interception occurs with maximum dry mass production as a result (Light use efficiency = 1.25 g MJ^{-1} light intercepted). Distribution of dry mass between the various organs is also temperature driven. Approximately 75% of total dry mass production is distributed to the tubers by the end of the growing period. Subsequently, fresh tuber weight is calculated from total tuber dry weight (dry matter content of tubers = 21%).
The input data required are weather data (average daily temperature, total daily radiation, precipitation and evapotranspiration), cultivation data (date of planting, planting depth and data of haulm killing) and data on soil type. These cultivation data, actual yield and applied irrigation were collected by interviewing farmers. The weather data were provided by the project partner when available. When data were not available, they were derived from the PRI-database containing weather data of the Climatic Research Unit (CRU) (Jones & Harris 2008).
The objective of this part of the study was to identify the yield gap between attainable yields and yields found in several provinces in China and further more in four different regions in Heilongjiang for various potato cropping systems.

4.3.4 Greenhouse gas emissions

Potato production is associated with the use of energy. So it is equally associated with the costs of energy. When potato arrives at its final destination (wholesale) market in the cities for fresh potatoes, at the factory gate for processing potato and at the potato field for seed potatoes, the following energy/money costing phases apply:

- Production stage at the field (seed, inputs, field operations including irrigation),
- Storage for varying durations,
- Transport to field, market or factory.

A bench marking tool to address this energy use is the Cool Farm Tool (CFT, Haverkort & Hillier 2011). The level of carbon-dioxide (CO_2) in the air in the northern hemisphere was 315 parts per million (ppm) in 1958 and currently it is 400 ppm. The CO_2 concentration continues to rise despite global efforts to reduce it such as carbon rights trading between countries and companies. In addition to CO_2, other greenhouse gases such as N_2O and CH_4 are emitted. The total effect of these gases is expressed as CO_2-equivalents (CO_2-eq), whereby N_2O and CH_4 are strong greenhouse gases: N_2O is 300 times more effective than CO_2 and CH_4 is 20 times more effective.
Water vapour in the air, although not a greenhouse gas, has the same function. Especially these gases contribute to the greenhouse effect as they are more effective than carbon dioxide. It is estimated that agriculture is responsible for about 11% of greenhouse gases caused by man. A reduction of greenhouse gas emission by agriculture could be a substantial means of mitigating its effect on climate change. A new tool to calculate the CO_2 emitted in the production of crops or animals in agriculture is the CFT developed by dr. Jon Hillier with co-workers at the University of Aberdeen commissioned by Unilever and dr. A. Haverkort of Wageningen University & Research, the Netherlands (2011). Recently with the aid of McCain potato agronomists at a few continents dr. Hillier and dr. A. Haverkort made it potato specific: The CFT-Potato, aired as a web version in October 2013: app.coolfarmtool.org. The tool – an MS Excel spreadsheet – at page one requires the site and country the crop is in. This is important as some countries have a high emission level of electricity production where mainly coal is used (South Africa) whereas e.g. France has a low level as in this country the majority of electricity is from nuclear energy. When using power for water pumping or cooling the carbon load varies according to country. The farmer also has to indicate the soil type (sandy, medium or heavy) as this determines energy requirements for ploughing and harvesting. Soil organic matter, humidity and acidity are reported as they influence nitrogenous fertilizer break down to volatile compounds and high organic matter soils loose soil carbon when exposed to oxygen which is aggravated by working the land. Fertilizers – total amounts and type - such as ammonium nitrate or urea are noted as well as the sources of potassium, phosphorus and calcium. The latter two are presented in the results as fertilizer related emissions. Organic amendments also can be mentioned such as farm yard cow manure. The grower fills in the number of applications of herbicides, insecticides and fungicides. Based on these data CFT sums up all the energy that is needed to produce the chemicals in the factory and how much CO_2-equivalents of nitrous oxygen is emitted from the soil resulting from fertilization. Subsequently the grower completes a page with all operations such as ploughing, ridging, destining, spraying, spreading, irrigation, on farm transport of materials and tubers and harvesting. CFT then calculates – based on ASABE data of the American Society of Agricultural and Biological Engineers - how much diesel and electricity is used and converts it into kg CO_2. Finally, CFT asks whether the product is washed, graded, loaded into a store and stored with ventilation and refrigeration and about the use (number and dose) of sprout suppressant. The original CFT originally did not contain information nor questions about irrigation, grading, storage and sprout control. So data were collected from various operations and CFT came up with easy questions such as how many millimetre did you apply in total and for how many weeks did you store and how many degrees was the potato in the store cooler than the average outside temperature. From original data we know how much electricity it costs to irrigate one mm, or to cool potatoes down per degree for one week. Finally the grower has to fill in the yield and the seed rate and CFT calculates the greenhouse gas emissions (in CO_2-eq) associated with the production of one tonnes of potato.
The collected data were input of the Excel Spreadsheet (beta 4.1) version of the Cool Farm Tool (exactly the same as the web based (app.coolfarmtool.org) version.

4.4 Results

4.4.1 Data collection

Data collected in the national study

An overview of all answers in the questionnaires is given in Annex 5. A summary table of data used in the LINTUL growth model for potato and the Cool Farm Tool-Potato is given in Table 4.2. A fixed harvest date was chosen to be used in calculations with the crop growth model. Below some remarks on the summary table:

- The net delivered yield as indicated in the questionnaire may not include home consumption or use of by-product in case of seed potato in Ningxia – Xiji, Heilongjiang – Keshan (seed) and Hebei – Chabei. However, the greenhouse gas emission must be calculated for the total usable yield. Therefore, greenhouse gas emissions for these provinces/autonomous regions are calculated for the gross yield.
- The yield of the Heilongjiang Keshan seed potato production is given to be 52.5 tons/ha. That yield is produced with moderate inputs of fertilizers, which seems unrealistic.
- The Heilongjiang Keshan seed potato production was irrigated once in 2012 with 29 mm. Normally, depending on rainfall, this crop is irrigated more often.
- In Fujian – Yutian, irrigation is indicated to be 6 mm. The application method is flooding. It is difficult to estimate the irrigated amount of water in flooding systems and 6 mm seems very little. Therefore, model estimates suggest that approximately 100 mm irrigation is needed to produce this crop and is used in the Cool Farm Tool.
- Irrigation amounts are not provided for Ningxia – Xiji and Ningxia – Yanchi. Model estimated suggest that approximately 300 and 700 mm irrigation is needed for the potato production in Ningxia – Xiji and Ningxia – Yanchi which is used in the Cool Farm Tool.

Table 4.2 *Overview of data provided by contact persons for the six provinces/autonomous regions in China (per hectare). Note: this table mainly contains quantitative questions/answers needed to complete the LINTUL growth model and the Cool Farm Tool-Potato to allow foot printing of land and water.*

Province	Ningxia -Xiji	Ningxia -Yanchi	Inner Mongolia – Dalate	Heilongjiang – Keshan (seed)	Hebei - Chabei	Fujian - Yutian
Seed transport (km)	50	3	350	0.5-30	15	2000
Yield gross (ton/ha)	20.2	30	40	52.5	45	35
Yield net delivered (ton/ha)	9.1[1]	30	40	44.6[1]	20[1]	33
Distance to market (km)	1.5	3	0.35	1500	15	0.3
Seed rate (ton/ha)	1.8	1.95	2.7	2.6	2	1.5
Soil Texture	Medium	Medium	Course (sand)	Medium	Medium	Course (sand)
Date of planting	12-May	25-Apr	28-Apr	28-Apr	1-May	15-Nov
Planting depth (cm)	20	15	15	15	9	20
Soil organic matter (%)	5.2<SOM<10.3	5.2<SOM<10.3	SOM<1.7	1.7<SOM<5.2	SOM<1.7	1.7<SOM<5.2
pH	7.3 <pH<= 8.5	pH>8.5	pH>8.5	5.5<pH<=7.3	7.3<pH<= 8.5	pH <=5.5
N (kg/ha)	225	216	444	105	395	230
P_2O_5 (kg/ha)	75	120	285	105	270	160
K_2O (kg/ha)	300	84	457	128	360	215
Foliar NPK (kg/ha)	+	+	+	+	+	+
Manure (t/ha)	57	24	-	-	-	1.5
Type of manure	Straw, sheep /goat, cattle	Sheep, goat, pig, human being/compost				Solid duck manure
Manure transport (km)	5	2	0	0	0	0
#Seed treatment	1	1	1	1	2	0
Soil treatment (kg/ha)	-	-	-	-	-	-
# Post em. Treatment	3	9	11	14	11	11
# chisel plough	2	1	2	2	0	0
# Power harrow	1	0	1	0	0	1
# sub-soiling	1	0	3	3	1	1
# moldboard	2	2	1	0	1	1
Harrowing	0	0	1	0	0	0
Planting	1	2	3	1	1	1
Ridging	1	2	3	1	1	1
Tine harrow	1	0	0	1	1	0
# Machine sprayer	1	2	1	5	2	4
# Fertilizer sprays	1	2	5	0	15	0
# Fertilizer spreads	1	2	5	0	15	0
Irrigation (mm)	0	?	357	29	300	6
Depth irrigation water (m)	-	0.1-0.25	80	130	80	5
Distance irrigation (m)	-	1000	0	0	500	20
Irrigation type	None	Drip irrigation	Pivot	Pivot	Pivot	Flooding
Irrig % electrical/diesel	-	Electricity	Electricity	Electricity	Electricity	Electricity
Date of haulm killing	1-Sep	1-Oct	1-Oct	23-Sep	20-Sep	15-Mar
Type of harvest	Manual	Fully mechanical	Fully mechanical	Windrowing	Windrowing	Manual
Grading (%)	0	85	100	85	0	80
Grading diesel/electrical	-	Electricity	Electricity	Electricity	0	Electricity
Stored (%)	55	100	100	15	55	15
Storage electrical/diesel	Electricity	Diesel	Diesel	Petrol	Electricity	??
# months stored	6	7	4.5	6	5	-
# degree < ambient	0	0	0	0	0	-
CIPC # treatments	0	0	0	0	0	-
CIPC	-	-	-	-	-	-

dose/treatment

[1] The greenhouse gas emission is calculated for total harvested yield as the delivered yield may not include home consumption and emissions need to be calculated for the total potato yield produced.

Harvest dates as given by contact persons:

- Ningxia: The harvesting date very much depends on the variety. In Xiji, the early-matured potato is harvested in July and late-matured potato is harvested in October, while in Yanchi, early-matured is harvested around 15 September, and late-matured is harvested around 15 October.
- Inner Mongolia: harvest date from Sep. 18 to Oct 15 for 500 ha.
- Heilongjiang: harvest date from Sep. 1 to Oct 15, for 670 ha.
- Hebei: harvest date from Sep 1 to Oct. 10, for 550 ha.
- Fujian: planting is from October 28 to December 28, mostly from November 15 to December 15. Length growing period is usually about 100-120 days. Typical planting-harvest dates: November 25 - March 15.

The weather data are presented as average daily temperature (minimum and maximum), total precipitation and average daily radiation (Figure 4.3 and Figure 4.4). The green bars indicate the potato growing season.
The total precipitation in the growing season ranges from approximately 250 mm in Inner Mongolia to around 400 mm Fujian. The growing period is for most provinces a summer crop from May to August/September. Only in Fujian potato cropping season is in the winter during November to March (Figure 4.3 and Figure 4.4).

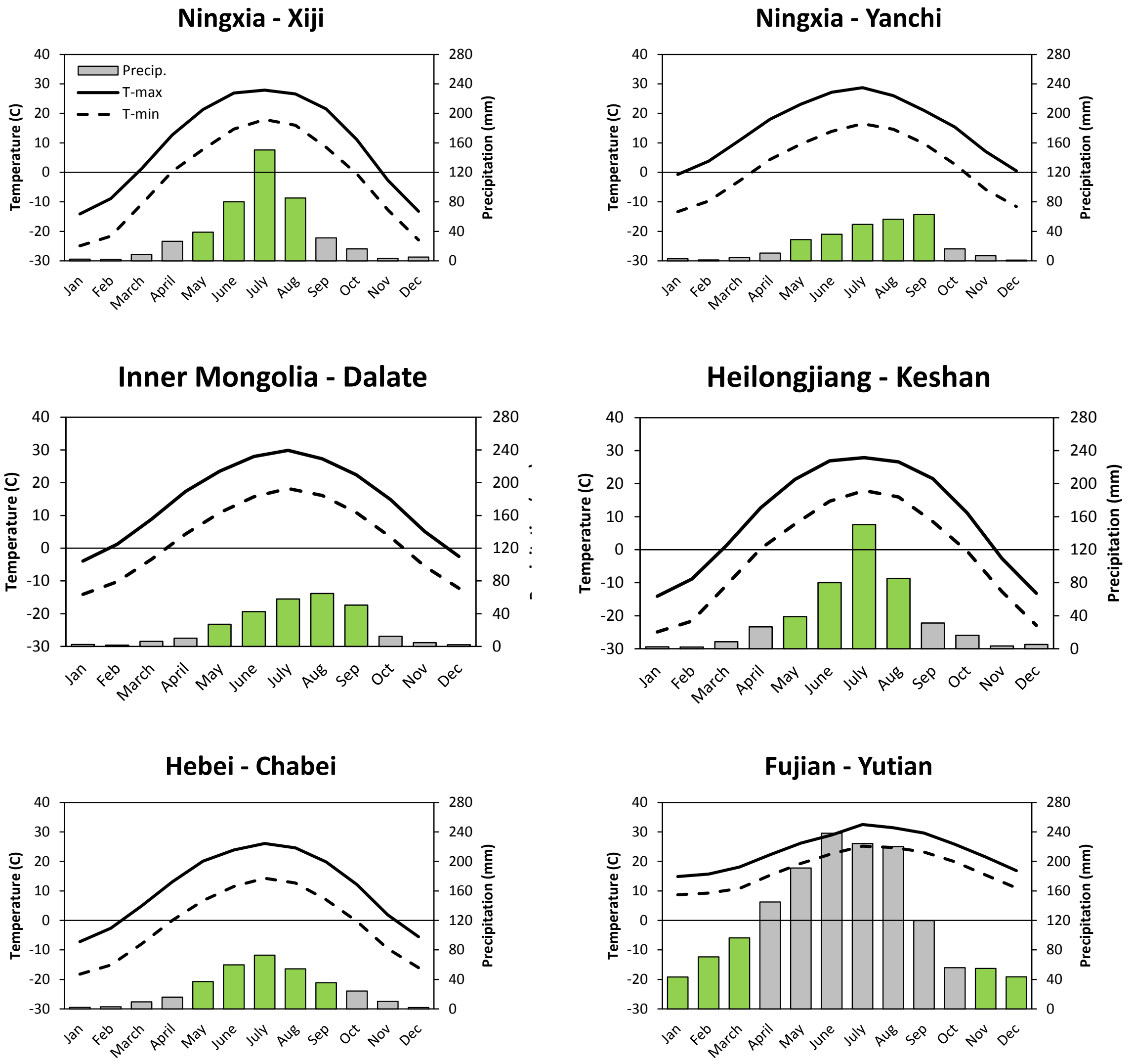


Figure 4.3 *The minimum (T-min; ℃) and maximum (T-max; ℃) temperature and total precipitation per month (Precip.; mm) for six locations in China. Green bars indicate the potato growing season.*

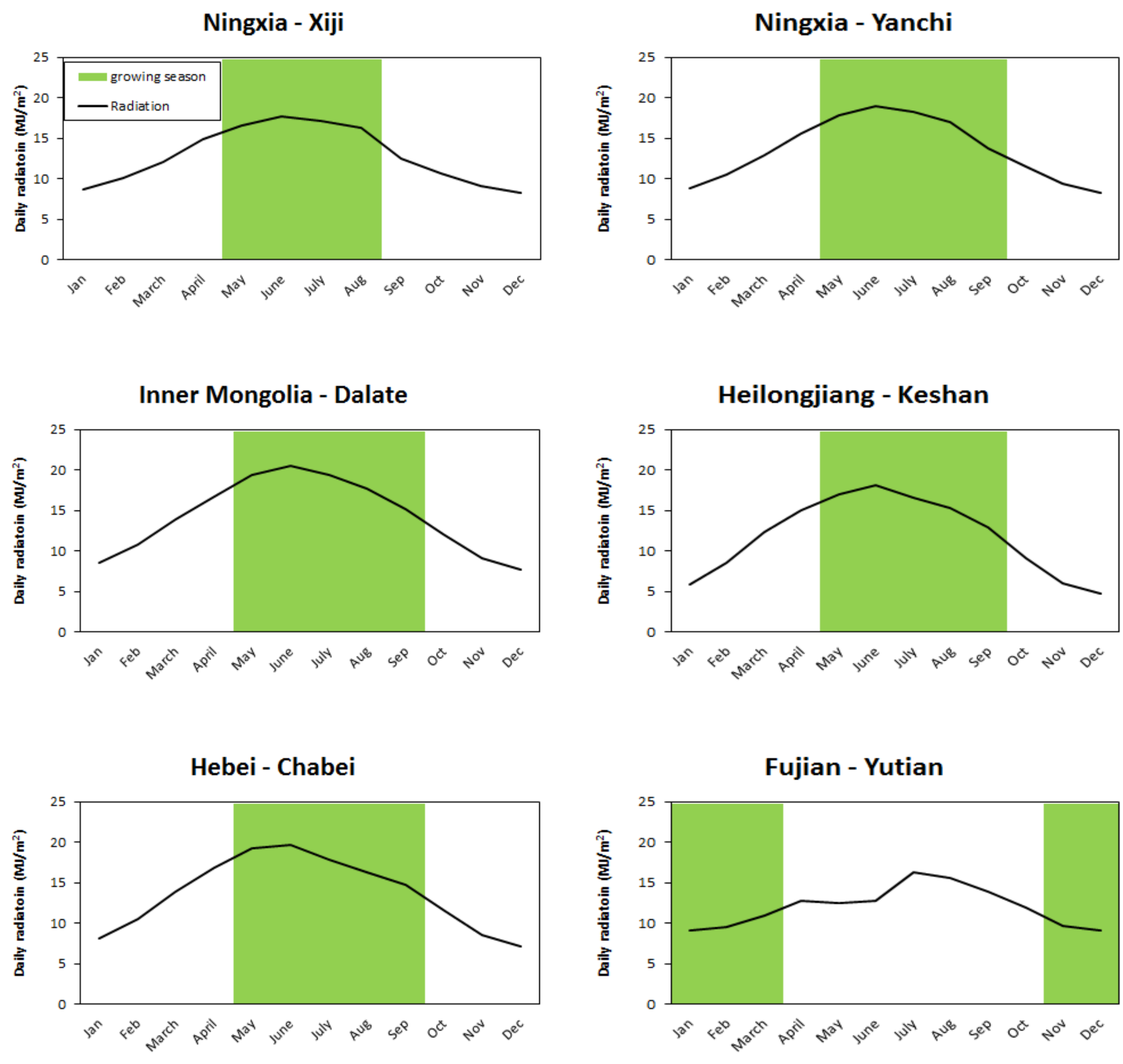


Figure 4.4 *Average daily radiation per month (MJ/m^2) for six locations in China. The green area indicates the potato growing season.*

Data collected in the provincial study

An overview of all answers of the questionnaires of the provincial study is given in Annex 6. A summary table of data used in the LINTUL growth model for potato and the Cool Farm Tool-Potato is given in Table 4.3. Below some remarks on the summary table:

- The net delivered yield as indicated in the questionnaire may not include home consumption or use of by-product in case of seed potato in Ningxia – Xiji, Heilongjiang – Keshan (seed) and Hebei – Chabei. However, the greenhouse gas emission must be calculated for the total usable yield. Therefore, greenhouse gas emissions for these provinces/autonomous regions are calculated for the gross yield.
- The yield of the Heilongjiang Keshan seed potato production is given to be 52.5 tons/ha. That yield is produced with moderate inputs of fertilizers, which seems unrealistic.
- The Heilongjiang Keshan seed potato production was irrigated once in 2012 with 29 mm. Normally, depending on rainfall, this crop is irrigated more often.
- In Fujian – Yutian, irrigation is indicated to be 6 mm. The application method is flooding. It is difficult to estimate the irrigated amount of water in flooding systems and 6 mm seems very little. Therefore, model estimates suggest that approximately 100 mm irrigation is needed to produce this crop and is used in the Cool Farm Tool.

- Irrigation amounts are not provided for Ningxia – Xiji and Ningxia – Yanchi. Model estimated suggest that approximately 300 and 700 mm irrigation is needed for the potato production in Ningxia – Xiji and Ningxia – Yanchi which is used in the Cool Farm Tool.

Table 4.3. *Overview of data of contact person for four locations in Heilongjiang (per hectare). Note: this table mainly contains quantitative questions/answers needed to complete the LINTUL growth model and the Cool Farm Tool-Potato to allow foot printing of land and water.*

Location	Khesan	Zhaodong	Hulan		Minzhu
Product	Seed	Ware	Seed	Ware	Ware
Farm size	67	500	564	564	560
Hectares potato	67	200	300	200	12
Seed transport (km)	50	50	1.5	1.5	40
Yield gross (ton/ha)	30	22	45	45	30
Yield net delivered (ton/ha)	24	16	35	35	24
Distance to market (km)	50	50	50	50	40
Seed rate (t/ha)	2.625	2	1.65	1.65	2
Soil Texture	Medium	Medium	Medium	Medium	Medium
Date of planting	15-May	1-May	20-Apr	20-Apr	1-May
Planting depth (cm)	6	10	10	10	10
Soil organic matter (%)	1.7 - 5.2	1.7 - 5.2	1.7 - 5.2	1.7 - 5.2	1.7 - 5.2
pH	5.5 - 7.3	5.5 - 7.3	5.5 - 7.3	5.5 - 7.3	5.5 - 7.3
N (kg/ha)	165	150	250	250	200
P_2O_5 (kg/ha)	120	100	150	150	120
K_2O (kg/ha)	225	200	300	300	250
Foliar NPK (kg/ha)	+	+	+	+	0
Manure (t/ha)	no	no	2	2	no
Type of manure			Pigs/poultry	Pigs/poultry	
#Seed treatment	1	no	no	No	no
Soil treatment (kg/ha)	no	no	no	No	no
# Post em. Treatment	11	3	7	6	6
# chisel plough			1	1	1
# Power harrow					2
# sub-soiling	1	1			
# moldboard			1.5	1.5	1
Harrowing	1	1	1	1	
Planting	1	1	1	1	1
Ridging	2	2	3	3	2
Tine harrow					1
Manure transport (km)			1.5	1.5	
# Machine sprayer	9	3	6	5	5
# Fertilizer sprays	5	0	2	3	
# Fertilizer spreads	2	1	1	1	1
Irrigation (mm)	118[1]	-[1]	no[1]	no[1]	-[1]
Depth irrigation water (m)	100	50	-	-	60
Distance irrigation (m)	0	0	-	-	0
Irrigation type	Pivot	Pivot	-	-	Rain gun /Flooding
Irrig % electrical/diesel	Electrical	Electrical	-	-	Electrical
Date of haulm killing	25-Sep	15-Sep	5-Sep	5-Sep	10-Sep
# Windrowing	1	1	1	1	1
On Farm Transport (km)		50	1.5	1.5	40
Grading (%)	0	0	0	0	0
Grading diesel/electrical	-	-	-	-	-
Stored (%)	30	50	80	100	50
# months stored	5	5	5	5	5
# degree < ambient	3	4	4	4	4
CIPC # treatments	No	No	No	No	No
CIPC dose/treatment	No	No	No	No	No

[1] Data on the amount of irrigation were not provided by contact person. Therefor twice the calculated precipitation deficit is used as irrigation applied.

The weather data are presented in Figure 4.5 and Figure 4.6. Figure 4.5 shows monthly values for temperature (minimum and maximum) and precipitation. Figure 4.6 shows daily values for radiation. The green bars indicate the potato growing season.
Only moderate differences between the regions in Heilongjiang Province are found. The growing season in all regions is from April/May till September (Figure 4.6). Only in Hulan potatoes are planted late April compared to May in the other regions (Table 4.3).

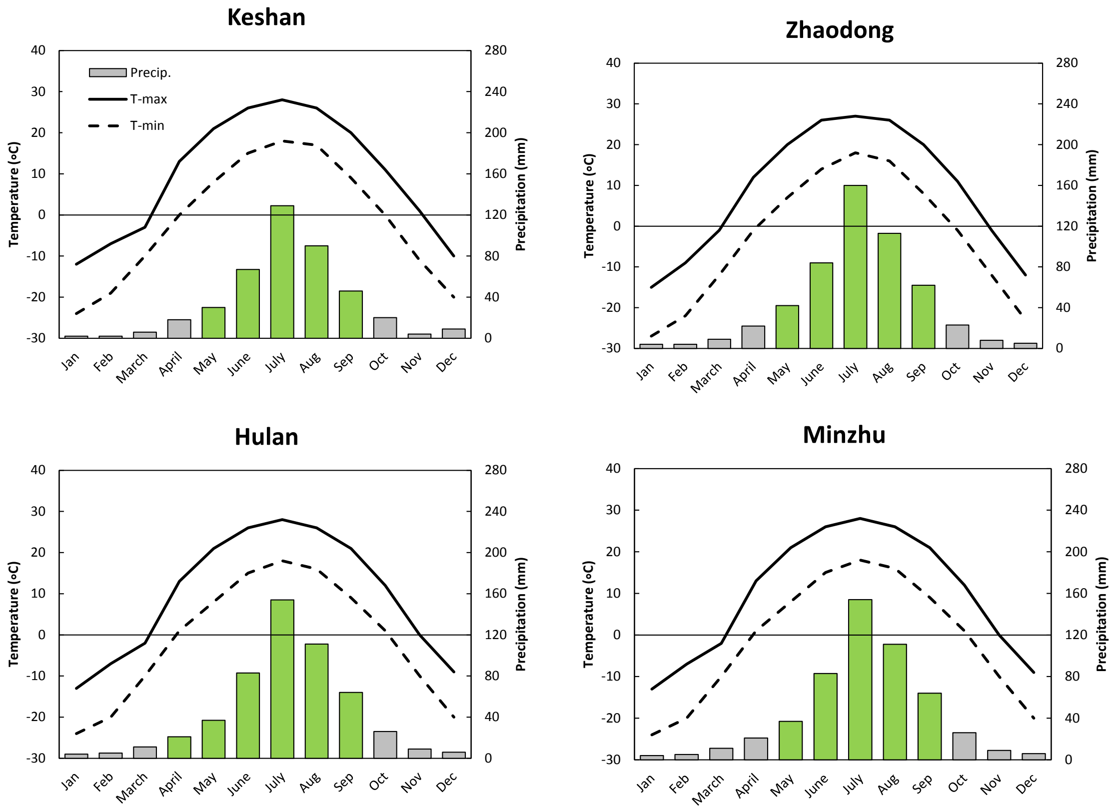


Figure 4.5 *The minimum (T-min; ℃) and maximum (T-max; ℃) temperature and the cumulative monthly precipitation (Precip.; mm) for four locations in Heilongjiang. Green bars indicate the potato growing season.*

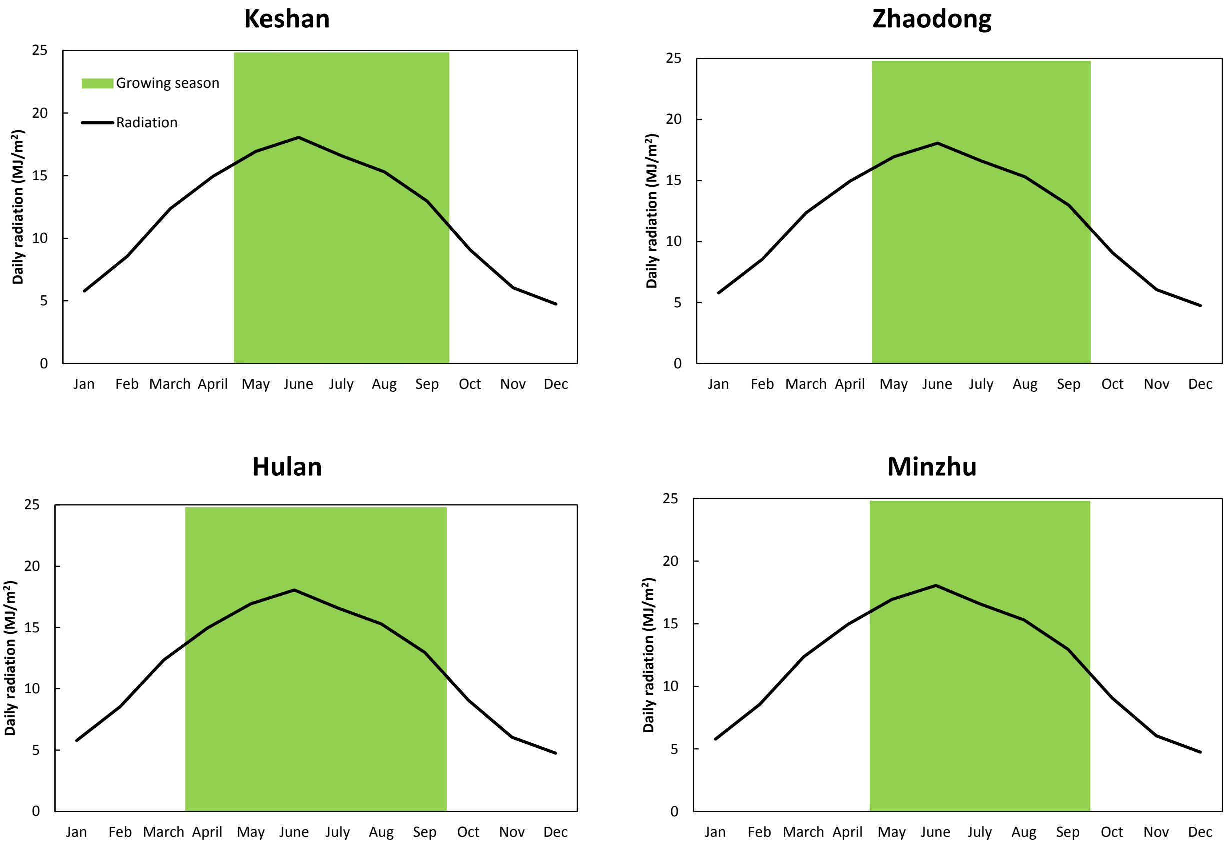


Figure 4.6 *The daily radiation (Radiation, MJ/m^2) during the year and the growing season for four locations in Heilongjiang. The green area indicates the potato growing season.*

4.4.2 Yield gap analysis

Yield gap analysis of the national study

Using the input data from Table 4.2 yields in an attainable fresh tuber yield which varied between 55 to over 80 tons/ha (Figure 4.7A). Compared to the practiced yields the yield gap ranges between 12 and 45 tons/ha for five provinces. Model calculations however, show attainable yields for Fujian to be approximately 37 tons/ha where practised yield is about 35 tons/ha. Further inquiry on average yields in Fujian revealed that yields close to 26 tons/ha were common.

Irrigation is needed in all provinces, according to the model (Figure 4.7B). Irrigation is practised, but not in all provinces. In Inner Mongolia and Heilongjiang irrigation practised approaches irrigation needs. In Hebei, irrigation practised is more than the irrigation need. In Ningxia, no irrigation is practiced in Xiji and in Yanchi it was not clear how much irrigation was applied.

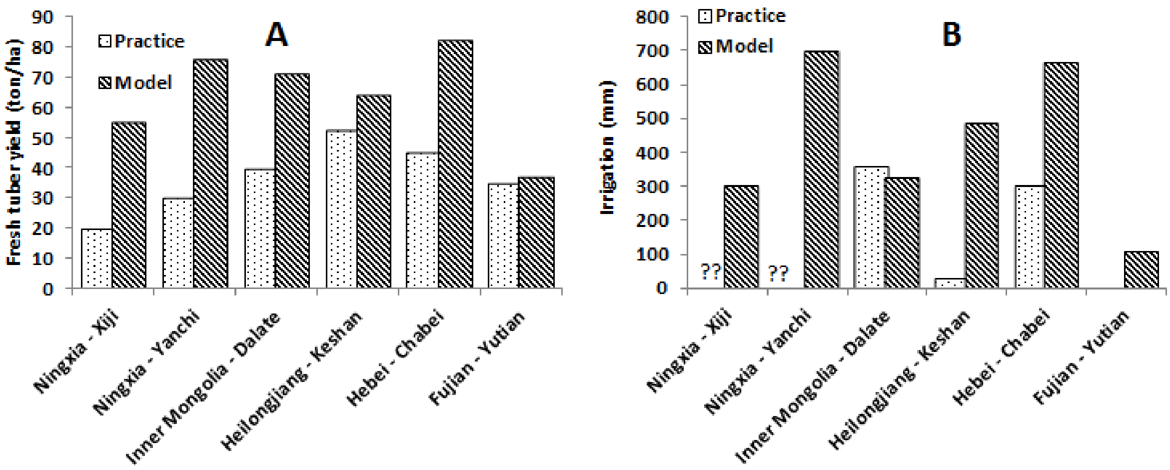


Figure 4.7 *The estimated attainable fresh tuber yield (Model) and the actual fresh tuber yield (Practice) for the six provinces/autonomous regions of China (A) and the practiced irrigation and irrigation needed according to the model estimates (mm season^{-1}; B).*

Yield gap analysis of the provincial study

Using the input data from Table 4.3 the attainable fresh tuber yield is estimated to range from 62 to 66 tons/ha (Figure 4.8A). The irrigation need according to the model calculations differed between the different locations and varied between 58 and 700 mm (Figure 4.8B). Data on practiced irrigation were not provided. Data are difficult to gather and there is large variation in practice as well as need due to irregular rain fall.

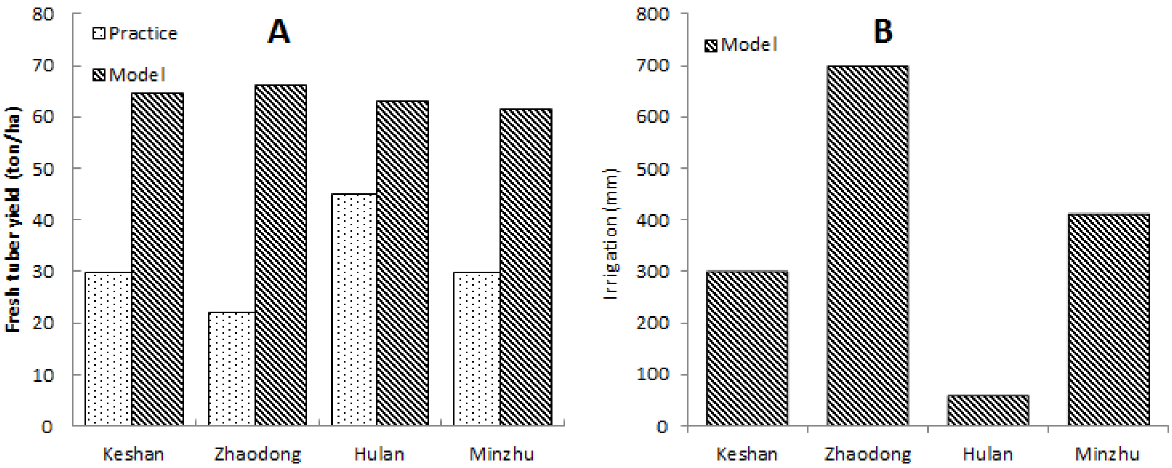


Figure 4.8 *The estimated attainable fresh tuber yield (Model) and the actual fresh tuber yield (Practice) for the different regions of Heilongjiang (A) and irrigation needed according to the model estimates (B).*

4.4.3 Greenhouse gas emissions

Greenhouse gas emission calculations of the national study

Inserting the data of Table 4.3 into the Cool Farm Tool model yields Table 4.4. In Table 4.4 the model output data for fertilizer CO_2-equivalents associated with fertilizer production in the factory, (N_2O – nitrous oxide gas) and back-ground from the soil and CO_2-eq associated with residue of the potato crop, are lumped under the heading "Fertilizer related".

Some general remarks regarding all six provinces/autonomous regions:

- Till harvest:
  - o Differences between provinces/autonomous regions are mostly related to differences in yield.
  - o Typically for all provinces/autonomous regions the fertilizer related greenhouse gas emissions (CO_2-eq) is the largest load and varies between 32 and 162 kg CO_2-eq/tonnes potatoes produced.
  - o Irrigation contributes considerable to the kg CO_2-eq/tonnes and is the second largest load.
  - o Seed production and transport contributes between 6% and 12% to the total load in Hebei/Fujian and Ningxia – Xiji respectively.
  - o Keshan in Heilongjiang had a substantial lower kg CO_2-eq/tonnes compared to all other provinces due to low input requirements (seed production) and high yields.

- Plus storage and transport:
  - o Differences in kg CO_2-eq/tonnes are related to differences in ambient temperature an cooling temperature, amounts of potatoes stored and the period of storage. In Heilongjiang Keshan, only 15% of the potatoes are stored for 6 months and little energy is needed as ambient temperatures in this area are low during storage period. In contrast, storage in Ningxia - Xiji contributes considerable to the CO_2-eq1 load as energy is used to actively cool the stored potatoes.
  - o Transport contributes only small amounts as most potatoes are delivered close to the production areas. Only the seed production in Keshan travels to the south of China and transport contributes considerable to the CO_2-eq load per tonnes potatoes.

Table 4.4 *Greenhouse gas emissions of the various components (kg CO_2-eq/ton) for the production of potatoes in several provinces or autonomous regions in China.*

	Ningxia - Xiji	Ningxia - Yanchi	Inner Mongolia – Dalate	Heilongjiang – Keshan	Hebei - Chabei	Fujian - Yutian
Seed production and transport	18	19	26	4	12	9*
Fertilizer related	79	120	162	32	113	104
Pesticides	4	7	6	6	6	7
Field Energy Use (excluding irrigation)	15	15	9	7	8	5
Irrigation	35	53	73	7	57	5
Grading	0	0	0	0	0	0
Off-site transport	1	0	5	0	0	18
Total at harvest, no transport	151	215	282	55	195	148
Total plus storage	316	238	291	58	204	148
Total plus storage plus transport	316	238	291	318	207	150

* Seed potatoes from Fujian. Normally, seeds used in Fujian come from other provinces. In that case transport related CO_2 will be much higher.

Greenhouse gas emission calculations of the provincial study

Inserting the data of Table 4.3 into the Cool Farm Tool-Potato model yields Table 4.5. In Table 4.5 the model output data for fertilizer include CO_2-eq associated with fertilizer production in the factory, (N_2O – nitrous oxide gas), back-ground from the soil and that associated with residue of the potato crop are lumped under the heading “Fertilizer related”.

Some general remarks regarding all four crops:

- Till harvest:
  - o Typically for all regions the fertilizer related greenhouse gas emissions (CO_2-eq) varies between 31 and 105 kg CO_2-eq/tonnes and is the largest load.
  - o Irrigation contributes as the second largest load (kg CO_2-eq/ton) in all regions where irrigation is applied due to electrical pumping.
  - o Storage costs are low compared to those for crisping potatoes in the Netherlands.

- Plus storage and transport:
  - o Storage costs are low and comparable to those for crisping potatoes in the Netherlands.
  - o Transport costs are low. The transport distances are only 40 to 50 km reported in the questionnaire. However, seed potatoes travel all over China, which increases the CO_2-eq load considerable.

Table 4.5. *Greenhouse gas emissions of the various components (kg CO_2-eq/ton) for a crisping potato crop in the Netherlands and various potato production systems in Heilongjiang.*

	Netherlands	Keshan	Zhaodong	Hulan		Minzhu
	Crisping, slurry used	Seed	Ware	Seed	Ware	Ware
Seed production and transport	5	19	18	5	6	13
Fertilizer related	31	85	105	78	78	92
Pesticides	13	8	3	3	3	4
Field Energy Use (excluding irrigation)	15	15	16	6	6	16
Irrigation	1	38	9	0	17	19
Grading	0	0	0	0	0	0
Off-site transport	4	1	1	0	0	1
Total at harvest, no transport	69	166	151	93	111	144
Total plus storage (5 months)	76	167	153	95	117	147
Total plus storage plus transport	117	176	161	104	139	154

The greenhouse gas emission calculations in the national study resulted in 55 kg CO_2-eq/tonnes potatoes produced for Heilongjiang Keshan (seed, no storage, no transport) whereas the greenhouse gas emission calculations in the provincial study showed 93 kg CO_2-eq/ tonnes potatoes produced (Hulan, seed, compare results of Table 4.4 with those of Table 4.5). This difference is mainly due to differences in fertilizer related kg CO_2-eq, compare Table 4.2 and Table 4.3), but also to a slightly lower yield in the provincial study compared to the national study (45 tons/ha compared to 52 tons/ha, respectively). In addition, irrigation applied is higher in the provincial study. These higher demands for inputs result in increased CO_2-eq production per tonnes produced potatoes.
Transport costs are low for ware potatoes, both in the national as in the provincial study as the produce is mainly sold locally. For seed, transport costs can increase considerable depending on the final market, for instance Fujian. That variation in transport costs of deliverable seed potatoes is not included in the study.

4.5 Discussion and Conclusions

The average potato yield in the top 10 provinces or autonomous regions of China ranged from 8 to approximately 17 ton/ha in 2006 (Table 4.1). Yields provided by the contact persons for different provinces / autonomous regions were higher than in 2006 and higher than the countries average up to 2013 (Figure 4.1A). In addition, the attainable yield was higher than the practiced yields on the selected locations and farms. From this, it can be concluded that the average countries yields are poor, that better yields are produced on specialised farms and that these yields can be improved by proper support on cultivation practices as attainable yields are higher than the practiced yields.

The carbon foot print of the different potato production systems in the national study showed a smaller CO_2 load for the production of potatoes during the winter period as for the summer period, except for Keshan. Compared to winter crops in other areas of the world, for instance India, the CO_2-eq load of Fujian is low. Potato production in India as a winter crop ranges from 282 to 374 kg CO_2-eq/tonnes potatoes produced, storage not included (Pronk *et al.* 2014). The largest loads in the Indian winter crop production systems are seed transport and irrigation. Both are very low in Fujian Province, where fertilizer related contributes the most. According to the model calculations, irrigation need in Fujian is low, only 100 mm as precipitation during the growing period covers almost all crop demand. The low CO_2-eq load of the production of potatoes in Heilongjiang Keshan of the national study compared to the provincial study indicates that more inputs are used by specialized farms and yields may not always be as high as in the national study. Further in depth interviews with farmers may broaden the view on inputs, yields and identify targets to improve production.

In conclusion it can be stated that:

- The results of this study are for specialized potato producing farms. It may well be possible that on non-specialised farms the CO_2-eq per tonnes potatoes is larger than the finding of this study.
- Model calculations on attainable yield show room for improvement of production.
- Irrigation needs to be investigated as this was identified as a major production limiting component and data provided was poor.
- The Carbon footprints reported are low compared to other Asian production regions (India) as storage energy use is low.
- Transport of yield to the final destination or transport of potato seed for planting can contribute considerable to the CO_2-eq load.
- Improvements on fertilizer use may reduce costs. This needs to be investigated.

5. Impressions on potato storage in Heilongjiang province

Romke Wustman, Wageningen Plant Research

5.1 Abstract

Total Heilongjiang potato production amounts to 8.3 million tonnes per year. Accurate statistics on the storage capacity of Heilongjiang are lacking. However, this capacity should be over 7 M tons if more than 80% of the produce is stored. We estimate that 5 - 10% of the Heilongjiang annual potato production is stored in modern stores with air ventilation and climate control to keep the potato quality at the required level. This figure could be underestimated knowing the fast increase in starch and flakes factories in the province. These factories have own modern stores. A large part of the Heilongjiang potato produce is stored in traditional stores at town and city levels, may be up to 80% of the Heilongjiang produce. The traditional stores lack ventilation and air circulation systems and rely upon cool air within the stores.

5.2 Introduction

Harvested potatoes have to be stored in order to be seeded, traded, processed and/or consumed later on. Storage time could be as long as 12 months up to the next harvest, depending on the intended use of the harvested potatoes and rate of availability of new produce. Storage conditions have a major effect on the quality of the potatoes that are taken out of stores. For instance, potatoes for French fries production should be stored in cool and well ventilated stores, but storage temperature should not be below 7˚C to prevent break down of starch into sugars. Seed potatoes can be stored a bit lower temperatures: 3-4˚C.
Sprouting of tubers during storage should be inhibited. Different methods have been developed to slow down or inhibit sprouting. These systems generally require a ventilation system in the store.
As all major potato producing regions, Heilongjiang has to have sufficient potato storage capacity. Total annual potato production in Heilongjiang province is about 8.3 million tons grown on about 320,000 ha. This is an average of about 25 tons per ha. If we assume that 80% of the potato produce in Heilongjiang is stored for more than 1 month, the province requires storage capacity for almost 7 M tonnes of potato. Knowing the cold winters in Heilongjiang, the stores have to be constructed in a way that they can withstand outside temperatures of – 40˚C (see Figure 4.5).
The prevailing potato storage systems in Heilongjiang province are farmers' stores. In chapter 5.3 some details and images on farmers' stores are presented. A limited share of the total potato production in Heilongjiang is stored in advanced potato storage systems. We estimate this share about 5 to 10%, but we did not have accurate data. A major part of these systems is operated by the potato processing company McCain in Harbin. McCain's storage capacity is about 110,000 tons in Heilongjiang and will be doubled in the next few years. In chapter 5.4 some details and images on advanced potato stores operated by McCain are presented. Besides McCain stores, there are several starch and flakes factories in Heilongjiang which have stores with climate and air ventilation control.

5.3 Traditional potato stores

In Heilongjiang, farmers use one of two types of traditional stores for potato storage:

- Tunnel store;
- Pit store.

Both types accommodate all potatoes stored in Heilongjiang province from August thru to April; 8 months of storage. Farmers are aware of the required product temperature during the storage period. Temperatures are recorded and ventilation shafts consisting of chimneys on top and horizontal ducts in between storage chambers allow air movement through each storage chamber. Sprout inhibiting compounds are not applied as product temperature can be maintained at 3-4°C.

Figure 5.1 *Front view of tunnel stores (left), tunnel store (right).*

The dimensions of a chamber in the visited tunnel store were about 3 m * 3 m * 30 m; accommodating about 150 tons of potato per storage chamber.

Figure 5.2 *Horizontal ventilation ducts in a tunnel store (left), top view of a pit store (middle) and top an opening of pit store for loading and unloading (right).*

The pit store shown in Figure 5.3 in Xing Ping city below was visited in September 2013. This Oval shaped pit could hold about 100 tonnes of potato.

Figure 5.3 *Potato pit store in Ping Xing city.*

5.4 Advanced potato storage systems

About 5 to 10% of the potato production volume of Heilongjiang is stored in advanced storage facilities with sufficient air ventilation and climate control to keep the quality of the potatoes at the required level. This figure could be underestimated, but accurate data could not be obtained yet. A major part of these systems is operated by McCain in Harbin. McCain operates modern storage facilities for its processing plant near Harbin. McCain's near future raw material requirement is about 250,000 tons per year, which is the equivalent of 3% of the provincial annual production. Currently, they store over 110.000 tonnes. The ventilation capacity (m^3 air.m^{-3} potato.$hour^{-1}$) is, reportedly, similar to West European ventilation rates; 100 $m^3.m^{-3}.hour^{-1}$. Figure 5.4 and 5.5, show impressions of McCain storage facilities in Harbin.

Figure 5.4 *The McCain storage facility in Harbin (April 2014).*

Figure 5.5 *Inside the McCain storage facility (April 2014).*

5.5 Discussion & Conclusion

Total Heilongjiang potato production amounts to 8.3 million tons per year. Accurate statistics on the storage capacity of Heilongjiang is lacking. However, this capacity should be over 7 M tonnes if more than 80% of the produce is stored.
We estimate that 5 - 10% of the Heilongjiang annual potato production is stored in modern stores with air ventilation and climate control to keep the potato quality at the required level. This figure could be underestimated knowing the fast increase in starch and flakes factories in the province. These factories have own modern stores. A large part (ca. 80%) of the potatoes in Heilongjiang is stored in traditional stores at town and city levels. In coming years, traditional stores will be replaced by upgraded and advanced stores. We recommend to study in more detail the storage capacity of Heilongjiang to be able to estimate the requirements for sustainable production and storage of potatoes in this province.

6. Aphid control in seed potato production based on monitoring data

Anton Haverkort, Wageningen Plant Research

6.1 Abstract

The HAAS potato team carried out aphid trapping at their field trials from 2011 through 2014. The figures show 4 years of aphid trapping. The 2011 data are from the suction trap, the 2012, 2013 and 2014 are from yellow trap counting’s. Two peaks in aphid populations were observed in course of the seasons: end of July/early August and in late September – early October. *Myzus persicae* peeks end of July and/or early August are likely to contribute the most to the spread of viruses in seed potatoes.

6.2 Observations, suggested additions and interpretations

- In each growing season there are two peaks in the movement of aphids (Figure 6.1).
- An early peak in the population in the first week of August and a second one late September early October (Figure 6.1).
- The early peak in the cropping season is most important for virus transmission as plants then still are young and infection from leaves to tubers is effective, both in a persistent and non-persistent manner.
- The second peak is of no significance as plants then are mature and show ‘maturity resistance’ or ‘senescence resistance’ to virus transmission by aphids. Aphids may suck and transmit viruses but the plant does not transport the virus effectively to the tubers anymore.
- There is no clear distinction (no trend) whether the first or the second wave of aphids is more dominant. Therefore a longer period of observations is needed (more years).
- The aphid counts show that a certain species dominates and that *Myzus persicae* is the second in importance. Yet it is known that when it comes to efficacy of virus transmission *M. persicae* (green peach aphid) is 10 times more effective than any other aphid, some of them being hardly effective at all.
- The low levels of detection during the major part of the growing season from mid-August to mid-September, the absence of aphids, may be associated with the incidence of rain. This needs to be investigated, further explored.

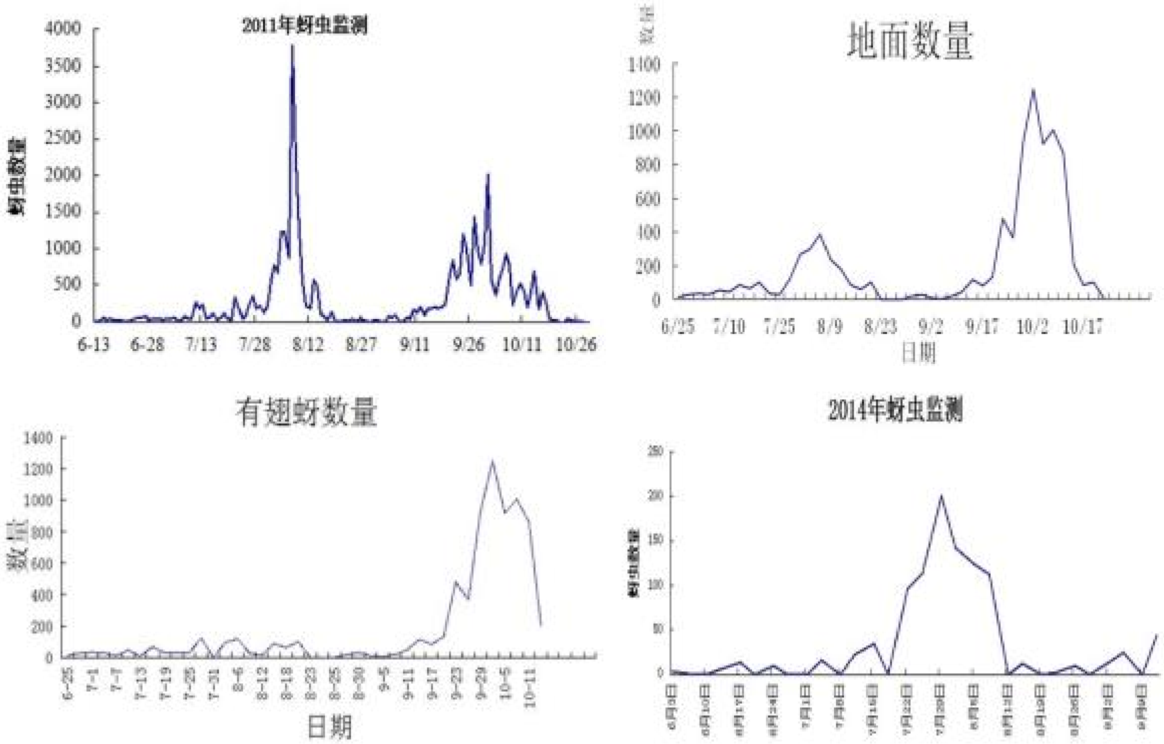


Figure 6.1 *Suction trap countigs of total number of aphids in 2011(left above) and yellow trap countings of total number of aphids in 2012 (right above), 2013 (left below) and 2014 (right below).*

6.3 Recommendations for seed production

From these observations the following recommendations for seed production can be derived:

- In future (but also in the years 2011-2014) plot total number of aphids and also the single number of *Myzus persicae* to detect if the two peaks co-inside or of those of *M. persicae* deviates. If it does, the population development of *M. persicae* should be leading when it comes to drawing consequences for aphid control.
- In order to arrive at total aphid pressure the cumulative aphid count of *M. persicae* must be plotted beside the daily (or weekly) count.
- Also plot rainfall per day against aphid counts during the two population peaks and apply a regression: y= aphid number, x=mm rainfall per day. From the correlation coefficient (R^2) it can be derived if rain fall amount is a good indicator for aphid control.
- Effective aphid control seems possible when a first insecticide spray is applied during the last few days of July and a second one a week thereafter in the first week of August. It is not necessary to control the aphids at the second peak.

Suggestions for next trials.

The following experiments can be carried out:

1. Repeat the harvest dates trial that was carried out in 2014. This will give a good indication of the yielding ability of the potato crop around July 25, August 25 and September 25. Virus frequency observation through ELISA will give a good indication of progress of virus incidence when the crop is harvested later in the season. Moreover the experiments should also give a good indication of the crop value at each harvest date. Therefore the following observations need the be carried out:

- Total yield in grams/m^2 or tons/ha
- Fraction of seed sized tubers (and its price per kg), also price differentiation if cleaner seed tubers with less virus represent a higher value

- Fraction of consumer larger sized tubers(and its price per kg)
- Total crop value.

Note: in The Netherlands seed potatoes are harvested when the crop is still mid-season. This has the following advantages:

- less virus is transmitted by aphids so farmers get a higher price
- less tubers grow too large so ha higher proportion of the crop is seed sized for which farmers get a higher price.
- These two advantages by far outweigh the advantage of letting the crop grow until maturity because then most tubers have grown too large to sell as seed and also many seed lots will be sold at lower classes due to increased virus incidence.

2. Assessment of efficacy of aphid control. It is suggested to set up a trial with two treatments in 3 or 4 replicates, planting mini-tubers that are 100 % devoid of virus (virus free).

- Plant mini-tubers in a field with aphid control by two sprays late July and early August as suggested above,
- Similarly a plot with mini-tubers in which no aphid control takes place.

Two harvests are carried out: 1) mid-August and 2) late September and the PVY virus incidence (ELISA) is determined. It may be decided to plant the resulting G1 in 2016 season again to observe virus expression in the field.

7. GAP experiments in 2015: Minzhu and Keshan

Shuming Wan & Dianqiu Lyu, HAAS, with support of Geert Kessel & Corné Kempenaar, Wageningen Plant Research and Aeres students Henk Mantingh & Maarten Tenkink.

7.1 Abstract

In 2015, experimental fields were laid out on two locations in Heilongjiang province. Innovative Dutch technologies and know-how on potato production were studied under Chinese cropping conditions. The results show that there is much room for improvement of cropping methods and increase of yields. A basis for further cooperation on experimental fields was laid.

7.2 Introduction

GAP in potato are related to soil tillage, seed quality and treatment, planting methods, fertilizer use, irrigation, weed control and disease and pest management, and harvest methods. In 2015, the PPP set up field experiments to test Dutch technologies on experimental sites in Heilongjiang province. WPR staff provided guidelines for the experiments, while private partners provided products and services. The results were monitored and reported.

7.3 Materials and methods

7.3.1 Experiments in Minzhu on Good Agricultural Practises compared to Common Practices

The soil type of the Minzhu demonstration flied is a black clay, which has been used for planting potato for 4 years without rotation. Two varieties of mini-tuber (Kexin 13 and Zhongshu 5) were used for the demonstration. A series of treatments were set to show the different performance of potato between good agriculture practice (GAP) and common practice (CP). The potatoes of the GAP field were planted on 22 May 2015 and the potatoes of the CP field were planted on 15 May 2015 which was 7 days earlier than GAP.

Figure 7.1 *Some impressions during seedbed preparation and planting.*

Experimental design:
Twelve treatments were set as shown in Table 7.1. Each row was 0.90 m wide, and 75-100 m long. Table 7.2 shows the differences in crop management for GAP and CP.

Table 7.1 *Length of treatment for the two varieties and the number of rows.*

		Irrigation		Irrigation		
Treatments		Kexin 13	Zhongshu 5	Kexin 13	Zhongshu 5	Rows
1	DSS HAAS	100 m	100 m	75 m	75 m	10
2	DSS WUR	100 m	100 m	75 m	75 m	10
3	CP	100 m	100 m	75 m	75 m	12
4	Seed Cut	200 m	--	150 m	--	6
5	Fertilizer + Amistar	100 m	100 m	75 m	75 m	6
6	CP + Amistar	100 m	100 m	75 m	75 m	2
7	CP	100 m	100 m	75 m	75 m	4
8	Amistar	100 m	100 m	75 m	75 m	4
9	CP	100 m	100 m	75 m	75 m	2
10	Seedbed preparation	100 m	100 m	75 m	75 m	6
11	CP	100 m	100 m	75 m	75 m	24
12	GAP	100 m	100 m	75 m	75 m	24

Table 7.2 *Crop management of Good Agricultural Practices (GAP) and Common Practices (CP) in the demonstration field.*

	GAP		CP	
Field	Subsoiler (0.5 m deep) & Power harrow		Plough (0.335 m deep)	
Rotation	--		--	
Variety	Kexin 13; Zhongshu 5		Kexin 13; Zhongshu 5	
Seed preparation	Amistar		Amistar	
Planting	Machine		Manual	
Ridging	First time at planting, 1 time after planting		3 times after planting	
Fertilizer application	N:	230 kg/ha	N:	180 kg/ha
	P_2O_5:	130 kg/ha	P_2O_5:	120 kg/ha
	K_2O:	235 kg/ha	K_2O:	150 kg/ha
Weed control	Acetochlor:	1.5 L/ha	Acetochlor:	1.5 L/ha
	Pendimethalin:	3.0 L/ha	Pendimethalin:	3.0 L/ha
Disease control	According to DSS WUR		According to DSS HAAS	
Irrigation	According to soil sensor		--	
Harvest	Manual		Manual	

7.3.2 Demonstration in Minzhu on late blight control

The demonstration field for late blight control was located at Minzhu. The field was chosen to be good isolated from the GAP demonstration field. The aim of this demonstration was to compare the performance of the DSS of WUR and the DSS of HAAS on late blight control and potato yields.

Table 7.3 *Design of the demonstration on late blight control.*

Treatment	Variety	
	Zhongshu 5	Kexin 13
Common Practice (No spray)	CK1	CK2
DSS of HAAS	ZM	KM
DSS of WUR	ZW	KW

Table 7.4 *Fungicides used in the demonstration on late blight control*

Fungicide	% active component	Dosage / 667 m^2	Manufacturer
Cymoxanil + mancozeb	72%	100 g	DU PONT
Fluazinam	50%	25 mL	ISK
Mancozeb	75%	100 g	Syngenta
Propamocarb-HCl + fluopicolide	68.75%	75 mL	BAYER
Mandipropamid	25%	50 mL	Syngenta

7.3.3 Demonstration in Keshan on fertilizer recommendations

This demonstration was done to evaluate the fertilizer recommendations of the potato production in the Netherlands on nitrogen (N), phosphate (P_2O_5) and potassium (K_2O). A soil sample from the demonstration field in Keshan and sent to Eurofins Agro (http://eurofins-agro.com) in the Netherlands for analysis and recommendations on fertilizer use for potato production. The varieties used in the demonstration were Eugene 885 and Favorite. The recommended fertilizer application rates are shown in Table 7.5 and Table 7.2.

Table 7.5 *Recommended fertilizer application rates based on the soil analysis of Eurofins Agro.*

Variety	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Favorite	215	136	235
Eugene 885	196	112	235
	194	135	235

7.4 Results

7.4.1 Experiments in Minzhu on Good Agricultural Practises compared to Common Practices

The potatoes in the GAP treatment sprouted 17 days after planting. For Kexin 13, the treatment using Amistar for seed protection gain the highest emergence rate (Table 7.6), and for Zhongshu 5 is DSS HAAS. The Amistar treatment of Zhongshu 5 also had a good performance on the emergence. So the using of Amistar is helpful to improve the emergence. The GAP did not have a good performance on emergence, which might because the seed quality and the late planting date.

Table 7.6 *Emergence dates*

	Kexin 13 (%)	Zhongshu 5 (%)
CP	84.62^{a}	76.92^{b}
GAP	66.67^{c}	71.79^{b}
Subsoiler	84.62^{ab}	74.35^{b}
Amistar	97.44^{a}	82.05^{ab}
Fertilizer + Amistar	82.05^{abc}	74.35^{b}
Seed cut	71.79^{bc}	71.79^{b}
DSS WUR	76.92^{bc}	74.35^{b}
DSS HAAS	82.05^{abc}	94.87^{a}

*Note: a, b, c were at 5% significant level.

The yield of different treatments varied from 13.6 t/ha to 43.3 t/ha (Table 7.7). Kexing 13 received the highest yield on treatment of seed cut, while the Zhongshu 5 had a best performance on DSS WUR. For both Kexin 13 and Zhongshu 5, the treatment using subsoiler and power harrow also achieved relative good yields. Besides this, the recommendation use of fertilizer from WUR students could also improve the yield of Kexin 13 compared with CP.

The integrated GAP did not show obvious advantage than CP and other treatments on yield. The reasons could be:

- GAP was planted 7 days later than CP for the machine prepare and weather;
- The seed size and quality for GAP were poorer than CP, DSS HAAS and DSS WUR; the weight of the mini-tubers for GAP was around 10 g to 15 g, but for other treatments was around 30 g to 50 g;
- The ridging machine did not cover enough soil, and the ridging times for GAP was 1 time less than CP.

Table 7.7 *Yield of the demonstration field*

Treatments	Kexin 13 （kg / ha）	ZS 5 （kg / ha）	Rows
CP	16946^{bc}	34189^{bc}	44
GAP	13676^{c}	26878^{d}	24
Subsoiler	20249^{bc}	32900^{c}	6
Amistar	16213^{c}	23164^{e}	4
Fertilizer + Amistar	25219^{b}	21438^{e}	6
Seed cut	35196^{a}	--	6
DSS WUR	25167^{b}	43329^{a}	10
DSS HAAS	20627^{bc}	36166^{b}	12

*Note: a, b, c were at 5% significant level.

7.4.2 Demonstration in Minzhu on late blight control

The first spray was conducted on July 2, according to DSS-HAAS. The total spry times for DSS-HAAS was 5, which is 1 time more than WUR-DSS (Table 7.8).

Table 7.8 *Pesticide application dates*

DSS-HAAS		DSS-WUR	
Fungicide	**Date**	**Fungicide**	**Date**
Mancozeb	7.2		
Propamocarb-HCl + fluopicolide + Mancozeb	7.28	Propamocarb-HCl + fluopicolide + Mancozeb	7.28
Cymoxanil+mancozeb	8.5	Oxadixyl	8.5
Mandipropamid	8.25	Mandipropamid	8.25
Fluazinam	9.5	Fluazinam	9.5

For Zhongshu 5, the first infection of late blight was detected on August 13, and the infected plants were less than 5% (Figure 7.2, left). As Zhongshu 5 is an early variety, the plant went into stable stage after August 20. Therefore, the late blight did not exploded, and finally reached 5% under the two spray according the DSS system.
Kexin 13 is a resistant variety, the first infection was also on August 13 (Figure 7.2, right). CK 2 got 5% on August 17, which was 5 days earlier than the forecast. The infection of CK 2 exploded to 25% until September 2, meanwhile other treatments were infected around 5%-10%. According to the results, the DSS-HAAS and DSS-WUR both showed significant control on late blights infection compared with CK 1 and CK 2, but they did not have this significant between each other. However, 1 spray could be saved according the WUR system.

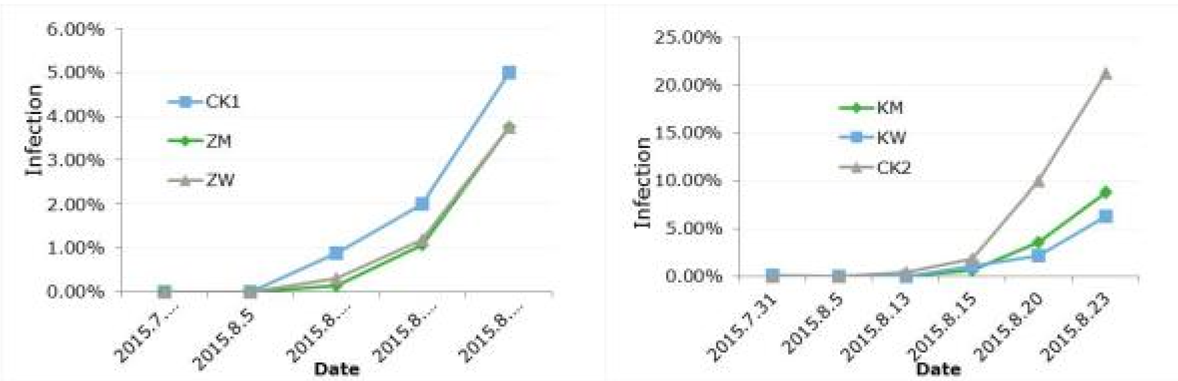


Figure 7.2 *Infection of Zhong 5 (left) and Infection of Kexin 13 (right).*

The ZW and KW achieved the highest yield for Zhongshu 5 and Kexing 13 (Table 7.9), which are spray according the DSS-WUR. The yield of ZW increased 33.94% and showed significant difference compared with CK 1. KM and KW also showed significant increase compare with CK 2 in 22.42% and 50.32%. Also, CK 2 showed the highest rot rate in 9.33%. The rot rate of Kexin 13 was higher than Zhongshu 5, which reflected the tuber of Kexin 13 was more sensitive to late blight.

Table 7.9 *Yield and rot rate of potato in various treatments*

Treatment	Yield (t/ha)	Increased compared with control (%)	Percent rot (%)	Significance level (%)	
				0.05	0.01
CK1	25.75	/	3.42	a	A
ZM	27.12	5.32%	2.01	ab	A
ZW	34.49	33.94%	1.06	b	B
CK2	12.58	/	9.33	c	C
KM	15.40	22.42%	4.81	d	D
KW	18.91	50.32%	4.03	e	E

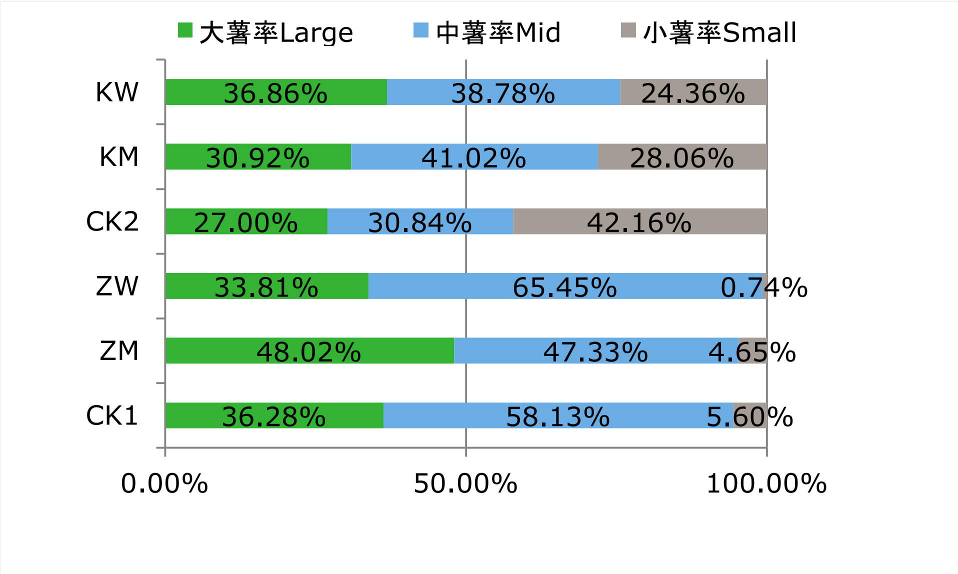


Figure 7.3 *Percentage of tubers in different size classes*

The tuber size of different treatments was also investigated during this field test (Figure 7.3). The late blight infection rate showed a good correlation with the small size rate. For Zhongshu 5, ZW showed the best performance on tuber size, meanwhile the KW was the best for Kexin 13. The test showed a significant difference on small tuber rate between different varieties, and small rate of Kexin 13 was much higher than Zhongshu 5.

7.4.3 Demonstration in Keshan on fertilizer recommendations

The potato production in Keshan was conducted by an agriculture company which ran successfully for many years. This company owns series of advanced machines for planting different kinds of crops. Adding the good management and advice from HAAS and WUR, the yield here was much higher than the average which other small farms could match. The yield in this base was list in the Table 7.10.

Table 7.10 *Potato yield of the demonstration in Keshan.*

Variety	Average yield (t/ha)
Eugene 885	37.5
Favorite	45.0

7.5 Conclusions and recommendations

The set up and implementation of joint experimental fields in China yielded the following conclusions and recommendations:

1. GAP experimental fields can provide valuable information on performance of innovative methods in potato project when set up with good preparation and monitoring during the season.
2. Innovation of soil tillage and use of good quality seeds and planting methods are crucial for high potato yields in Heilongjiang province because of specific soil conditions.
3. Subsoiler and power harrow showed good effect on seed bed.
4. Due to differences in seed quality in different treatments, we cannot conclude on effects of GAP treatments on yield.
5. Crop protection uses according to GAP improved emergence of the potatoes and gave, in combination with WUR DSS better disease control of late blight.

8. GAP Experiments in 2016: Keshan, Wangkui, Minzhu and Zhangjiakou

Zhenyu Liu, Yong Li & Dianqiu Lyu, HAAS, with support of Geert Kessel & Corné Kempenaar, Wageningen Plant Research and Aeres students Coen van den Bighelaar, Jasper Blok, Leon Haanstra & Dirk Luyck.

8.1 Abstract

In 2016, two experimental fields were laid out on two locations in Heilongjiang province (Keshan and Wangkui). Two more fields to be used in demonstrations at the 2nd Sino-Dutch potato workshop, were laid out in Zhangjiakou on Snow Valley farm and on Minzhu farm of HAAS. Innovative Dutch technologies and know-how on potato production were studied and/or demonstrated on the fields under Chinese cropping conditions.

The results show that there is much room for improvement of cropping methods and increase of yields. A basis for further cooperation on experimental fields was laid.

8.2 Introduction

A basis for joint research on experimental sites in China was laid in 2015. Building on the experiences, improved experimental designs, protocols and monitoring programmes were implemented in 2016. Intensive experimentation was done on two locations in Heilongjiang province: Keshan and Wangkui, on practical farms. On the other locations, specific objects were laid out on plots to be demonstrated in dissemination and communication events.

The protocol of the experiments is show in the table below, reflecting all aspects of potato crop management. A new element in 2016 was the use of a GIS platform.

Table 8.1 *Objects overview in experiments 2016, Good Agricultural Practices (GAP) and Common Practices (CP).*

Topic	GAP	CP
Soil tillage	Plough + Rotation	Plough + Subsoiler
Seed quality	Uncut seeds	Cut seeds
Seed density	20 or 30 stems/m^2	6plants/m2
Seed treatment	Sprayed on tuber and soil	Sprayed on tuber
Fertiliser use	Recommendation by soil testing	By experience
Planting	Small ridge with disk	Large ridge with plough
Ridging	Ridging before emergence	Ridging after emergence
Weed control	Same herbicides	Same herbicides
Disease and pest control	According to DSS WUR	By experience
Irrigation	Weather station + soil sensor	By experience
Harvest method	Haulm killing herbicide + mechanical harvesting	Mechanical harvest
GIS crop management planform	Yes	No

8.3 Materials and methods

8.3.1 Experiments in Keshan and Wangkui

Two demonstrations were set up, one in Keshan and one in Wangkui for seed potatoes and ware potatoes in 2016. The soil types of the demonstration fields of Keshan and Wangkui is a black clay. In Keshan the previous crop was China-Hemp, and before that wheat was grown. In Wangkui maize has been cultivated for the last 4 years. Two varieties were planted, Eugene in Keshan and Atlantic in Wangkui. A series of treatments were set to show the different performance between Good Agriculture Practices (GAP) and Common Practices (CP) (see also Table 8.1). The potatoes in Keshan were planted on 5 May 2016 and the potatoes in Wangkui were planted on 1 May 2016.

Figure 8.1 *An example of the seed bed preparation (upper left), the difference between ridges in GAP and CP (upper right), Ridging of GAP field (middle left), the differences between plant growth (middle right), the plant growth of tuber expansion stage (bottom left) and the differences in yield between GAP and CP (bottom right).*

Experiment layout

At both locations, three treatments (GAP-uncut, GAP-cut and CP) were set as shown in Table 8.2. The row distance (from ridge to ridge) in Keshan was 0.90 m and 0.80 m in Wangkui (Table 8.2). Table 8.3 shows the differences of crop management between GAP and CP.

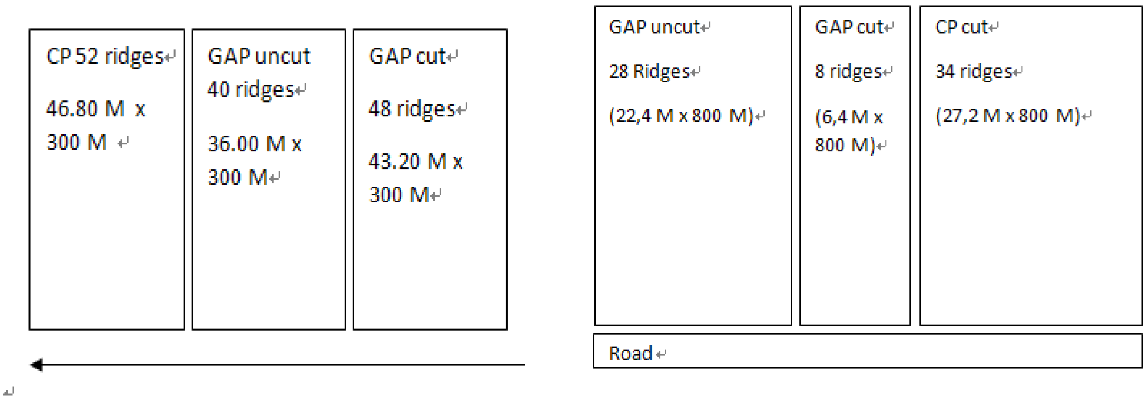


Figure 8.2 *Field map in Keshan (left) and Wangkui (right).*

The size of Keshan base is 3.78 ha, GAP-uncut is 1.08 ha, GAP-cut is 1.296 ha and CP is 1.404 ha. The size of Wangkui base is 4.48 ha, GAP-uncut is 1.792 ha, GAP-cut is 0.512 ha and CP is 2.176 ha. Seed density in GAP-cut and GAP-uncut was the same.

Table 8.2 *Different treatments with varied factors.*

	Keshan			Wangkui		
Treatments	**GAP-uncut**	**GAP-cut**	**CP**	**GAP-uncut**	**GAP-cut**	**CP**
Cultivation model	WUR	WUR	HAAS	WUR	WUR	HAAS
Seed treatment	Uncut	Cut	Cut	Uncut	Cut	Cut
Ridge wide (m)	0.90	0.90	0.90	0.80	0.80	0.80
Treatment length (m)	300	300	300	800	800	800
Number of rows	40	48	52	28	8	34
Seed density	16	16	17	20	20	16

Table 8.3 *Crop management on demonstration field.*

	GAP	CP
Soil Tillage	Plough + Power rotation	Plough +Harrow
Seed quality	Uncut and cut seeds	Cut seeds
Seed density	20 or 30 stems/m^2	6 plants/m^2
Seed treatment	Sprayed on tuber with Celeste Sprayed on soil with Cruiser and Amistar	Sprayed on tuber with talcum or Celeste
Fertilizer use	Recommendation by soil testing	By experience
Planting	Small ridge with disk	Large ridge with plough
Ridging	Ridging before emergence	Ridging after emergence
Weed control	Same herbicides with half dosage	Same herbicides
Disease control	According to DSS WUR	By experience
Irrigation	According to soil sensor	By experience
Harvest	Mechanical Haulm killing and harvesting	Mechanical Haulm killing and harvesting
GIS	Yes	No

Late blight and Early blight control

The pesticide plan of GAP for late blight and early blight control was recommended by WUR DSS, and the plan of CP was used by experiences of HAAS experts.

Table 8.4 *Fungicides applied in the demonstration in Keshan for late blight control. Some insecticides are applied also.*

		GAP				CP				
	Time	Fungicide	Dose	Insecticide	Dose	Time	Fungicide	Dose	Insecticide	Dose
1	6.26	Revus	0.6 L/ha	Kung fu	0.38 L/ha	7.03	Dithane	2.3 kg/ha	Kung fu	0.38 L/ha
2	7.03	Revus	0.6 L/ha	Kung fu	0.38 L/ha	7.10	Dithane	2.3 kg/ha	Deltamethrin	0.38 L/ha
3	7.12	Revus	0.6 L/ha	Kung fu	0.38 L/ha	7.21	Dithane	2.3 kg/ha	Kung fu	0.38 L/ha
4	7.20	Infinito	1.6 L/ha	Kung fu	0.38 L/ha	7.30	Revus	0.6 L/ha	Deltamethrin	0.38 L/ha
5	8.08	Infinito	1.6 L/ha	Kung fu	0.38 L/ha	8.10	Cabrio	150 g/ha	Kung fu	0.38 L/ha
6	8.10	Infinito	1.6 L/ha	Kung fu	0.38 L/ha	8.15	None	None	Foggo+ Dimethoate	120 g/ha + 0.45 L/ha
7	8.26	Shirlan	0.4 L/ha	Kung fu + Foggo	0.38 L/ha + 120 g/ha	8.26	None	None	Dimethoate + Deltamethrin	0.6 L/ha + 0.45 L/ha

Table 8.5 *Fungicides applied in the demonstration in Wangkui for late blight control.*

		GAP		CP	
	Time	Fungicide	Dose	Fungicide (active ingredient)	Dose
1	6.28	Revus	0.6 L/ha	Curzate	1.8 kg/ha
2	7.04	Infinito	1.6 L/ha	Infinito	1.5 L/ha
3	7.12	Infinito	1.6 L/ha	Zineb + (Fluopicolide + propamocarb hydrochloride)	0.5 kg/ha + 1.0 L/ha
4	7.23	Infinito	1.6 L/ha	Prochloraz + (Dimethomorph)	0.5 L/ha + 0.5 L/ha
5	8.09	Infinito	1.6 L/ha	(Dimethomorph)	1.4 L/ha

Table 8.6 *Fungicides applied in the demonstrations for early blight control.*

	Keshan					Wangkui		
	GAP		CP			GAP		CP
Time	Fungicide	Dose	Time			Fungicide	Dose	
27th week (7.40-7.80)	Amistar Top	1.65 L/ha	7.30	The high	0.6 L/ha	Amistar Top	1.65 L/ha	None
29th week (7.18-7.22)	Amistar Opti	2.70 L/ha	8.10	The high	0.6 L/ha	Amistar Opti	2.70 L/ha	None
31st week (8.10-8.50)	Amistar Top	1.65 L/ha				Amistar Top	1.65 L/ha	None
33rd week (8.15-8.19)	Amistar Opt	2.70 L/ha				Amistar Opt	2.70 L/ha	None

8.3.2 Recommendation fertilizer use

The soil samples were taken from the demonstration fields in Keshan and Wangkui and sent to Eurofins Agro in the Netherlands for analysis and to provide a recommendation on fertilizer use for GAP. The plan of fertilizer use for CP was recommended by experiences of HAAS experts. The varieties used in these demonstrations were Eugene and Atlantic. The recommended fertilizer application rates are shown in Table 8.7. Fertilizers were applied during planting

Table 8.7 *Recommended fertilizer application rates for the demonstrations in Keshan and Wangkui based on soils samples analysed by Eurofins Agro (GAP treatment) and expert knowledge of HAAS (CP treatment).*

Location	Treatment	Variety	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Keshan	GAP	Eugene	208	112	210
	CP	Eugene	168	140	215
Wangkui	GAP	Atlantic	210	92	203
	CP	Atlantic	145	104	188

8.4 Results

8.4.1 Experiments in Keshan and Wangkui

The potatoes in the GAP treatment sprouted 25-30 days after planting. In Keshan, the treatment GAP-uncut had the most stems, 20/m^2 which was an increase of 73% compared to the stem density of CP with the same plant density (Table 8.8). The demonstration showed that using uncut seed is very helpful to increase the number of main stems and thus to get more seed potatoes. In Wangkui, the treatment GAP-cut also had a good performance on main stems, 16/ m^2, which was an increase of 12% compared to the stem density of CP. Differences might be due to the seed density of GAP-uncut in Wangkui which was 0.20 m and 0.16 m and which was smaller than in GAP.

Table 8.8 *Number of main stems (#/m^2) in Keshan for variety Eugene and in Wangkui for variety Atlantic.*

Treatment	Keshan, Eugene	Wangkui, Atlantic
GAP-uncut	20	16
GAP-cut	13	9
CP	12	14

The yield of different treatments varied from 45 t/ha to 53 t/ha (Table 8.10). In Keshan, the treatment GAP-uncut had the highest yield, 53 t/ha. This yield was 12.5% higher than the yield in the treatment CP. The yield of the treatment GAP-cut was 51 ton/ha which was 7.42% higher than the yield of treatment on CP. Treatment GAP-uncut had obvious advantages of the yield in the level of less than 200 g, while GAP-cup had a best yield in the level of more than 200 g (Figure 8.3, left); For seed potato production, the rate of uncut seed potatoes which can be used to plant next year in GAP-uncut is 2 times higher than CP and GAP-cut (Figure 8.4).
For Wangkui base, GAP-uncut also received the highest yield at 51 ton/ha, up 13.86% on CP, but the yield of CAP-cut is 44 ton/ha, off 2.80% on CP. GAP-uncut also had a good performance on yield in the level of less than 200 g, while GAP-cut had a good yield in the level of more than 200 g (Figure 8.3, right).

There were significant differences in GAP-uncut, GAP-cut and CP of Keshan and Wangkui bases on 50-100 g level, and the yield of GAP-uncut were significant differences compared with GAP-cut and CP on the level of more than 200 g in Keshan base (Table 8.9).
Note: Potatoes were taken from two ridges long 5 m, wide 0.9 m in Keshan and 0.8 m in Wangkui, to measure yield. The area of plots is about 9 m^2 in Keshan and 8 m^2 in Wangkui, and 3 plots per treatment as GAP-uncut，GAP-cut and CP are taken. The yield of each plot is turned to the yield per hectare.

Table 8.9 *Yield ton/ha) of different size classes of demonstration fields.*

Keshan, Eugene				Wangkui, Atlantic			
Class	GAP-uncut	GAP-cut	CP	Class	GAP-uncut	GAP-cut	CP
<50g	3.70^a	1.33^a	0.91^a				
50-100g	9.47^a	4.01^b	4.31^b	<100g	11.25^a	6.79^a	8.67^a
100-150g	11.14^a	7.59^a	9.37^a	100-200g	20.96^a	16.38^b	17.92^b
150-200g	14.32^a	9.52^a	9.11^a				
>200g	14.41^b	28.61^a	23.00^{ab}	>200g	18.27^a	21.15^a	18.67^a
Total	53.05^a	50.64^a	47.13^a	Total	50.48^a	44.31^a	45.25^a

Note: a, b were at 5% significant level.

Table 8.10 ***Table 8.10*** *Yield (ton/ha) of demonstration field in Keshan, variety Eugene and in Wangkui, variety Atlantic.*

	Keshan, Eugene	Wangkui, Atlantic
GAP-uncut	53.1	51.27
GAP-cut	50.7	43.77
CP	47.2	45.03

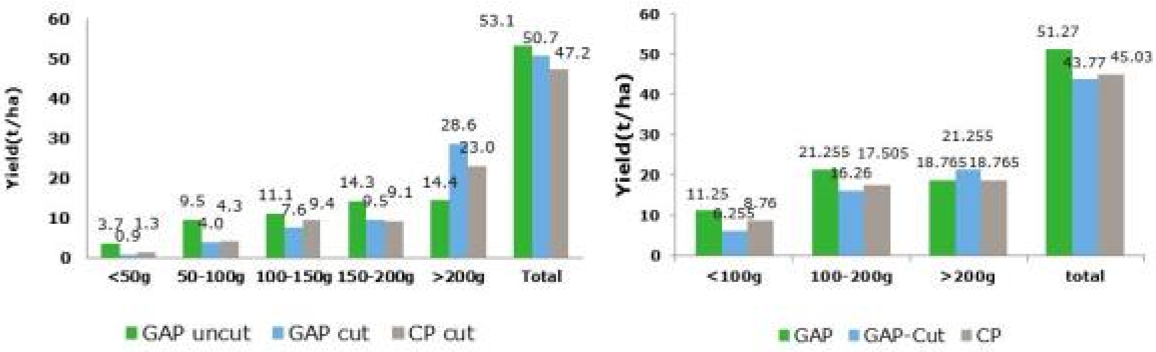


Figure 8.3 *Different levels of potato yield in Keshan (left) and in Wangkui (right)*

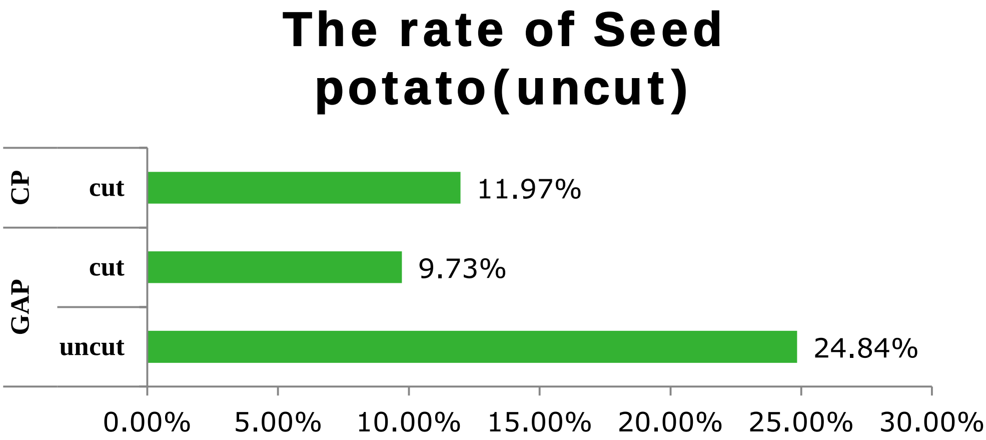


Figure 8.4 *The rate of seed potato (uncut).*

8.4.2 Disease and pest control

Late blight control

The first spray in the treatments GAP and CP were conducted on 26 June in Keshan and 28 June in Wangkui, according to DSS-WUR, and according to the advice of experts of HAAS. GAP and CP almost sprayed at the same time which was once every 7-10 days. In Keshan, 7 sprays were applied which was twice the times in Wangkui (Table 8.4 and Table 8.5).

The applications in Keshan had a good effect on the control of late blight in both treatments GAP and CP: no late blight was found in fields. The applications in Wangkui yielded slightly different results. After the first application of Revus one infected plant with Late blight was found. According to the DSS WUR a curative late blight fungicide was applied, Infinito (Table 8.5). No late blight was found after that in both treatments GAP and CP. There were little to no differences between the treatments GAP and CP to control late blight. The weather conditions may had an effect as there was an unusually long-term drought period during the growing season and subsequently low disease pressure of late blight.

Pest control

Insecticides were used to control aphids in the demonstration in Keshan for seed potato production to prevent virus transmission. In the treatment GAP the insecticide Kung fu was sprayed 7 times as a tank mix with the fungicide applications for late blight spraying control (Table 8.4). The control of aphids was very successful up to the 7^{th} application. After 8 August, many aphids were found on the back of leaves. This suggest that long-term single insecticide spraying may cause and stimulate resistance of aphids to insecticides.

Early blight control

GAP sprayed 4 times to control early blight, once every 2 weeks (Table 8.6), had good effect of early blight control, only found early blight control in Keshan base, but occurring rate of early blight is about 20% in CP fields of Wangkui, because no fungicides were used to control early blight in CP of Wangkui.

Table 8.11 *Disease survey in Keshan.*

Treatment		Number: 100 Black scurf	Common Scab	Wet rot	Dry rot	Weight (kg)	Level
GAP	Uncut	129	14	3	0	50	Seed
	Cut	94	23	0	0	50	Seed
CP	Cut	80	8	0	2	50	Seed

Other diseases and pest control

GAP used Celeste on tubers and Cruiser, Amistar on soil to control other soil-borne diseases and pests, CP only used Celeste or talcum on tubers. For Keshan base, the rate of black scurf and common scab in GAP is higher than CP (Table 8.11), while the rate of diseases for GAP in Wangkui is very low, that show good effect of disease control with the same treatment as Keshan (Table 8.14).

Table 8.12 *Disease survey in Wangkui.*

Treatment		Number: 100 Black scurf	Common Scab	Wet rot	Dry rot	Weight (kg)	Level
GAP	Uncut	0	0	0	0	50	Ware
	Cut	3	0	0	0	50	Ware
CP	Cut	71	0	4	18	50	Ware

Virus incidence PVY and PLRV

Potatoes from Keshan and Wangkui bases are tested for PVY and PLRV with 5 times repetition (Table 8.13). The incidence rate of ALL Potatoes from Keshan and Wangkui is 100% to have PVY. The rate of potatoes only in GAP-uncut and GAP-cut of Keshan base is 5.43% to have PLRV.

Table 8.13 *Detection of PVY and PLRV in demonstration field*

Incidence rate	Keshan, Eugene			Wangkui, Atlantic		
	GAP-uncut	GAP-cut	CP	GAP-uncut	GAP-cut	CP
PVY	100%	100%	100%	100%	100%	100%
PLRV	5.43%	5.43%	0%	0%	0%	0%

Cost and benefit analysis

For Keshan base, the cost of GAP-uncut is 190 RMB/mu higher than CP, and the profit of GAP-uncut is 584 RMB/mu more than CP (Table 8.14). GAP-uncut can get more money from the sale of seed

potatoes which are less than 150 g, while GAP-cut and CP can get more money from the sale of ware potatoes which are more than 200 g (Figure 8.5).
For Wangkui, the cost of GAP-uncut is 259 RMB/mu higher than CP, but the profit of GAP-uncut only is 64 RMB/mu more than CP (Table 8.14), because Chinese consumers prefer bigger ware potato with higher price than medium-size potato. Note: 1 mu = 667 m^2.

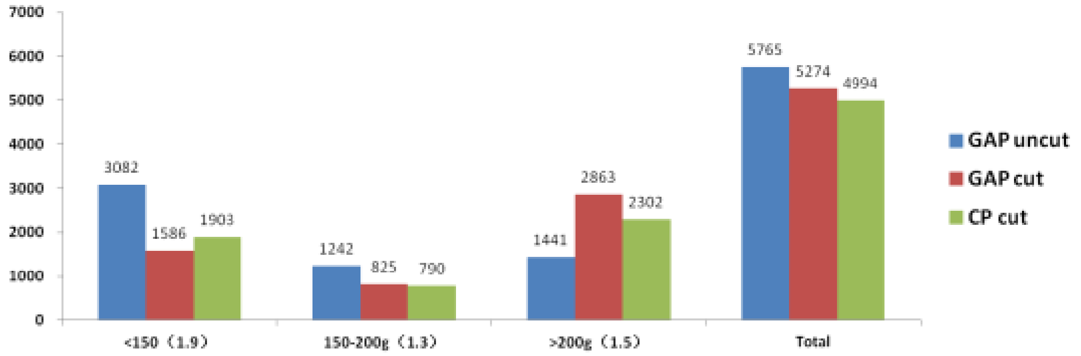


Figure 8.5 *The benefit analysis of Keshan.*

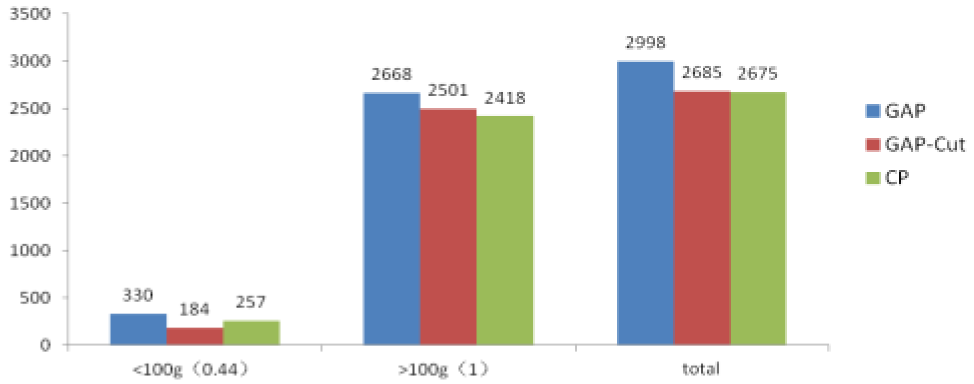


Figure 8.6 *The benefit analysis of Wangkui.*

Table 8.14 *Cost and benefit analysis of Keshan and Wangkui.*

		Keshan, Eugene			Wangkui, Atlantic		
Treatment		Costs	Sale	Profit	Costs	Sale	Profit
GAP	Uncut	2090	5765	3675	1239	2998	1795
	Cut	2090	5274	3184	980	2685	1705
CP	Cut	1900	4994	3094	980	2675	1695

8.4.3 Nutrient analysis

The potatoes from Keshan and Wangkui bases were tested for starch, protein, dry matter content, reducing sugars and vitamin C (Table 8.16). There were significant differences between GAP-cut and CP in Keshan on reducing sugars. Also, the dry matter content of the treatment GAP-uncut was significantly lower that the dry matter content of treatments GAP-cut and CP in Wangkui base, compare 25% with 28 and 29%.

Table 8.15 *Nutrition analysis in demonstration fields for treatments good agricultural practices (GAP) uncut, cut and conventional practices (CP) in Keshan and Wangkui*

	Keshan, Eugene			Wangkui, Atlantic		
Nutrient	**GAP-uncut**	**GAP-cut**	**CP**	**GAP-uncut**	**GAP-cut**	**CP**
Starch	13.49 [a]	12.38 [a]	12.81 [a]	16.29 [a]	18.70 [a]	19.68 [a]
Protein	2.29 [a]	2.15 [a]	2.14 [a]	2.71 [a]	2.35 [a]	2.20 [a]
Dry matter content (%)	21.95 [a]	21.43 [a]	22.79 [a]	25.05 [b]	28.26 [a]	29.20 [a]
Reducing sugars	0.10 [ab]	0.07 [b]	0.11 [a]	0.07 [a]	0.04 [a]	0.07 [a]
Vitamin C	238.23 [a]	240.50 [a]	232.20 [a]	224.30 [a]	213.43 [a]	214.70 [a]

Note: a, b were at 5% significant level.

8.5 Conclusions

The advantages of uncut seed potatoes:

- **Demonstration in Keshan:** Compare to GAP-cut, the seeds of GAP-uncut increased 38.46%, main stems increased 56%, yield raised 4.73%, the amounts of tuber improved 62.81%, the profit increased 15.42%, with the same planting density.

- **Demonstration in Wangkui:** Compare to GAP-cut, the seeds of GAP-uncut increased 72%, main stems increased 81.3%, yield raised 17.14%, the amounts of tuber improved 39.17%, the profit increased 3.17 %, with the same planting density.

The advantage of cultivation model:

✓ Different treatment of seed and soil
✓ Different method of planting
✓ Different fertilizer application
✓ Different method of ridging
✓ Different method of diseases and pests control

Demonstration in Keshan: Compare to CP, the seeds of GAP-cut increased 4%, main stems increased 38.89 %, yield raised 7.42 %, the amounts of tuber reduced 2.40%, the profit increased 2.91 %.

The comprehensive advantage: uncut seed potato + new cultivation model

- **Demonstration in Keshan:** Compare to CP, the seeds of GAP-uncut increased 44%, main stems increased 116.67%, yield raised 12.5%, the amounts of tuber improved 58.90%, the profit increased 18.78%.

- **Demonstration in Wangkui:** Compare to CP, the seeds of GAP-uncut increased 47.43%, main stems increased 12.5%, yield raised 13.86%, the amounts of tuber improved 14.39%, the profit increased 3.78%. Incidence of diseases and pests decreased significantly, and the rate of black scurf decreased 13.3%.

GAP-uncut can produce more small and medium, good and healthy potatoes than CP for seed potato production with the higher price in the market, but it’s poor to product bigger ware potatoes which has high price in China market. GAP can make good ridge body to break clods in black clay soil, and make plants have more sunshine and water easily than CP, but GAP need more qualified uncut seed and better machinery like power rotary cultivator, ridging machinery, harvester.

8.6 Problems

General problems:

- **Seed bed preparation:**
  Plough with general cultivator in autumn had better effect; Plough in spring needs power cultivator to mash soil clods to get good effect as plough in autumn.

- **Seed potato:**
  Qualified uncut potatoes which can be used to plant next year are only 24% of total yield in Keshan base. We need more time and labour to seek out qualified uncut potatoes, and increased the cost as the cost of cutting potatoes. Now the amount of uncut potatoes is very hard to meet all planting of potato.

- **Planting:**
  The driver can't make straight ridges in planting, because of tractor without GPS or low driving technique. It's easy to make potato out or on the side of ridge in ridging, haulm killing and harvesting, reduce the yield and quality of potato.

- **Disease control:**
  The rate of black scurf and common scab in GAP is higher than CP, but GAP had coating with Celeste, soil treatment with Cruiser and Amistar, CP only had coating with Talcum in Keshan. Wangkui base had good control effect of black scurf and common scab in the same treatment.

- **Machinery:**
  Farmers in China lack good machinery like power cultivator, power ridge machinery and combine harvester, so it's hard to solve the problems of black clay soil to get high yield and good quality of potato.

Problems in Keshan

- **Lodging:**
  The plants of GAP are stronger than CP in growing season, but plant lodging is two weeks early than CP, possibly because we use too much N in GAP to make plants grow too high.

Problems in Wangkui

- **Irrigation:**
  Drought stage of this year is longer, and caused the shortage of water in fields of Wangkui. Potato can't get enough water to grow by the lack of irrigation devices, and affecting the yield of potato, especially GAP-uncut.

Figure 8.7 *Some examples of problems: partial ridging (left) and lodging of plants (right)*

9. Evaluation of spraying techniques

Jean-Marie Michielsen, Wageningen Plant Research

9.1 Introduction

A mission was carried out from 22 May till 4 June 2016 to evaluate the spraying techniques at Snow Valley, Hebei and at the Heilongjiang Academy of Agricultural Science (HAAS), Harbin.

The purpose of the mission was to evaluate the spraying techniques and meanwhile to inform parties on spraying techniques.

9.2 Visit to Snow Valley, Hebei

9.2.1 Testing drones

In Snow Valley a drone was tested perform the weed control on a field grown with oats (Figure 9.1). There was a lot of wind (there is always wind on this plane), perpendicular on the spray direction. Because of that, the drone flew irregular, both in height as in horizontal directions. The drone was manually controlled. At the end of the field a colleague informed the controller through a walki talki what to do and what was happening. The drone owner has been informed about nozzles (Teejet brochure) and on effects of height variation on spraying efficacy and on techniques to reduce emissions by emission reducing nozzles. Mr. Xue Si Sun was informed that due to the large observed variation and irregular flying, the effects of the spraying are probably low to non. He promised to evaluate the effects of the application.

Figure 9.1 *Filling (left), controlling (middle) and flying (right) the drone.*

Snow Valley has 19 sprayers in use of which 15 are Hardi (Denmark, APH-Group). The settings at the field visit of a farmer were adequate, although the driver of the equipment was not able to read the information displayed as this information is not in Chinese.

Figure 9.2 *A Hardi sprayer with a width of 24 m (left), the sprayer computer display (middle).*

On another location a Tecnoma sprayer (France) was used. In the greenhouses with mini-tubers water, nutrients and chemicals/pesticides are applied with a spraying robot, fertilizer doses are applied with a dosatron (Figure 9.3 right).

Figure 9.3 *The Tecnoma sprayer with a width of 24 m (left), a sprayer boom in the mini-tuber production greenhouse (middle) and a dosatron fertilizer (right).*

The equipment and all other machines in Snow Valley were in good shape and looked well maintained. Labour is well educated to use and maintain the equipment.

9.2.2 Skin tester

Snow Valley had indicated to be interested in the evaluation different haulm killing techniques. Comparable trials have been done in India (Pronk *et al.* in prep). Different haulm killing techniques are spraying with a herbicide such as gramoxzone or diquat, compared to the standard manual haulm killing. To evaluate the effect of haulm killing on skin curing a skin tester can be used. The skin tester evaluates the skin resistance to peeling, a measure for skin curing. Potatoes are best lifted mechanically when the skins are sufficiently cured to withstand mechanical handling.
The WUR skin-tester was used to evaluate the skin resistance to peeling of freshly harvested potatoes of variety Snow Valley 7 and Innovator (Figure 9.4) of another part of China and potatoes from the storage. A similar skin-tester was made by WUR for Snow Valley delivered to Aviko in August.

Figure 9.4 *Zewen and Hai Long Li familiarise themselves with the skin-tester (left), evaluation of the skin resistance of Snow Valley 7 (middle) and Innovator (right).*

Table 9.1 *Results of the skin resistance measurements of the varieties Snow Valley 7 and Innovator.*

	Variety	
	Snow Valley 7	Innovator
Planting date	15-Jan-16	1-May-15
Harvesting date	18-June-16	15-Sepember-15
Measuring date	25-June-16	25-June-16
tuber 1 (mNm)	19.8/21.2/26.3/19.6/26.3	33.8/36.7/37.3/30.9/32.2
mean tuber 1 (mNm)	22.6 ± *3.4*	34.2 ± *2.8*
tuber 2 (mNm)	26.6/25.6/24.6/24.1/22.5	31.0/31.5/34.0/37.3/33.3
mean tuber 2 (mNm)	24.7 ± *1.6*	33.4 ± *2.5*

9.2.3 Demonstrations of Akkerweb

It was not possible to demonstrate Akkerweb as Google and Google Chrome are restricted in China. To overcome this, the students had installed a VPN-programme on their laptops and Akkerweb was used for demonstrations.
The demonstration field of Snow Valley looked well (Figure 9.5, left). On the property of Snow Valley a meteo-station was build (Figure 9.5, middle end right). It took some time (and patience) to have the meteo-station send data to the computer.

Figure 9.5 *The experimental field in Snow Valley (left), the meteo-station (middle) and the anemometer (right).*

9.3 Visit to HAAS / Harbin

The first activity in 1 July at HAAS was to give a presentation on the effects of spraying techniques on late blight (Phytophthora infestans) of Dutch research (20 years) HAAS members of staff. After the presentation, a visit was paid to the greenhouses where mini tubers were grown (Figure 9.6).

Figure 9.6 *Mini-tubers (left), the greenhouse (middle) and the welcome of Jean-Marie (right)*

9.3.1 Students at HAAS

Two students stayed for a longer period in the region, Coen and Leon (Figure 9.7). Their long term visit in China made it possible to perform nice trials and to support visits from Dutch delegations. They had some difficulties but managed to get things done. Although they already spent a lot of time in the car traveling from field to field, they were still very motivated. During travelling they processed data collected and worked on their report.

Figure 9.7 *From left to right: Shuming, Leon and Coen traveling from one experimental field to the next one.*

9.3.2 Visit to the Wangkui demonstration field

In Wangkui, the demonstration field on seed and ware potatoes was visited (see par. 8.3.1). The first fungicide applied was Revus. The product was delivered in bags of 40 g. The fungicide was applied by the field trial manager Zhao Jingyu (wklsls@163.com/www.hljcoop.com) with a John Dear self-propelled sprayer (29 rows = 29 * 0.80 m = 24 m). The row distance was 0.80 m. The demonstration field showed two different management systems, Good Agricultural Practices (GAP) with a field width of 28 rows and 800 m long, Common Practice (CP) with a field width of 8 rows and 800 m long. Maize was grown for the past 4 years and before that pepper was grown. The cultivation is irrigated with groundwater of 80 m deep. The volume of the spraying liquid per application aimed for was 800 L/ha. One Revus bag of 40 g is enough for 20 L spraying liquid, the content of a knapsack sprayer. As these fields are tractor sprayed with 800 L/ha, 1.6 kg product per ha is used, representing 40 bags of Revus per application (Figure 9.8, middle).

Figure 9.8 *Field inspection (left), a Revus bag (middle) and the John Dear sprayer (right).*

Akkerweb was used to estimate the effect of the fungicide application. Leon was trained to use the app and to explore different scenario's, such as different fungicides or doses. When successful, involve the farm manager into the use of the app.

9.3.3 Visit to the Keshan demonstration field of the Bei Du Ang Potato Group

The mission delegates besides myself of this visit were Epi Postma and Nancy (B&E bv.). Several fields were visited and different machines were seen at the contractor's place but also of the Bei Du Ang Potato Group (BPG, Figure 9.10).

Figure 9.9 *The experimental field of the Bei Du Ang Potato Group (BPG, 100 ha, left), the sprayer of the contractor (middle) and of BPG, the Hagie (right).*

Most sprayers are locally made. The locally made sprayers had different nozzles on one boom (Figure 9.10). This promotes irregular spraying patters which is most unwanted for pesticide applications. To spray effectively, the application of the pesticide must be as evenly distributed on the crop as possible. Different nozzles with different spraying patterns will not be able to distribute pesticides evenly on the crop. Sprayers also seemed hardly ever cleaned. Sprayers need to be cleaned regularly to prevent clogging of nozzles and tubs.

The findings of the visit are summarized below:

- The fields I've visited had a good soil with a good structure.
- Due to the way the soil was treated by tillage the good structure was put backwards. It would be a good improvement to use a mechanically driven rotary tiller to prepare the soil and build the ridges.
- As a result of the poor building of the ridges the potatoes and tubers grow shallow.
- I didn't see equipment for irrigation at the fields. Is there no need for this or is this to expensive?
- The fields are very long, which means that the sprayer needs to have a big tank to drive up and down. I didn't saw sprayers with big tanks (not more than 1000 L). A contractor showed a mobile water tank to carry water to the fields to fill the sprayer. But this means nevertheless a lot of fillings to spray one field.
- The locally produced sprayers do have the most important parts for a proper spray application (pump / tank + agitator / pressure valve / spray boom adjustable in height). However, I noticed on several machines different nozzles in use (Figure 9.10). In the meeting at BPG I addressed this point and advised to pay attention to this because this will give a poor spray distribution, which can lead to a poor late blight control.

Figure 9.10 *Two examples of different nozzles on sprayer booms: blue, yellow and red nozzles (left) and green, brown and red nozzles (right).*

- The sprayers weren't clean, also addressed at the meeting. This can lead to problems: clogging and a bad distribution. Also contamination from different pesticides is possible and has to be avoided. It is also bad to for the operator and the environment.
- The working width. In the Netherlands and EU the machines are standardised, for the growing of potato mostly on a width of ridge on 0.75 m. Here at BDG most of the ridges were 0.80 m, but also 0.90 and 1.10 m occurs. The working has to adjusted to that, which isn't now, with the consequence that the connecting spray paths will have an either overdose or (worse) an low dose.
- The timing of spraying: At BPG they will start when the potato plant is ~0.20 m high (this year on 20 June). Then, taking in account weather + occurrence of late blight, every 7-10 days fungicides are applied.
- The farmer gives instructions to the contractor to spray his field and supplies the fungicides.
- By placing yellow aphid traps the occurrence of aphids is monitored, and insecticides are applied depended on this result.
- The haulms of seed potatoes were killed by spraying diquat twice, the haulms of starch potatoes are killed mechanically.

9.4 Conclusions and recommendations

The conclusions of the evaluation are:

- In Snow Valley, the equipment for spraying was up to date and of good quality.
- In Snow Valley, knowledge on GAP for spraying was well in place by management. The actual field workers who do the spraying were sometimes behind in knowledge.
- At HAAS, the equipment was available but collected from different sources and most of the time not adequately assembled to meet demands for effective spraying.
- At HAAS, the knowledge on GAP for spraying was most of the time adequately developed by management although a refresher would be most beneficial. The actual field workers who do the spraying are less skilled in GAP for spraying. In combination with the suboptimal performing equipment, improvements need to be made.

The recommendations based on the evaluation are:

- Training of field workers/operators who do the actual spraying is needed.
- The training should include:
    - Read the manual of the sprayer,
    - Understand how the controller works,
    - Learn how to check the functions and how to act on the information,
    - How to keep sprayers clean,
    - Learn how to calculate the dose of fungicides,
    - Training on awareness of safety issues associated with use of pesticides.
- Awareness training on how to keep the environment clean:
    - Collect empty pesticide bags/bottles and dispose properly,
    - How to handle surplus spraying liquid.

10. Communication

10.1 Abstract

Between December 2012 and end of 2016, over 20 missions from Dutch experts in the China Potato GAP PPP to China and from Chinese experts to The Netherlands took place. Aims of the missions were exchange of knowledge and protocols, trainings, and visits to potato expo's, production demonstrations and field experiments. Also, two large symposia to inform external parties were organized in 2015 and 2016. And large number of presentations and publications was realized within the frame of the project.

10.2 Communication activities and results

10.2.1 Communications in 2012

Missions, symposia, contacts:

One mission of potato experts from China to the Netherlands took place. A Potato Workshop was held on December 7, 2012, at WUR PRI. Twelve participants attended the workshop: 6 representatives from HAAS and Chinese MoA, and 6 staff members of Wageningen UR and Dacom.

Presentations:

Heemskerk, J., 2012. Dacom systems and solutions. Dacom. Presentation at HAAS – NL meeting on December 7, 2014, meeting in Wageningen.

Kessel, G.J., 2012. R&D on *Phytophthora infestans* at PRI. WUR-PRI. Presentation at HAAS – NL meeting on December 7, 2014, meeting in Wageningen.

De Ruijter, F., Haverkort, A.J., Kempenaar, C., 2012. Good agricultural practices in potato production and Sustainability evaluation. WUR-PRI. Presentation at HAAS – NL meeting on December 7, 2014, meeting in Wageningen.

Publication:

Potato GAP in China: Nederlandse technologie en kennis voor duurzame aardappelproductie en –bewaring, gevalideerd en gedemonstreerd in China in het kader van exportpromotie. Projectvoorstel TKI-AF-12030. Penvoerder G. Wassink, DLV Plant, namens APH Groep, Dacom, Syngenta en WUR-PRI.

10.2.2 Communications in 2013

Missions, symposia, contacts:

Four international missions of potato experts from the Netherlands to China, and vice versa, took place. And two PPP meetings with the Dutch members of the consortium took place in 2013 to plan activities, and to discuss results and reporting.

1. A Potato GAP Workshop was held on March 17 and 18, 2013, at WUR PRI. Sixteen participants of HAAS, NATESC, ICAMA, Syngenta, McCain, APH Group Dacom, DLV Plant and Wageningen UR attended the workshop. Contribution to the Sino Dutch potato workshop on march 21, 2013, at the Potato Expo in Beijing (>200 attendees).
2. Visit to HAAS institute, McCain company, potato state exhibition, first week of September 2013. From Dutch side, Harm Brinks, Geert Kessel and Corné Kempenaar joined the mission.
3. Visit of 8 potato experts potato experts and high level representatives from China to the Netherlands, signing MoU, September 2013.
4. Visit of 8 Guizhou potato experts (Institute of Potato Research, Guiyang) to the Netherlands, November 2013. Trip organized by NAFTC. Experts also visited CAH Vilentum in Dronten.

Presentations:

Brinks, H., 2013. Best practices in potato production. DLV Plant. Presentation at workshop 17-18 March 2013, meeting in Beijing.

Brinks, H., 2013. Seed potato quality. DLV Plant. Presentation at workshop 2-3 September 2013, workshop in Harbin.

Brinks, H., 2013. Extension services in the Netherlands. DLV Plant. Presentation at workshop 2-3 September 2013, workshop in Harbin.

Eilander, M., 2013. Mechanization trends in potato production. APH Group. Presentation at workshop 17-18 March 2013, meeting in Beijing.

Haverkort, A.J., 2013. Sustainability evaluation of potato production. WUR-PRI. Presentation at workshop 17-18 March 2013, meeting in Beijing.

Haverkort, A.J., 2013. Sustainability evaluation of potato production. WUR-PRI. Presentation at workshop 29 November 2013, workshop in Wageningen.

Kempenaar, C., 2013. Good agricultural practices in potato production. Presentation held at the Potato Expo in Beijing, March 21, 2013. 200 attendees.

Kempenaar., C., 2013. Good agricultural practices in potato production. WUR-PRI. Presentation at workshop 2-3 September 2013, workshop in Harbin.

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Kessel, G.J., and Kempenaar., C., 2013. R&D on *Phytophthora infestans* at PRI. WUR-PRI. Presentation at workshop 17-18 March 2013, meeting in Beijing.

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10.2.3 Communications in 2014

Missions, symposia, contacts:

Three international missions of potato experts from the Netherlands to China, and vice versa, took place.

1. A workshop on the development of the ToDoIPM project, 24-26 Feb. 2014 in Beijing. Representatives of CAAS, HAAS, IMU, AUH, CIP attended the meeting. From DLO-side Piet Boonekamp, Yu Tong Qiu.
2. Visit to HAAS institute, McCain company, 1 to 5 April 2014. Workshop on development of protocol for field trials. From DLO-side Romke Wustman, Geert Kessel.
3. Visit to HAAS institute and McCain, 19-22 August 2014. Visit field trials and contribution to HAAS field demonstration day. From DLO-side, Romke Wustman.

Presentations:

Kempenaar, C., 2014. Progress report PPP Potato GAP China. Presentation held at progress meeting of PPP, 18 April, at Dacom, Emmen.

Kessel, G.J., 2014. Towards the next level IPM for Potato late blight Control. WUR-PRI. Presentation at HAAS, 1-5 April 2014, meeting in Harbin.

Kessel, G.J., 2014. Protocols (EuroBlight and NL) for late blight research on host resistance and herbicide efficacy. WUR-PRI. Presentation at HAAS, 1-5 April 2014, meeting in Harbin.

Qiu, Y.T., 2014. ToDo IPM. Horizon 2020 SFS3B project proposal. Presentation held at project preparation meetings in Wageningen, the Netherlands, and Beijing, China, January and 25 February 2014.

Wustman, R., 2014. Seed potato quality and certification. WUR-PPO. Presentation at HAAS, 1-5 April 2014, meeting in Harbin. Repeated in August 2014.

Wustman, R., 2014. Potato storage management. WUR-PPO. Presentation at HAAS, 1-5 April 2014, meeting in Harbin.

Wustman, R., Kessel, G.J., 2014. Progress in Potato GAP project. WUR-PPO/PRI. Presentation at McCain, 1-5 April 2014, meeting in Harbin.

Wustman, R., 2014. Nutrient management in potato production. WUR-PPO. Presentation at HAAS, 19-22 August 2014, meeting in Harbin.

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10.2.4 Communications in 2015

Missions, symposia, contacts:

Seven international missions of potato experts from the Netherlands to China, and vice versa, took place. Two students stayed for 3 months in China to support demonstration trials. Also the private partners in the PPP made individual potato business missions to China.

1. Visit to HAAS institute, McCain company and YAAS institute, 29 March –5 April 2015. Workshop on development of protocol for demonstration fields and set up GAP workshop. From DLO-side Anton Haverkort & Corné Kempenaar.
2. Visit to HAAS institute, 12 – 16 May 2015. Workshop on development of protocol for field trials. From DLO-side Romke Wustman.
3. Student internship's at HAAS, May to July 2015. Maarten Tenkink and Henk Mantingh, to support demonstration trials.
4. A workshop on the GAP project, 22 – 24 July 2015 in Harbin. Representatives of Dutch Potato GAP China PPS, HAAS, SIATIP, others. From DLO-side Piet Boonekamp, Anton Haverkort, Corné Kempenaar, Yu Tong Qiu (300 attendees).
5. World Potato Conference 2015, 28 – 30 July. Presentation on Good Agricultural Practice potato production by Anton Haverkort (500 attendees), and interaction with NAFTC DPC China members (10 attendees).
6. Visit of HAAS to NL, Dianqiu Lyu, 8 – 10 September 2015. Contacts with NAK and potato breeding companies.
7. Visit of HAAS to NL, Shuming Wang, 10 December 2015 – June 2016. To be trained in GAP.

Presentations:

Boonekamp, P.M., 2015. IPM 2.0: Diagnostics, late blight control, Durph breeding and disease monitoring. Presentation held by PRI at China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Harbin, 22-24 July 2015.

Haverkort, A.J., 2015. Seed potato production and certification. Presentation held by PRI at China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Harbin, 22-24 July 2015.

Haverkort, A.J., 2015. Resource use efficiency of potato production in China. Presentation held by PRI at China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Harbin, 22-24 July 2015.

Haverkort, A.J., 2015. Public Private Partnerships in Potato Variety Development. Presentation held by PRI at World Potato Conference 2015 (WPC), Harbin, 28 - 30 July 2015.

Kempenaar, C., 2015. Progress report PPP Potato GAP China. Presentation held at progress meeting of PPP, 12 January 2015, at PRI, Wageningen.

Kempenaar, C., 2015. Progress report PPP Potato GAP China. Presentation held at progress meeting of PPP, 2 November 2015, at PRI, Wageningen.

Haverkort, A.J., & Kempenaar, C. 2015. Developments in sustainable potato production. Presentations at HAAS and YAAS, 29 March – 5 April 2015, at Harbin and Kunming.

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Wang, K., 2015. Crop protection stewardship, focus on potato. Presentation held by Syngenta at China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Harbin, 22-24 July 2015.

Zhang, X., 2015. Towards minimization of potato yield losses with modern technology. Presentation held by APH at China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Harbin, 22-24 July 2015.

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http://www.wageningenur.nl/nl/project/Potato-GAP-China-AF12030.htm

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http://www.gjmlslm.com/en_mlsdh/&i=10&comContentId=10.html

10.2.5 Communications in 2016

Missions, symposia, contacts:

Seven international missions of potato experts from the Netherlands to China, and vice versa, took place. Two students stayed for 3 months in China to support demonstration trials. Also the private partners in the PPP made individual potato business missions to China.

1. Visit to Snow Valley and HAAS institute, 7 - 11 March 2016. Workshop on development of protocol for demonstration fields and set up GAP workshop 2016. From DLO-side Geert Kessel & Corné Kempenaar. PPP partner APH and Syngenta provided know how for demonstrations.
2. Visit to Snow Valley and HAAS institute, May and June 2016. Validation and calibration field equipment in field trials. From DLO-side Jean-Marie Michielsen.
3. Student internship's at HAAS, March to July 2016. Jasper Blok, Coen van den Bighelaar, Leon Haanstra and Dirk Luykx, to support demonstration trials.
4. A workshop on the GAP project, 13 - 15 July 2016 in Zhangjiakou, plus visit to demonstration fields in Heilongjiang province 11-13 July. Representatives of Dutch Potato GAP China PPS, HAAS, SIATIP, Snow Valley, and other Dutch companies not part of the PPP. From DLO-side Geert Kessel, Anton Haverkort, Corné Kempenaar, Na Wang (400 attendees).
5. Visit of HAAS staff potato group to NL, Dianqiu Lyu group, 9 – 11 May 2016. Contacts with WUR, potato breeding company and potato storage company and visit to farm.
6. Visit of director and staff fertilizer group HAAS to NL, Yuxin Tong group, October 4 and 5 2016Meeting with WUR, and visit to farm.
7. Visit of Snow valley group to NL, to plan a new Sino-Dutch PPP, 4 November 2016.

Presentations:

Haanstra, L., Reijneveld, A., 2016. Sustainable fertilizer use in potatoes. Presentation held by Eurofins at 2nd China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Zhangjiakou, 15 July 2016.

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Kempenaar, C., 2016. Use of GIS-information system in potato crop management. Presentation held by WPR at 2nd China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Zhangjiakou, 15 July 2016.

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Kessel, G.J., 2016. Innovations in potato late blight control using the Akkerweb decision support system. Presentation held by WPR at 2nd China-Europe Workshop on Potato Sustainable production and technical Cooperation (CE-WPSP), Zhangjiakou, 15 July 2016.

Michielsen, J.M., 2016. The role of spray technology to control late blight in potato. Presentation held by Snow Valley, 26 June 2016.

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11. Concluding remarks and recommendations

This report contains information on state of the art of potato production in North East China and how this can be improved with GAP innovations from The Netherlands. It starts with an overview of issues and challenges potato production in China face. The issues are related to poor soil tillage, poor seed quality, and need of decision support for sustainable crop management. We lack hard statistics on the relative importance of the issues. We expect that China’s potato production will grow through the introduction of new technologies, better varieties, sustainable methods and more effective knowledge dissemination. Upgraded storage methods will contribute to better quality of potatoes and reduce losses.

Our study was focussed on North East China, in particular Heilongjiang province. In this part of China, we saw a clear trend to modernization of potato production with introduction of advanced technologies. In this part of China, only one potato crop per season is possible. During summer, conditions are favourable for high potato yielding crops (long days, optimal day-night temperature, rich soils, no water limitation). When farmers have access to good agronomic advices, modern technology and good seed material, they obtain yields of more than 40 tonnes per ha. Otherwise, yields will stay low, about 20 tonnes per ha. Only a few farmers manage to reach the 40 tonnes per ha yield in China. A clear modernization trend is seen also seen in other provinces such as Inner Mongolia and Hebei. We expect that this trend will also to take place in South West China, where summer and winter potato crops are grown depending on height and local climate. Investments in good seeds, modern technology and decision support services are only possible on large scale farms or farmers cooperatives.

The main issues of potato production in China, which are poor late blight control, moderate seed quality, sustainability of production methods and storage losses, still require major efforts to be solved.

Good varieties and good seed quality are a prerequisite for high yielding potato crops. The results in this report show that seed potato quality can be moderate to poor in China as a result of too many virus, bacteria and/or fungal infections of the tubers. China has several good laboratories to monitor quality of seed potatoes. In practice, seed lots with moderate or poor quality are marketed and contaminate the production system. When awareness of the importance of good seed quality is raised, and a more effective seed potato quality monitoring and certification system is implemented, large steps can be made here. Training, development of the system and national and provincial coordination are important next steps.

Another prerequisite for high crop yields, is good soil quality and seed bed preparation. Seed bed preparation should probably get more attention than it receives now. Especially when mechanization (planters, harvesters) is introduced, farmers should be aware that they have to prepare the soil in a way that the potato plant can grow to its highest potential. Some recommendations are given in the China potato GAP project.

Late blight control in China has been improved through the introduction of monitoring system and a nation-wide decision support system. The ChinaBlight system, equal to EuroBlight, is an example of a big step forward. CIP ad other parties play an important role in China in dissemination of the system. However, when looking at the efficacy trials in this report, the decision support system requires improvement to be able to deliver effective advices to farmers to better protect their potato crops against late blight disease. In dryer regions in China, early blight is a problem. Another aspect of good late blight control is that farmers have to comply with the recommendations of the advisory system and that they have good application technology and good fungicides. This requires training of farmers and availability of technology and products.

Introduction of more sustainable production methods will reduce unwanted side-effects of current potato production in China. Our sustainability study showed that irrigation and fertilizer use require attention in order to reduce the carbon foot print of potato production in China. Several technologies (e.g. sensors) and decision support systems are available to better apply irrigation and fertilizers. At the same, optimization of crop protection and minimization of pesticide emission requires attention to improve sustainability of potato production in China. Advisory systems for more sustainable crop protection in potatoes are available. We expect that storage facilities in many parts of China will be upgraded allowing storage of potatoes up to 12 months with good quality in a sustainable way. The North of China has (very) low temperatures in winter, which makes that energy costs during storage can be low.

The joint research and demonstration fields in 2015 and 2016 are a powerful tool to study, develop, calibrate and demonstrate Dutch GAP potato innovations in China. We recommend to continue this cooperation in the coming years. The field experiments showed the importance of application of GAP in all aspects of potato crop management in order to achieve high potato yields and high quality of the produce. The cooperation also showed that the jointly organized Potato GAP workshops are powerful tools to disseminate information on GAP to potato producing companies and stakeholders in China. We hope to continue this in 2017 and further on. Still much good work ToDo here.

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http:/www.eurofins-agro.com
http:/www.app.coolfarmtool.org

Annex 1 Protocol field testing *Phytophthora resistance* in potato varieties

Based on:
Protocol voor het Cultuur- en Gebruikswaarde Onderzoek van Aardappelen – 2013, Raad voor Plantenrassen, The Netherlands - March 2013

Introduction
The field trials are conducted under artificial inoculation. Progress of the epidemic is quantified at regular and appropriate intervals.

Experimental setup
- Incomplete random block design (complete replications with incomplete sub-blocks).
- Number of replications: 3
- Number of test locations: 1 (outside major potato growing areas when possible)
- Number of years of testing: a minimum of two years
- Number of plants per plot: 6

Experimental Lay Out:
The experimental field is divided in sections of 14 ridges each. Space between the sections: 4 ridges. The outer two ridges of each section will be planted with a late and moderately resistant variety (in the Netherlands e.g. Pimpernel or Irene). Perpendicular to the ridges are the rows, every 6th row is planted with the moderately susceptible variety Nicola (or equivalent). Nicola rows serve as infector rows allowing build-up of the epidemic. Every first, second and fifth row is empty. In between are rows with the varieties to be examined in plots of 3x2 plants (3 ridges wide, 2 plants deep, see figure – also see Colon and Budding, 1988).

The trial is planted early May, shortly AFTER the main crops have been planted.

Standard Varieties
Six (6) standard varieties are included in each trial to allow for comparison between trials and between years. These standard varieties should cover the entire range of resistance from Susceptible (S) to Moderately Susceptible (MS), Moderately Resistant (MR) to Highly Resistant (HR). In the NL the following standard varieties are used: Bintje, Eersteling, Eigenheimer, Irene, Karnico en Nicola. In Harbin a new set of (local) standard varieties will have to be established.

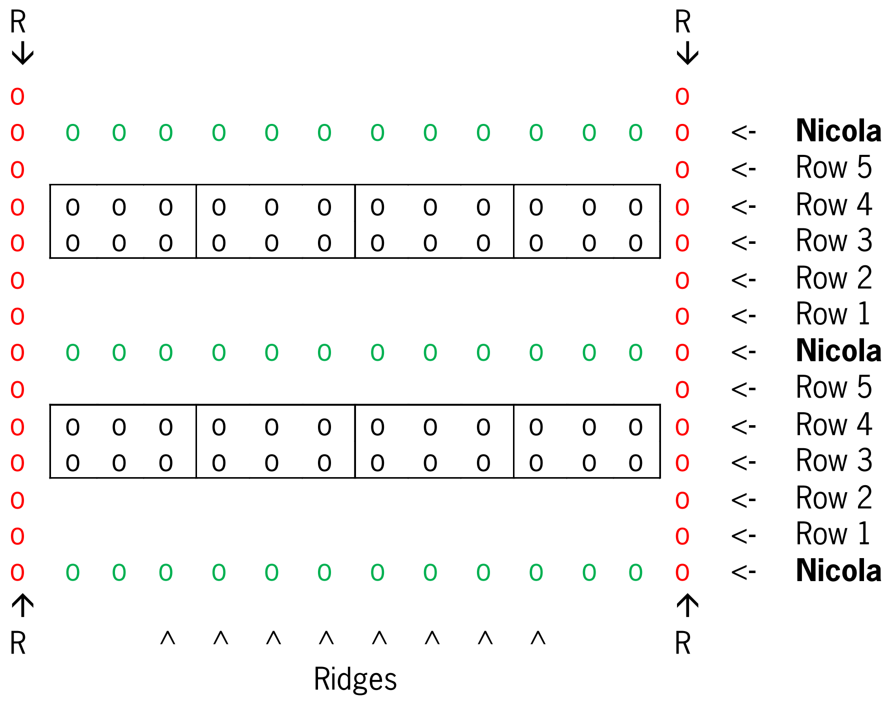

Figure 11.1. Experimental setup as described above under "Experimental setup". Variety Nicola (o) is moderately susceptible (MS). The outer two ridges are planted with a late and moderately resistant variety (o).

Inoculation

The whole field is spray inoculated with a mixture of zoospores and zoosporangia. First a zoosporangial suspension with 15000 sporangia/ml is produced which is subsequently kept at 4°C for several hours to produce the required mix of zoosporangia and zoospores. Inoculation takes place at/on a closed canopy, early July in the Netherlands. Prior to inoculation the crop is irrigated using overhead irrigation to produce a wet crop and a wet soil. The inoculum is sprayed over the entire crop just before sun set.

One (1!) complex, representative P. infestans isolate is used. In the NL this isolate is called IPOcomplex (or IPO 82001), physiological race 1.2.3.4.5.6.7.10.11. For use in Harbin, this isolate needs to be selected from local, complex, representative isolates present in the HAAS P. infestans culture collection.

Irrigation

Starting 1 day after inoculation, the field is artificially irrigated on a daily basis, early in the morning and prior to sun set, up to 3 – 5 hours at a time using overhead irrigation. Usually 1 – 2 hours of irrigation will suffice. This serves to extend the natural leaf wetness period. Local weather conditions must be taken into account to prevent flooding or excess water in the field. When the weather conditions are really wet, irrigation may even be skipped.

Disease assessment

Disease severity (% diseased foliage relative to the healthy, full crop at the time of inoculation) is assessed 6 - 10 times during the epidemic, usually in 3 – 4 day intervals.

Disease severity scale for estimating the % diseased foliage relative to the healthy, full crop at the time of inoculation:

Severity (% diseased Foliage)	Symptoms description
0	No infections visible
0.01	1 lesion per (6 plant) **plot**
0.02	2 lesions per plot
0.05	5 lesions per plot
0.1	6 – 10 lesions per plot
0.5	2 – 5 lesions per **plant**
1	6 – 10 lesions per plant
5	Up to an average of 20 lesions per plant
10	10% foliage dead, plants look healthy but lesions are easily visible.
25	25% foliage dead
50	50% foliage dead
75	75% foliage dead. Plot looks green with lots of brown spots. Lower leaf layers are dead.
90	90% foliage dead. Plot looks brown – green. Only top leaves are green. Stem lesions frequently occur.
97.5	97.5% foliage dead. Plot looks brown. Only the top leaves have green parts.
100	All foliage and stems are dead.

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Annex 2 Heilongjiang Academy of Agricultural Science (HAAS), Harbin, Heilongjiang (China)

Seed potato performance experiment 2014

Introduction

Performance of 25 seed samples of potato variety Keshan 13 is to be studied at HAAS experimental farm in Harbin during growth season 2014 season in collaboration with Wageningen University & Research (WUR). The trial protocol is as follows :

Experimental details

Experimental site:	HAAS experimental farm at Harbin
Test variety:	Keshan 13
Number of treatments (seed samples):	25 (2 HAAS samples + 23 farmers' samples)
Statistical design:	Randomized block design
Replications:	3
Sample:	50 tubers -> 3 samples of 50 tubers per farmer
Number of tubers per plot:	50 (5 rows, 10 plants/row)
Date of planting	May, 2014
Spacing:	75 cm x 30 cm
Fertilizers:	As per recommended practice by HAAS.
Seed treatment before planting:	No seed treatment
Disease and insect-pest control:	As per HAAS recommendations

Observations to be recorded

The following observations will be recorded on three central rows/plot and taking 8 plants per row:

- Days to 50% emergence
- Days to 90% emergence
- Number of emerged plants/plot
- Number of stems/plant (on randomly selected 5 plants / plot)
- Growth vigour (scale: 1 = poor; 9 = best); estimated at 6 and 10 weeks after planting (estimated for the net-plot (3 rows of 8 plants))
- Canopy development (% foliage ground cover) at 6 weeks, 8 weeks, 12 weeks after planting (estimated for the net-plot (3 rows of 8 plants))
- Number of virus affected plants
- Visual virus assessment in the field; focus on PVY, PLRV, PVX and PVA
- Visual assessment in the field of bacterial disease affected plants
- Visual assessment of foliar diseases incidence (late blight, early blight) at 4 weeks, 6 weeks, 8 weeks, 10 weeks, 12 weeks, 14 weeks after planting
- Date of maturity
- Tuber yield per plot and per hectare
- Tuber size /weight

Annex 3 Protocol field testing PVY resistance in potato varieties

Based on:
Protocol voor het Cultuur- en Gebruikswaarde Onderzoek van Aardappelen - 2013
Raad voor Plantenrassen, the Netherlands - March 2013

Introduction
The PVYN virus is a non-persistent virus and is transmitted by aphids. Various strains (YN, YC and YO) cannot be distinguished by serological means but their individual symptom expression can be quite characteristic: i.e. mosaic, crinkle. Resistance to PVYN is tested under field conditions in an experiment using infector plants. The virus transmission occurs in a natural way by aphids moving from infected plants to healthy plants.
The PVYN infector plants are infected from a selected, known PVYN strain. The experimental location should be separated from other potato fields in order to exclude the effect of infections of other PVY strains. The percentage of infected plants is post-harvest tested through serology.

Experimental set-up
- Incomplete randomized design with four replications of incomplete blocks of 8-10 plots.
- Number of years of testing: a minimum of two years
- Number of test locations: two
- Number of plants per plot (= per replicate): four
- Quality of seed potatoes to be used for the experiment: 100 % virus free, seed size 45-50 mm
- PVYN infector source: PVYN tolerant variety i.e. the virus multiplies within the plants but the variety is immune to other viruses
- PVYN infector source: to be replaced each two years as to avoid the build-up of other viruses and to reduce the possible impact of degeneration in the infector plants
- Four tubers of each to be tested variety are planted across four ridges (a, b, c and d), a PVYN infected seed tuber is planted in the ridge marked * (figure).
- Planting distance plant to plant: 40 cm
- Planting distance ridge to ridge: 75 cm
- Consequently each ridge is similarly close to the ridge of infector plants.
- Lay-out in field:

variety 2	->	a b c d * d c b a <-	variety 3
variety 1	->	a b c d * d c b a <-	variety 4

direction of ridges ^ ^ ^ ^ ^ ^ ^ ^ ^
* = ridge with infector plants

The experiment can be surrounded with one or more buffer ridges.
- The PVYN virus is transmitted by aphids in a natural manner. Insecticides must not be applied.

Standard varieties:
At least six standard varieties are included in the set of to be tested varieties. The standard varieties must cover the entire range of very susceptible to highly resistant varieties. The set of standard verities will be part of the experimental set-up for a large number of years and therefore need to be selected carefully.

Seed potatoes for experiment

- The to be tested varieties must be free from any virus; possibly the first field generation produced from mini-tubers will serve this purpose.
- The presence of any virus infection in the seed needs to be observed a few weeks after emergence.
- A variety with any PVY infection will be excluded from the experiment. All tubers from the infected variety will be rogued out and removed from the experiment immediately.

Planting of the experiment

- Time of planting: the experiment will be planted a few weeks after the average date of planting as to avoid differences in maturity resistance.
- Seed tubers of the infector variety are pre-sprouted to compensate for a possibly retarded plant development.
- The experiment is conducted in an area with high aphid pressure and a limited impact of virus infection from within this region.
- Agronomical practice such as NPK fertilization and weed control are as recommended.
- Technical staff will walk through to the experiment one of two weeks prior to canopy closure, this is to increase the activities of aphids.
- The aphid pressure at the experimental site can be monitored by placing a yellow aphid tray at the edge of the experiment.

Harvest

- The experiment is harvested at the end of the growing season. In case of very heavy aphid pressure: harvesting should be done earlier.
- Sample size for post-harvest testing: three tubers per each individual plant.
- Each plot is sampled individually i.e. 12 tubers per replicate.
- Four replicates and four plants per replicate result in 48 tubers per variety.
- The sampled tubers are stored at 10-15 ◦ Celsius.

Analysis

- An Elisa based test will be conducted three to four months after harvesting
- Each sampled tuber will be submerged for 20 minutes in 2 ppm Gibberellic acid.
- The apical sprout of each tuber is planted under controlled greenhouse conditions
- About six weeks after planting each plant is individually tested for the presence of PVYN virus through an ELISA test based on a polyclonal antiserum (Clark and Adams, 1977).
- The test is conducted according to the manual of the Netherlands General Inspection Service (NAK) (ELISA version 1993 - 1).
- The results are statistically analysed.

Result

The number of positive reactions in relation to the total number of tested tubers per each individual plot (i.e. the percentage of PVYN affected tubers per plot).

Literature

Clark, M.F. and Adams, A.N., 1977. Characteristics of the microplate method of enzyme-linked immunosorbent assay for the detection of plant viruses. Journal of General Virology 34: 475 - 483.

NAK, 1993. Elisa handleiding version 1993 - 1.

Annex 4 Questionnaire for data on potato production in China

Questionnaire for data on potato production in China - version 30-Nov-2012
For questions, contact: Frank de Ruijter, frank.deruijter@wur.nl

This questionnaire is on production of ware potatoes and potatoes for processing.

The aim of collecting these data is to make an evaluation of Chinese potato production in important regions. In this evaluation we calculate the options for yield improvement, and the footprints of potato production such as of land, water, energy and minerals. See also a previous email message that was sent by Corné Kempenaar and Anton Haverkort.

The required data are on averages: average production, average use of inputs in a region and average over several years (average weather conditions).

Together with this document, an example is sent of a completed questionnaire for a potato production area on sandy soil in the southeast of the Netherlands.

Choosing options
For some questions, different options are given. Please mark the box near the most appropriate option, as shown in the example below:

Soil Texture	Class		fine (clay)	Choose one of the options
		x	medium	
			course (sand)	

Parameter	Unit	Data		Explanation
Location		Give the name of the region/city or village where the potatoes are produced, together with a latitude and longitude. As example, the latitude and longitude of Beijing is given.		
Name				Name of region/city/village where potatoes are produced.
Latitude	xx°xx′xx″N			39°54′50″N (example for Beijing)
Longitude	xx°xx′xx″E			116°23′30″E (example for Beijing)
Altitude	M			
Soil properties				
Soil Texture	Class		fine (clay)	Choose one of the options (by marking the box before the appropriate option)
			medium	
			course (sand)	
Clay and silt content	%			% of weight. Clay and silt are all particles < 0.05 mm. Give an average value for the region
Soil Organic Matter (SOM)	%		SOM ≤ 1.7	Choose one of the options
			1.7 < SOM ≤ 5.2	
			5.2 < SOM ≤ 10.3	
			SOM > 10.3	
Drainage	Class		Poor	Choose one of the options
			Good	
Soil pH	Class		pH <= 5.5	Choose one of the options
			5.5 < pH <= 7.3	
			7.3 < pH <= 8.5	
			pH > 8.5	
Rooting depth	Cm			Give the rooting depth of potato on this soil

Growing period			
Date of planting	day/month		Fill in the date on which potatoes are generally planted (for example: 1 May)
Date of harvest	day/month		Fill in the date on which potatoes are generally harvested

Seed and harvest			
Seed rate	t/ha		Kg of seed potatoes planted per ha
Planting depth	Cm		Depth of seed tuber below soil surface
Seed transported	Km		Distance from seed grower to potato producer
Fertilizer input		*Calculate the pure nutrients that are applied with chemical fertilizers. Example: 100 kg/ha NPK-(15:5:20) = 15 kg N, 5 kg P_2O_5 and 20 kg K_2O*	
N from fertilizer	kg/ha		Kg pure N applied per ha
P_2O_5 from fertilizer	kg/ha		Kg pure P_2O_5 applied per ha
K_2O from fertilizer	kg/ha		Kg pure K_2O applied per ha

Parameter	Unit	Data	Explanation
Manure and compost		Give name and amount that is on average applied to potato, next to the fertilizer input as given above. Fill in the table below.	
Manure name	Amount applied (t/ha)	Type (slurry or solid)	Indicate from which animal
Crop protection products		**Give the number of treatments with a crop protection product before planting and during crop production. For treatments during harvest and storage: see under 'Harvesting and storage'. If mixtures are applied, count each product as a separate application, for example: 1 fungicide + 1 insecticide = 2 treatments**	
Seed treatments	number		
Herbicides (weeds)	number		Herbicides against weeds
Herbicides (haulm killing)	number		Herbicides used for haulm killing
Insecticides	number		
Fungicides	number		

Parameter	Unit	Data		Explanation
Field operations, mechanically powered				
Fuel type for tractor			diesel	Indicate the type of fuel that is used by your tractor
			petrol	
Ploughing (Indicate the number of operations: how often is it done? 1, 2 or 3x ….)				
Moldboard ploughing	number			This turns the topsoil almost completely over
Chisel ploughing	number			This does not invert the soil
Subsoiling	number			Deeper than chisel ploughing
Harrowing (Indicate the number of operations: how often is it done? 1, 2 or 3x ….)				
Power harrow	number			
Tine harrow	number			Tine or spike harrow
Disk harrow	number			
Roller harrow	number			
Chain harrow	number			
Other treatments (Indicate the number of operations: how often is it done? 1, 2 or 3x ….)				
Planting	number			Mechanical planting
Ridging	number			
De-stoning	number			Mechanical removal of stones
Mechanical weeding	number			
Fertilizer and manure - transport and application				
Slurry injection	number			
Slurry transport	Km			From animal house to potato field (km)

Manure spreading	number			Manure or compost
Manure transport	Km			From animal house to potato field (km)
Fertilizer spraying	number			For liquid fertilizer
Fertilizer spreading	number			For solid fertilizer. Give the number of times a spreader entered the field
Pesticide spraying	number			How often did the spraying machine enter the field with a single chemical or a mixture?
Irrigation				
Irrigation water	Mm			How many mm water irrigated during whole season?
Depth irrigation water	M			From how deep the water is pumped up
Horizontal transport distance	M			Distance between water source and field
Type of irrigation equipment			pivot	Choose one of the options
			rain gun	
			sprinkler	
			flooding	
			drip irrigation	
Power supply for irrigation			electricity	Indicate the type of fuel that is used for irrigation
			diesel or petrol	

Parameter	Unit	Data		Explanation
Foliage destruction (choose one or more of the options below)				
Type of foliage destruction	choose		spraying	Chemical leaves/stems destruction
			haulm flailing	Mechanical leaves/stems destruction
			manual	Manual removal of foliage
Harvesting and storage				
Type of harvest	choose		Fully mechanical	Mechanical lifting and mechanical loading
			Windrowing	Mechanical lifting and handpicking
			Manual	Fully manual harvest
Transport distance	M			Distance between field and farm store
Fresh product harvested	t/ha			Total product harvested from field (1 tonnes = 1000 kg)
Sold product	t/ha			Amount of product that is delivered to the factory or market
Washing potatoes	%			Percentage of harvested potatoes washed
Fuel type			electricity	Indicate the type of fuel that is used for washing
			diesel or petrol	
Grading potatoes	%			Percentage of harvested potatoes graded
Fuel type			electricity	Indicate the type of fuel that is used for grading
			diesel or petrol	
Storage of potatoes	%			Percentage of harvested potatoes that is stored.
Energy source for loading/unloading the storage			diesel	Choose one of the options
			petrol	
			electricity	
Duration of storage	months			Number of months
Temperature difference	°C			When cooled mechanically: how many degrees cooled by refrigerator (average temperature heap and outside during whole season)
Crop protection treatments	number			Number of treatments with a crop protection product during harvest and storage. If mixtures are applied, count each product as a separate application, for example: 1 fungicide + 1 insecticide = 2 treatments

Comments

Annex 5 Questionnaire responses of the national study

These data can also be found in "Questionnaire responses - 20121130.xlsx" where additional information from the questionnaire is given in comments in individual cells. In yellow data that were adapted by FdR/AH. Description of the changes made is given in the excel file.

	Ningxia - Xiji	Ningxia - Yanchi	Inner Mongolia - Dalate	Heilongjiang - Keshan	Hebei	Fujian - Yutian, Changle
Latitude	35°35' - 36°14'	37 °48′00″	40°45′55″ N	47°95′80″N	41°24'51"N	25°87′55″N
Longitude	105°20' - 106°04'	107 °01′56″	109°80′52″E	125°90′20″N	114°55'56" E	119°.45′76″E
Altitude (m)	1900	1500	1000	225	1375	35
Soil Texture	Medium	Medium	course (sand)	medium	medium	course (sand)
Clay and silt content (%)	10	35.6	0	15	20	15
Soil Organic Matter (SOM)	5.2 < SOM < 10.3	5.2 < SOM < 10.3	SOM < 1.7	1.7 < SOM < 5.2	SOM < 1.7	1.7 < SOM < 5.2
Drainage	Good	Good	Good	good	good	good
Soil pH	7.3 < pH <= 8.5	pH > 8.5	pH > 8.5	5.5 < pH <= 7.3	7.3 < pH <= 8.5	pH <= 5.5
Rooting depth (cm)	50	50	40	40	40	50
Seed						
Seed rate (t/ha)	1.8	1.95	2.7	2.6	2	1.5
Date of planting	12-mei	25-apr	28-apr	28-apr	1-mei	15-nov
Date of harvest	1-sep	1-okt	1-okt	23-sep	20-sep	15-mrt
Nr days growing season	112	159	156	148	142	121
Planting depth (cm)	20	15	15	15	9	20
Seed transported (km)	50	3	350	0.5-30	15	2000
Fertilizer input						
N from fertilizer	225	216	444	105	395	230
P_2O_5 from fertilizer	75	120	285	105	270	160
K_2O from fertilizer	300	84	456.75	127.5	360	215
Manure and compost (t/ha)						
1	30	22.5	-	-	-	1.5
2	27	1.2				
3	26					
Crop protection products						
Seed treatments	1	1	1	1	2	0
Herbicides (weeds)	1	2	1	1	1	2
Herbicides (haulm killing)	1	1	0	0	0	0
Insecticides	0	2	1	5	2	3
Fungicides	1	4	9	8	8	6
Field operations, mechanically powered						
Fuel type for tractor	Diesel	diesel	diesel	diesel	diesel	diesel
Moldboard ploughing	2	2	1	0	1	1
Chisel ploughing	2	1	2	2	0	0
Subsoiling	1	0	3	3	1	1
Power harrow	1	0	1	0	0	1
Tine harrow	1	0	0	1	1	0
Disk harrow	0	0	1	0	0	0
Roller harrow	0	0	0	0	0	0
Chain harrow	0	0	0	0	0	0
Planting (mechanical)	1	1	1	1	1	1
Ridging	1	2	3	1	1	1
De-stoning (mechanical removal of stones)	0	0	0	0	0	0
Mechanical weeding	1	3	0	1	1	0

Annex 6 Questionnaire responses of the provincial study

	Heilongjiang - Keshan	Zhaodong	Hulan		Minzhu
	Ware	Ware	Seed	Ware	Ware
Latitude	48°03′N	45°10′-46°20′	47°03′N	47°03′N	45°49′44.33″~ 45°51′1.60″
Longitude	125°87′E	125°22′-126°22′	126°87′E	126°87′E	126°48′55.64″~ 126°51′26.50″
Altitude (m)	223	190	218	218	194
Soil properties					
Soil Texture	Medium	Medium	Medium	Medium	Medium
Clay and silt content (%)					
Soil Organic Matter (SOM)	1.7<SOM≤5.2	1.7<SOM≤5.2	1.7<SOM≤5.2	1.7<SOM≤5.2	1.7<SOM≤5.2
Drainage	Poor	Poor	Good	Good	Good
Soil pH	5.5<pH<=7.3	5.5<pH<=7.3	5.5<pH<=7.3	5.5<pH<=7.3	5.5<pH<=7.3
Rooting depth (cm)	30	30	40	40	30
Seed					
Seed rate (t/ha)	2.625	2	1.65		2
Date of planting	15-May	01-May	20-Apr		01-May
Date of harvest	25-Sep	15-Sep	05-Sep		10-Sep
Nr days growing season	133	137	138		132
Planting depth (cm)	5-7	10	10		10
Seed transported (km)	50	50	1.5		40
Fertilizer input					
N from fertilizer	165	150	250		200
P_2O_5 from fertilizer	120	100	150		120
K_2O from fertilizer	225	200	300		250
Manure and compost (t/ha)					
1			2 ton/ha solid pig & chicken manure		
Crop protection products					
Seed treatments	1	0			0
Herbicides (weeds)	1	0			1
Herbicides (haulm killing)	0	0			0
Insecticides	4	0	1		0
Fungicides	6	3	5 to 6		5
Field operations, mechanically powered					
Fuel type for tractor	Diesel	Diesel	Diesel		Diesel
Mouldboard ploughing			2, 50% of the field		1
Chisel ploughing			1		1
Sub soiling	1	1			
Power harrow					2
Tine harrow					1
Disk harrow			1		
Roller harrow					
Chain harrow					
Planting (mechanical)	1	1	1		1
Ridging	1	1	1		1
De-stoning (mechanical removal of stones)					
Mechanical weeding	1	1	1		1
Slurry injection					
Slurry transport					
Manure spreading			1		
Manure transport (km)			1.5		
Fertilizer spraying	5				
Fertilizer spreading	2	1	2-3		1
Pesticide spraying	9	3	5-6		5
Irrigation					
Irrigation water (mm)					
Depth irrigation water (m)	100	50			60

Horizontal transport distance (m)				
Type of irrigation equipment	Pivot	Pivot		Rain gun/flooding
Power supply for irrigation	Electrical	electrical		
Foliage destruction				
Type of foliage destruction	haulm flailing	haulm flailing	haulm flailing	haulm flailing
Harvesting and storage				
Type of harvest	Windrowing	windrowing	windrowing	windrowing
Transport distance (km)	50	50	1.5	40
Fresh product harvested (t/ha)	30	22	45	30
Sold product	24	16	35-40	24
Washing potatoes (%)	0	0	0	0
Fuel type	-	-	-	-
Grading potatoes (%)	0	0	80	0
Fuel type	-	-	Manually	-
Storage of potatoes (%)	30	50	80	50
Energy source for loading/unloading the storage	diesel		Manually	Diesel
Duration of storage (months)	5	5	5	5
Temperature difference (°C - cooling)	2-4°C	2-4°C	2-3°C	2-4°C
Crop protection treatments	0	0	0	0
Comments				
No data on irrigation applied are provided				
Cropping system for ware and seed potatoes in Hulan are the same				

Annex 7 Information on PPP partners in Potato GAP China (January 2015)

In this Annex you find information on APH, Dacom, DLV Plant, Syngenta and Wageningen UR.

APH group
APH Group is a group of first class machinery manufacturers, which offers a complete range of equipment for potato, onion and carrot production. The group covers the complete range from planting till packing machinery. Besides high quality field equipment, they offer solutions for irrigation, in-store solutions and agricultural engineering. As a specialty APH Group is also able to offer turn-key projects. Such projects contain besides the necessary machinery, also the seeds, seed potatoes, fertilizing advises, technical assistance and storage technology. Throughout the season, one of our agronomists can visit your project on a regular basis to train and teach local people. Head office is in Heerenveen, The Netherlands.

Product range of APH:
- Baselier: Rotary ridgers, ridge formers and haulm toppers;
- Omnivent: Ventilation equipment, refrigeration and humidification for storehouses;
- Miedema: Planting & Intake lines;
- Dewulf: Potato and carrot harvesting equipment;
- Manter: Weighing and packing equipment.

APH Group is active in different regions and has therefore an extended dealer network and in some countries subsidiaries. The main working areas of APH Group are: (1) China, (2) Russia and former CIS countries, (3) Central and Eastern Europe, (4) Finland, (5) Turkey, (6) Latin America, (7) Northern Africa.

More information: www.aph.nl

Dacom
Dacom is an innovative high-tech company that develops and supplies specialized hardware, software and online advisory services to arable farms and the agribusiness around the world. Head office is in Emmen, The Netherlands.

The AYM (Agro Yield Monitoring) system developed by Dacom provides growers and the agribusiness around the world with practical solutions for profitable and sustainable agriculture. By combining sensor technology, internet and scientific knowledge, growers can continuously monitor and fine-tune their production process throughout the growing season and crop information is easily sharable with the surrounding partners. The agribusiness can continuously anticipate and optimize raw material supply through the consultation of field data and smart modules. This results in the maximum yield achievable through the economically sound and responsible use of agri-inputs like chemicals, water and nutrients.

Products of Dacom: (1) Sensetion soil moisture Package, (2) TerraSen station, (3) weather stations, (4) weather forecast and spray condition advice, (5) irrigation advice, (6) crop recording for tracking and tracing, and (7) crop protection advices.

More information: www.dacom.nl

DLV Plant
DLV Plant is a leading, independent advisory and research partner for the vegetative sectors. Its activities focus on advice, research and projects in the Netherlands and internationally. Head office is in Wageningen, The Netherlands.

The core business of DLV Plant is advising entrepreneurs in the primary agricultural sectors.
This advice is mainly given in the form of assistance to and guidance of companies. This advice not only takes into account the latest developments in the field of cultivation, but also developments on management level within the company.

The strengths of DLV Plant are the knowledge framework within its own organisation, its network within the agricultural and related sectors and the broad scope of its services. Expertise of the advisors is kept up to date by amongst others:

- exchange of knowledge within the organisation;
- contact with Dutch and foreign research institutes;
- attendance of conferences and seminars;
- making maximum use of its extensive network.

DLV Plant creates added value for entrepreneurs through the continuous marketing of innovative and contemporary services and products.

More information: www.dlvplant.nl

Syngenta
Syngenta is a global Swiss agribusiness that markets seeds and agrochemicals in over 90 countries. Syngenta is involved in biotechnology and genomic research. It was formed in 2000 by the merger of Novartis Agribusiness and Zeneca Agrochemicals. Syngenta employs over 28,000 people in over 90 countries, including China and The Netherlands. In its present form, Syngenta is a young company. But it stems from an industrial tradition going back almost 250 years. Head office of Syngenta is in Bazel, Switzerland. Country offices are e.g. in Beijing and Shanghai (China) and Bergen op Zoom (The Netherlands).

One of the unique things about Syngenta is that our actions and products can help address one of the planet’s most challenging dilemmas: how to grow more crops from less resources. That is why our ambition is to bring greater food security in an environmentally sustainable way to an increasingly populous world by creating a worldwide step-change in farm productivity. And that means on every farm - the 8 million large farms of over 100 hectares and also the 500 million farms of around only 1 hectare. Each farm and farmer has a role to play. Through deploying our world-class science, we aim to transform the way crops are grown and look beyond yield. This includes novel go-to-market models, building in particular on our success in reaching new customers in emerging markets.

More information: www.syngenta.com

Wageningen UR, Wageningen Plant Research.
Wageningen UR is a collaboration between Wageningen University and the specialised research institutes (St. DLO).
Wageningen UR combines the knowledge and experience of about 6,500 staff and 10,000 students from over 100 countries. Wageningen UR contributes actively to solving scientific, societal and commercial problems in the domain of (1) food and food production, (2) the living environment and (3) health, lifestyle and livelihood. These domains are studied from various disciplines and with an integrated approach to strike a balance between economics, culture and nature. The DLO institutes cover strategic, application driven and applied research for industry, governments and stakeholder groups.

Wageningen Plant Research is a private not for profit research institute with experienced personnel (about 600 fte) and specialises in strategic and applied research for industry and public institutions. By integrating knowledge on crop protection, crop ecology, agricultural systems, genetics and reproduction, Wageningen Plant Research serves the entire agro-production chain with scientific products, from the DNA level to production system concepts. Wageningen Plant Research regularly has articles in the leading scientific journals and has a superb research infrastructure.

More information: www.wageningenur.nl

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