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Progress Report China Potato GAP project

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Applied Plant Research & Plant Research International, part of Wageningen UR

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The logo's and images below show the parties who contributed to the project in 2013 and 2014. We acknowledge the contributions of APH, Dacom, DLV Plant, Syngenta, Dutch Ministry of Economic Affairs, TKI Agrifood, McCain, HAAS, Chinese government and other Chinese institutes and companies.

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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. In September 2012, this initiative has been broadened and adopted by some Dutch and Chinese stakeholders. A Pubic Private Partnership (PPS) on Good Agricultural Practice (GAP) in potato production and storage methods was established. 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.

In this report we describe the mid-term results of the R&D program of the PPS Potato GAP China. The Dutch partners in the PPS are APH Group, Dacom, DLV Plant, Syngenta and Wageningen UR – PPO/PRI. HAAS, a PPO/PRI counterpart in potato research in China, committed herself to the PPS 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 by HAAS (Heilongjiang Agricultural Academy of Science). The aim of the Potato GAP China PPS is to exchange information on GAP in potato production and storage, and to set up experiments and demonstration farms in China with Dutch technology and know-how. This last objective, the setup of Centres of Dutch potato Expertise in China, has not been achieved yet, but still has high priority in 2015. In this report, we describe the results of experiments, investigations and communications within the PPS in 2013 and 2014. The R&D topics are potato late blight disease monitoring and control, potato seed quality evaluation, potato storage investigation and sustainability evaluation of potato production.

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 also provided valuable crop production data.

The activities carried out by the Dutch parties were financially supported by The Dutch Ministry of Economic Affairs, TKI-office Agrifood and the Dutch companies involved. The activities carried out by the Chinese parties were financed with Chinese budgets and resources. We acknowledge the support and contributions of APH Group, Dacom, DLV Plant, HAAS, Syngenta, the Chinese and Dutch governments, and McCain. We also acknowledge contributions and communications with NAFTC China, CAAS, IMU, AUH, NAITS, YAAS and other provincial research institutes, and CIP Beijing during the course of the project.

Corné Kempenaar
Coordinator Wageningen UR research team

Executive summary

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. 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 the mid-term results of this Sino-Dutch Potato GAP China project, which started in 2013.

The outline of the R&D program in this report was developed in several meetings between Dutch and Chinese research institutes and companies between 2009 and 2013. In 2013, a Memorandum of Understanding (MoU) was signed by HAAS and the Dutch Potato GAP consortium to cooperate on at least five topics between 2013 and 2017:

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, Syngenta and Wageningen UR. The research in China is coordinated by HAAS in the first two years of the project. Other parties who participated in communications, workshops and/or trainings, were CAAS, YAAS (Yunnan), AUH (Hebei), IMU (Inner Mongolia), NAITS (Guizhou), CIP, ICAMA, NATESC, McCain, Aviko, Snow Valley and NAFTC Orange potato cluster.

In this report mid-term results of the R&D program are described. The program addressed issues related to late blight control, quality of seed potatoes, sustainability evaluation of production methods in different regions of China, and storage facilities.

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. 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. Aims of the missions were exchange of knowledge and protocols, trainings, and visits to potato expo's and specific potato fields. Over 25 presentations, several workshops and over 10 publications resulted from the project so far.

We recommend continuing the experiments described in chapters 2 to 4 of this report in 2015. Knowledge and technology dissemination will be accelerated if large scale field demonstrations can be set up in 2015. Tailor made soil tillage in combination with high quality seed potatoes and sustainable crop production methods will lead to higher yields of potato production in China. We hope to realize demonstration farms in 2015 and 2016 in China, in combination with specific workshops and trainings.

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 summarizes all communication activities in the Potato GAP project.

Most of the studies described in the chapters 2 to 5 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.

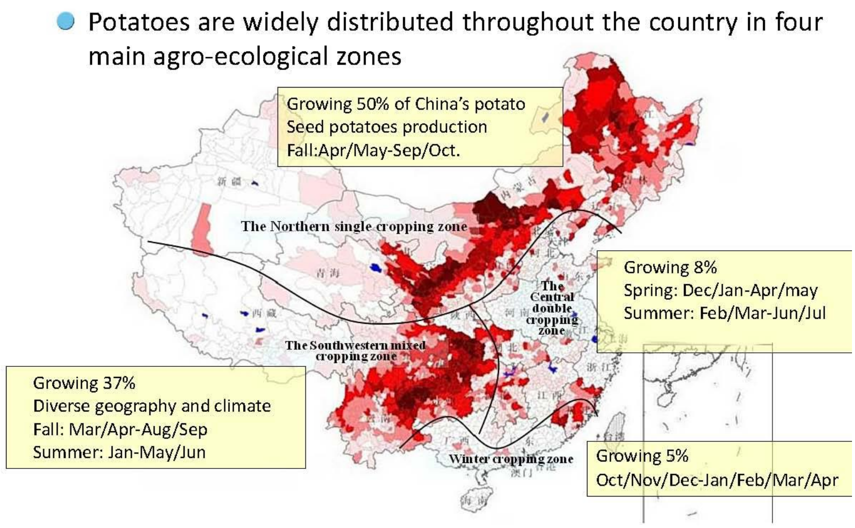

Figure 1.1. Overview of potato producing regions in China (Source: YAAS, 2015).

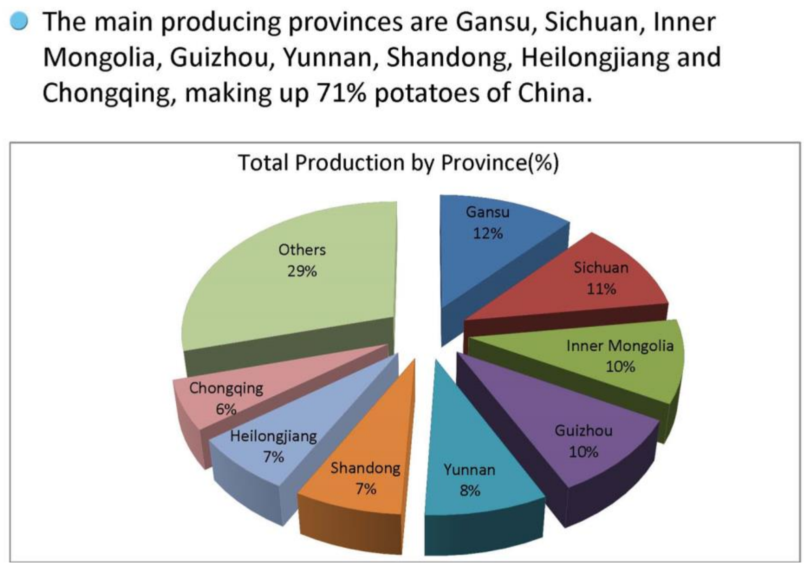

Figure 1.2. Overview of potato production in China per province (Source: YAAS, 2015). See also Table 4.1.

2. Late blight monitoring and control

Geert Kessel & Corné Kempenaar, Wageningen UR PPO/PRI
Fanxiang Min & Guo Mei, HAAS

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 PRI/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.

Area	Site	Number of isolates	A1		A2	
			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.

Area	Site	Number of isolates	Sensitive		Intermediate		Resistant	
			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 PRI and HAAS (see Appendix V).

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).

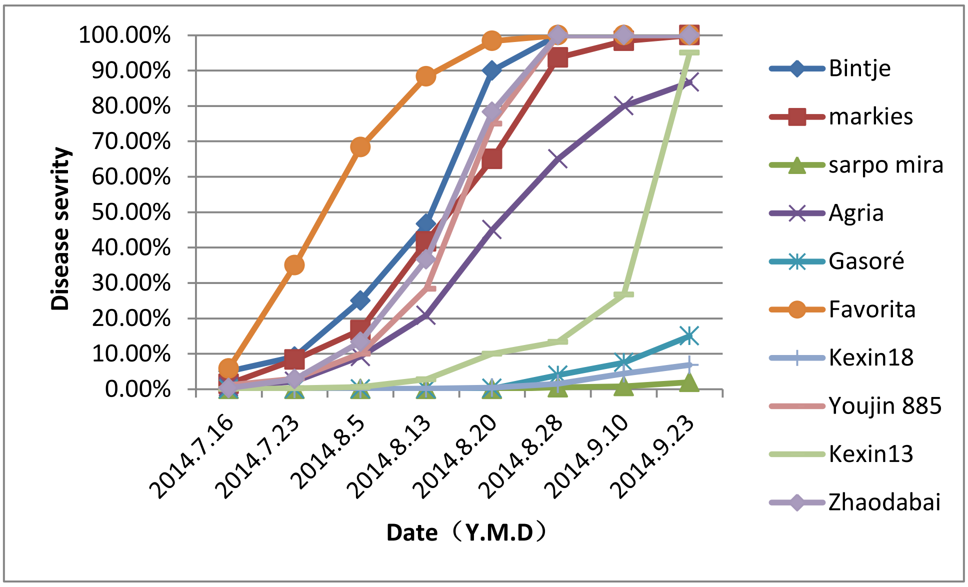

Figure 2.1. *Mean progression of foliage blight in trial of different potato varieties.*

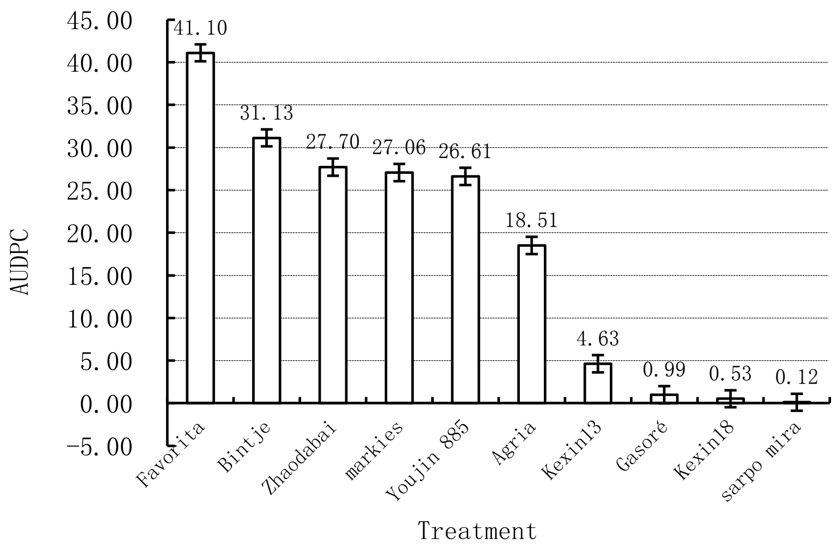

Figure 2.2. *AUDPC values in trial of different potato varieties.*

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).

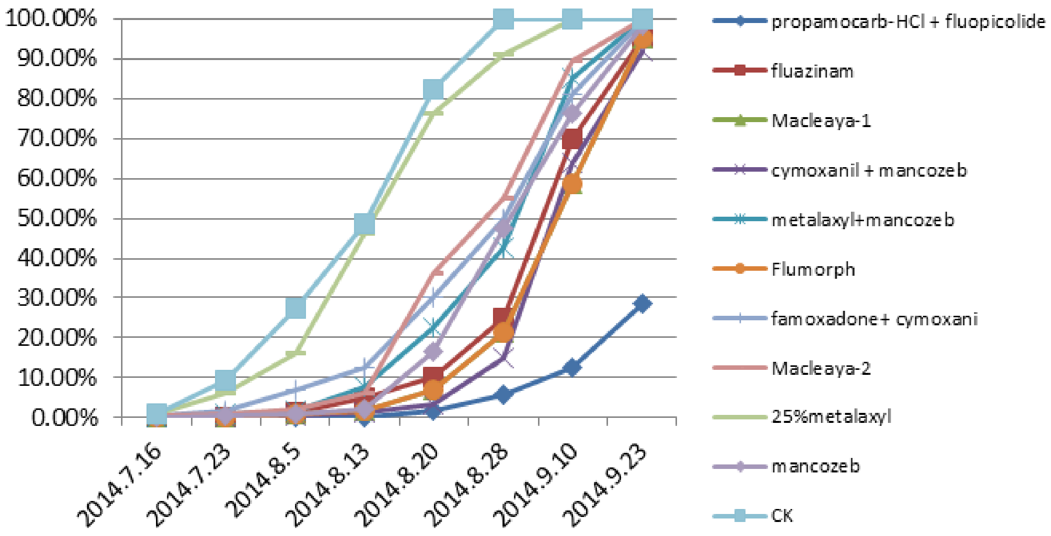

Figure 2.3. *Disease development curve of different treatments.*

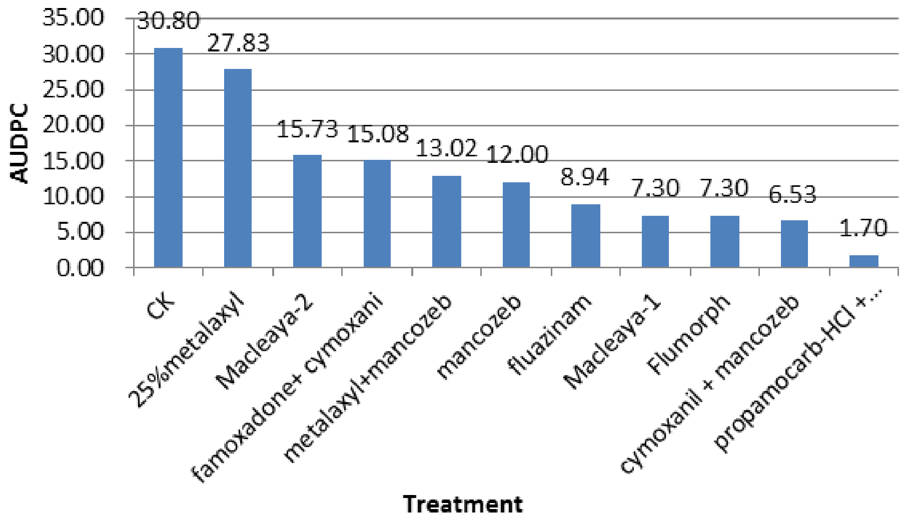

Figure 2.4. *AUDPC values in trial of different treatments.*

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.

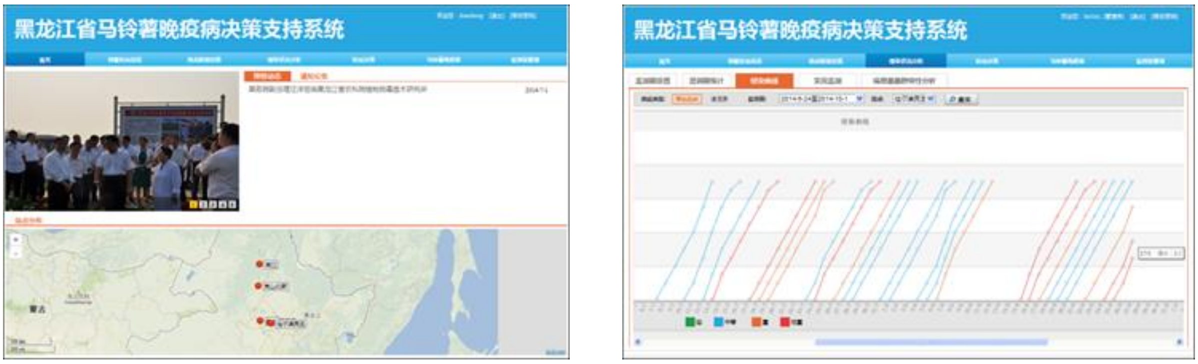

Figure 2.6. Screenshots of application of the HAAS-CRAW.

Figure 2.7. *Impressions of interaction and field visits staff DLV Plant, PPO/PRI 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

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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 Appendix 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).

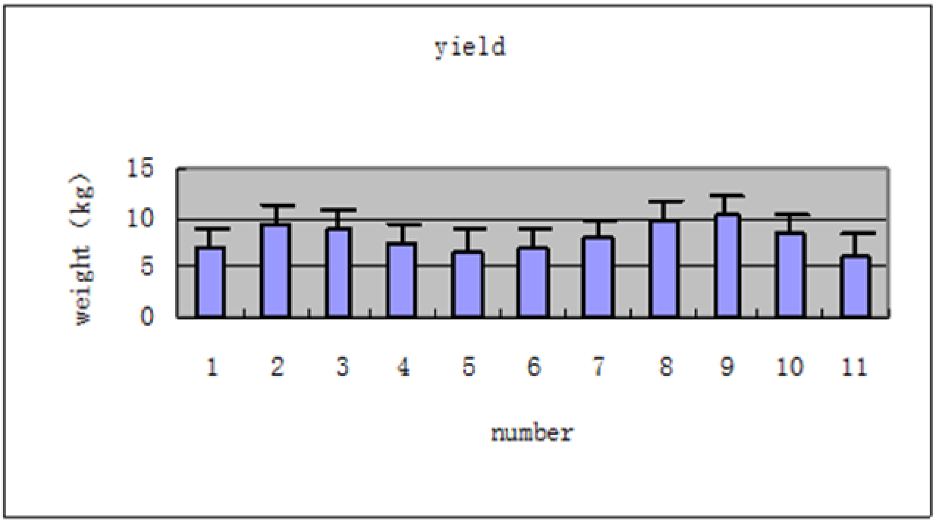

Figure 3.3. Mean tuber yield (kg per 1.95 m^2) per seed lot (unspecified date).

Figure 3.4. Pictures of plots of seed lot 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 June 3 and September 12 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 July 29 201 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).

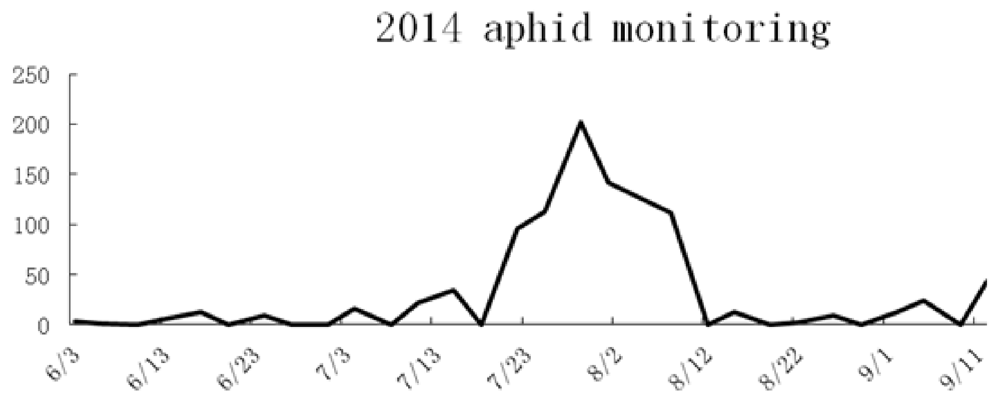

Figure 3.6. Number of aphids in yellow aphid trap (see Figure 3.5) during the growth season of 2014.

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 repetition of 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 UR PPO/PRI

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.

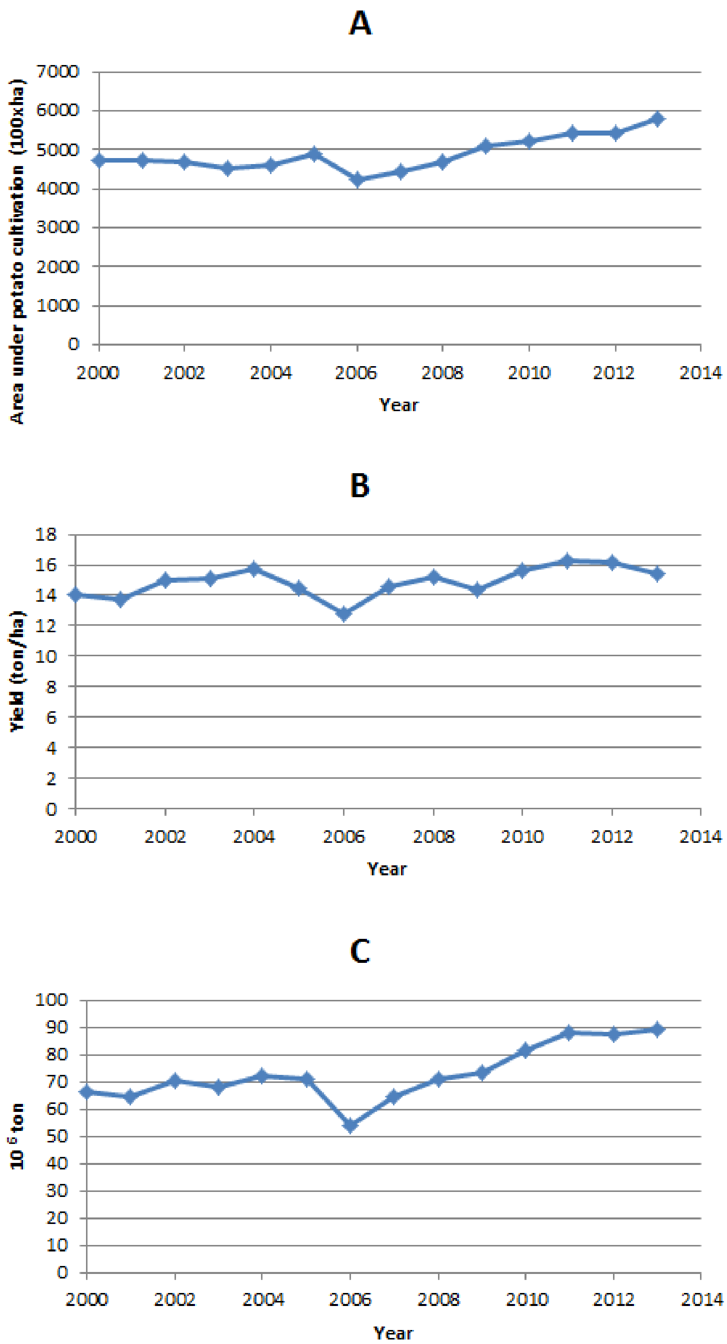

Figure 4.1. The total area under potato cultivation (A), the average yield of potatoes (B) and the total amount of potatoes produced (C) in China for the past 13 years (FAO STAT).

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).

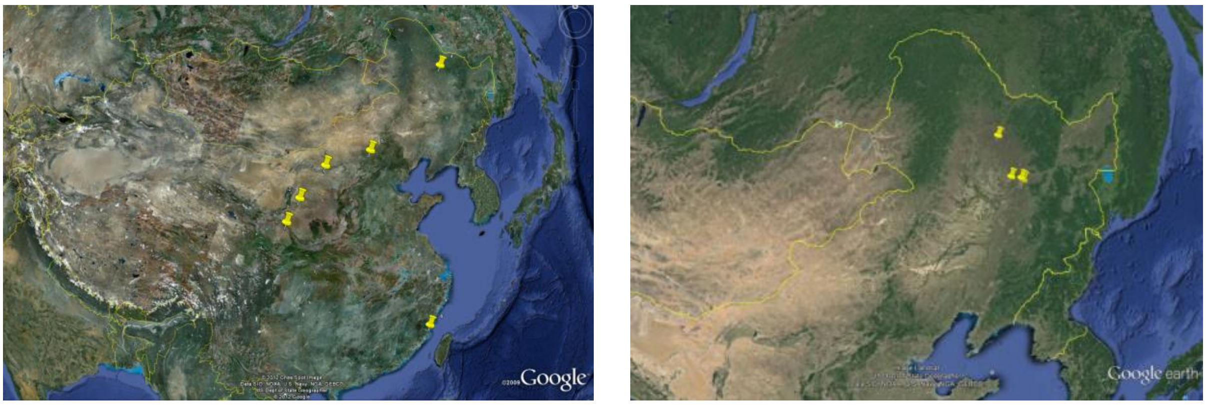

Figure 4.2. An overview of the study areas of the national study of China (left) and of the provincial study of Heilongjiang (right).

4.3.2 Data collection

Data were collected for the yield gap analysis and the carbon foot printing by email after sending a questionnaire (Appendix I) 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 and Research centre, the Netherlands (2011). Recently with the aid of McCain potato agronomists at a few continents dr. Hillier and dr. 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 general study

An overview of all answers in the questionnaires is given in Appendix IIA. 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 l 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).

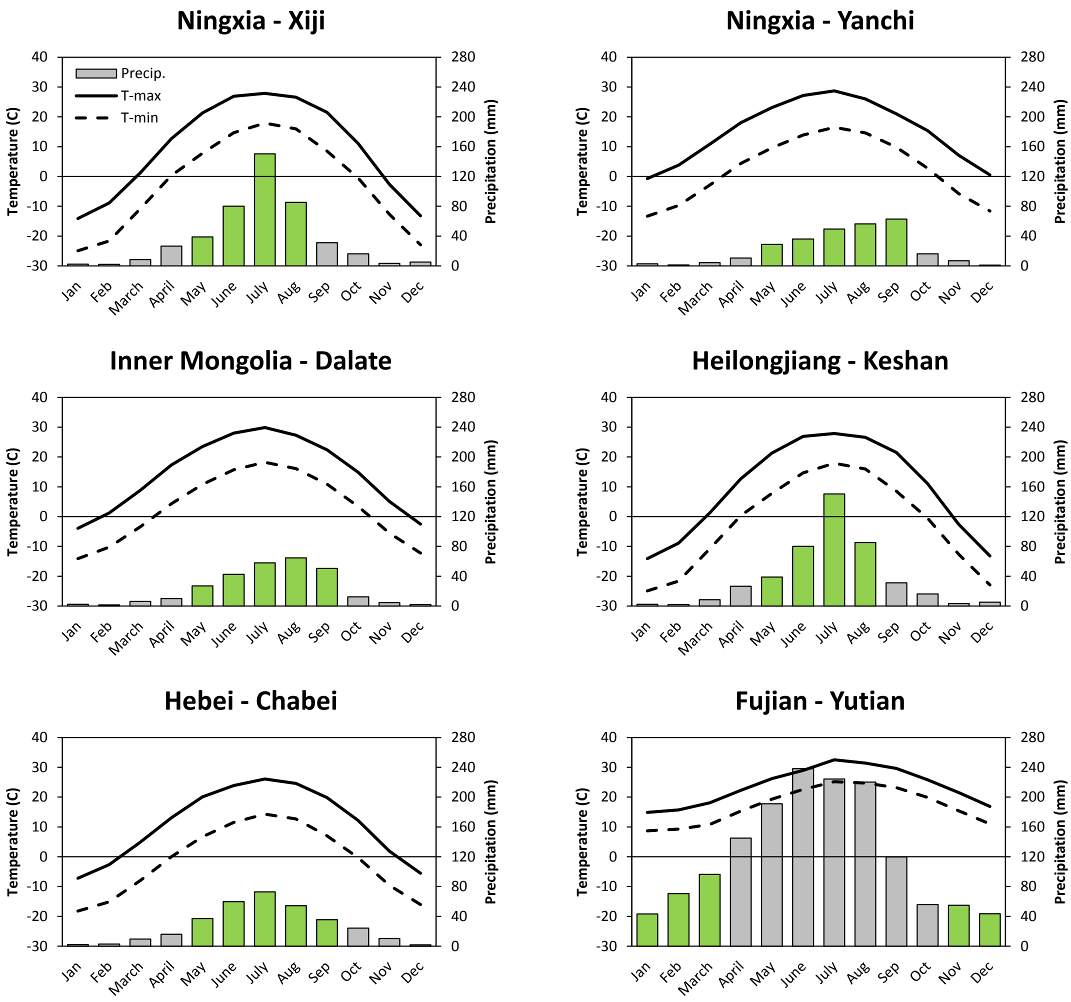

Figure 4.3. *The minimum (T-min; °C) and maximum (T-max; °C) temperature and total precipitation per month (Precip.; mm) for six locations in China. Green bars indicate the potato growing season.*

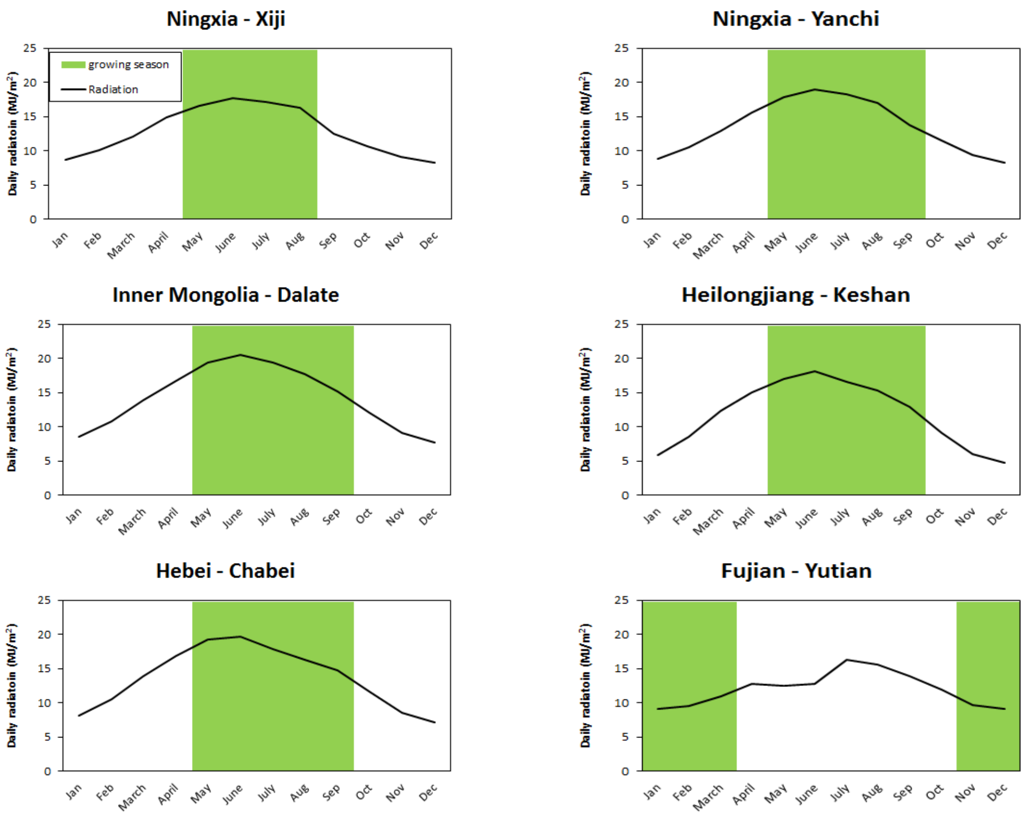

Figure 4.4. *Average daily radiation per month (MJ/m²) for six locations in China. The green area indicates the potato growing season.*

Data collected in the provincial study

An overview of all answers of the questionnaires of the provincial study is given in Appendix IIB. 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).

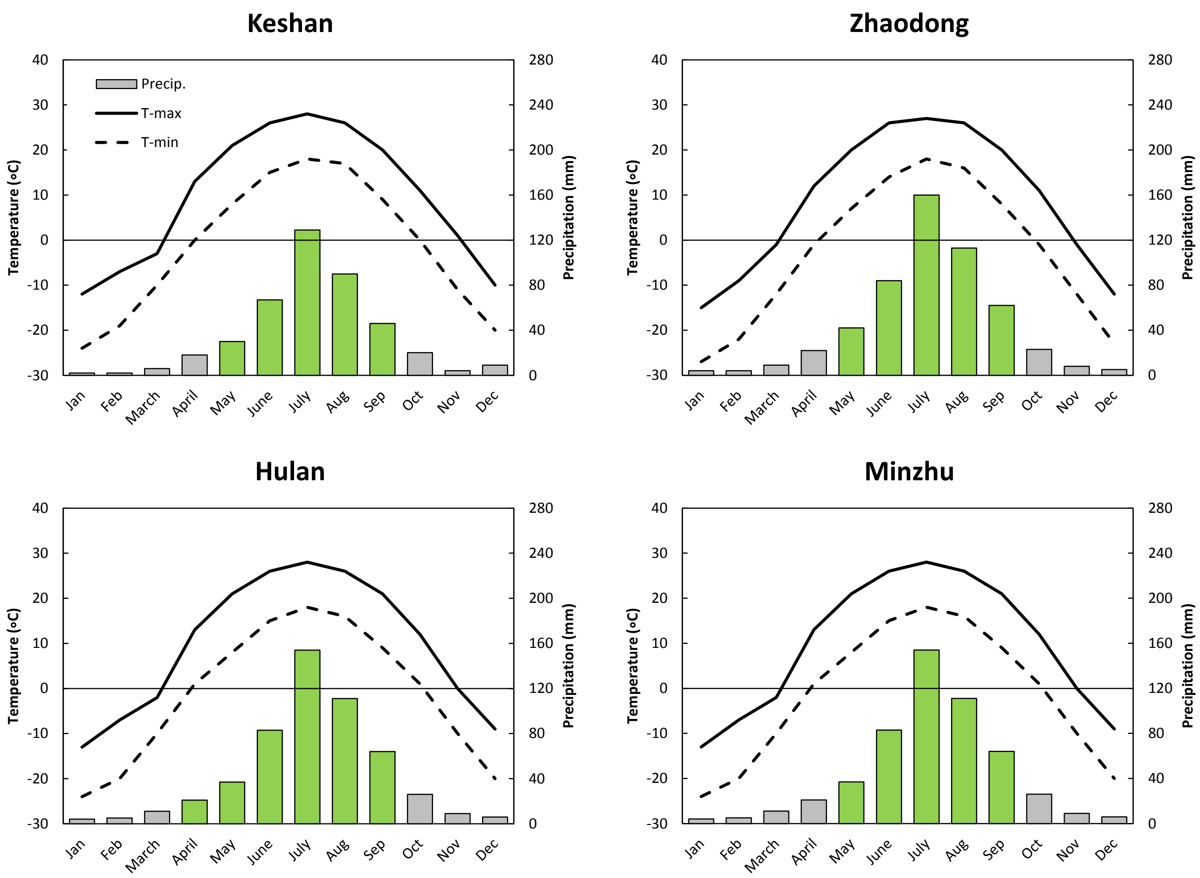

Figure 4.5. The minimum (T-min; °C) and maximum (T-max; °C) temperature and the cumulative monthly precipitation (Precip.; mm) for four locations in Heilongjiang. Green bars indicate the potato growing season.

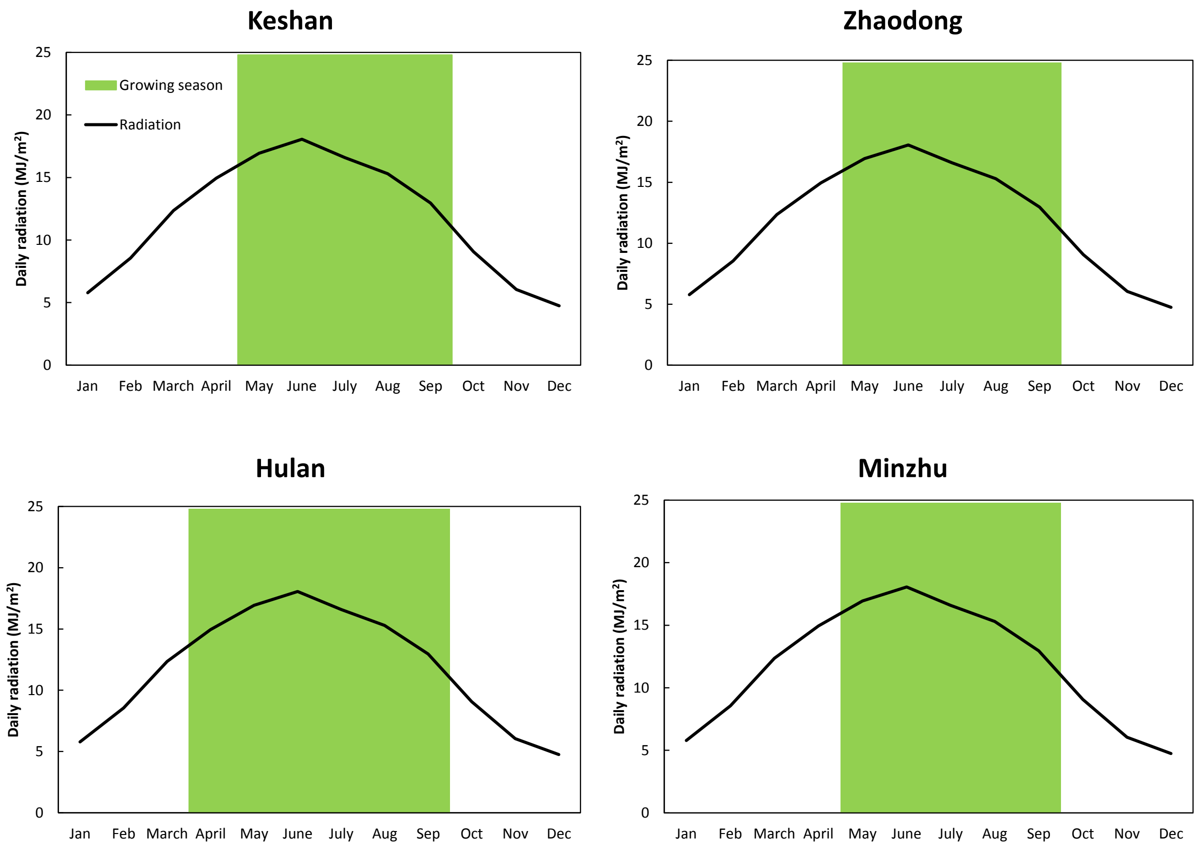

Figure 4.6. The daily radiation (Radiation, MJ/m²) during the year and the growing season for four locations in Heilongjiang. The green area indicates the potato growing season.

4.4.2 Yield gap analysis

Yield gap analysis of the national study

Using the input data from **Error! Reference source not found.** yields in an attainable fresh tuber yield which varied etween 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.

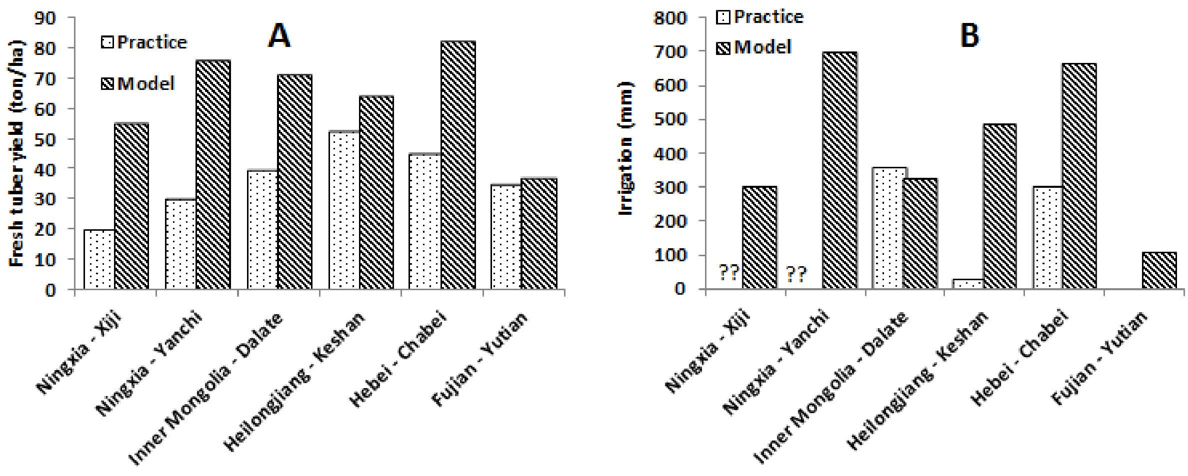

Figure 4.7. *The estimated attainable fresh tuber yield (Model) and the actual fresh tuber yield (Practice) for the six provinces/autonomous regions of China (A) and the practiced irrigation and irrigation needed according to the model estimates (mm season^{-1}; B).*

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 4.8*A). The irrigation need according to the model calculations differed between the different locations and varied between 58 and 700 mm (*Figure 4.8*B). 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.

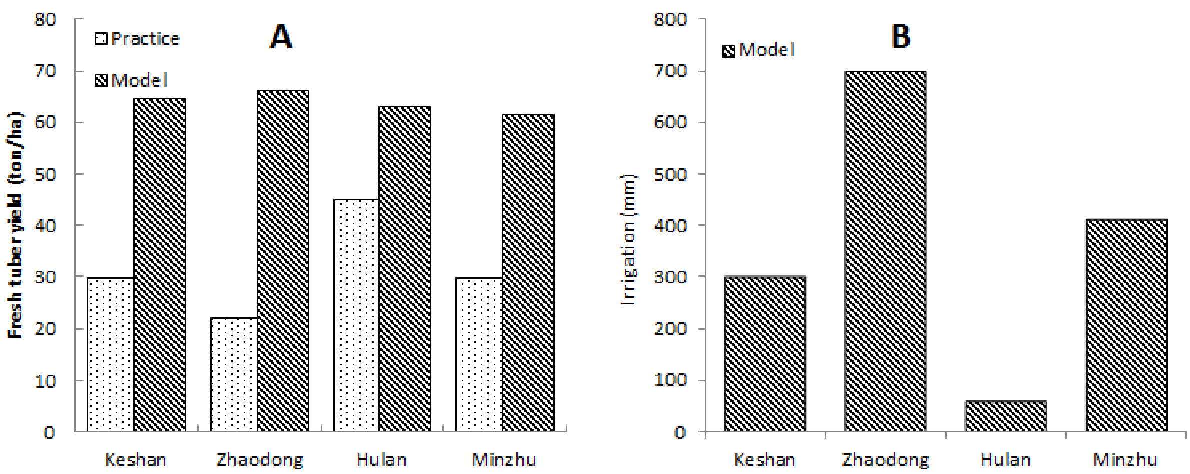

Figure 4.8. *The estimated attainable fresh tuber yield (Model) and the actual fresh tuber yield (Practice) for the different regions of Heilongjiang (A) and irrigation needed according to the model estimates (B).*

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:
  - Differences between provinces/autonomous regions are mostly related to differences in yield.
  - 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.
  - Irrigation contributes considerable to the kg CO_2-eq/tonnes and is the second largest load.
  - Seed production and transport contributes between 6% and 12% to the total load in Hebei/Fujian and Ningxia – Xiji respectively.
  - 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:
  - 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.
  - 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

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:
  - 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.
  - Irrigation contributes as the second largest load (kg CO_2-eq/ton) in all regions where irrigation is applied due to electrical pumping.
  - Storage costs are low compared to those for crisping potatoes in the Netherlands.

- Plus storage and transport:
  - Storage costs are low and comparable to those for crisping potatoes in the Netherlands.
  - 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.

4.6 References

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5. Impressions on potato storage in Heilongjiang province

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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 5.2 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 5.3 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. Pictures of McCain storage facility in Harbin (April 2014).

Figure 5.5. Pictures inside of 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. Communication

6.1 Abstract

In the years 2012 to 2014, 5 missions from Dutch experts to China and 3 missions 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. Over 25 presentations, several workshops and over 10 publications resulted from the project so far.

6.2 Communication activities and results

6.2.1 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.

6.2.2 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.
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:

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6.2.3 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.

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7. Concluding remarks

This mid-term report contains information on the status of China's potato production. It shows the issues of potato production in China. And it reports results of some studies carried out to solve these issues. We lack hard statistics on the relative importance of the issues, but the observed wide range of potato R&D by Chinese institutes and companies is an indicator that progress will be made in the coming years. 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. The modernization trend is also seen in other Northern provinces in China, like Inner Mongolia and Hebei. We expect this trend 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.

In the China potato GAP project, many communication activities took place. The activities were focussed on knowledge dissemination of different GAP topics. However, more efforts are needed to disseminate GAP knowledge to the end users in China. A good way to do this, is to develop tailor-made dissemination strategies per province or region in China to match relevant Chinese cultural and socio-economic conditions. The different dissemination pillars are: involvement of stakeholders in the R&D activities, demonstration farms on representative locations, 'train the trainer' activities (targeted at e.g. farm advisors and potato industry staff) and supporting communication activities. The China potato Gap project wants to cooperate with other knowledge transfer parties in China like CIP Beijing and extension services, under the flag of SAITIP or other coordinating bodies.

In conclusion, much progress is made in the past 10 years in potato production in China. But there is still a lot to be done in order to increase China's potato production in a sustainable way. Potato consumption in China is likely to double in coming 10 years. For the short term and the China potato GAP project, we recommend to continue the experiments described in chapters 2 to 4 of this report. Knowledge and technology dissemination in Heilongjiang will be accelerated if large scale field demonstrations can be set up in 2015, in combination with a symposium on promising new technologies, monitoring and decision support systems. Tailor-made soil tillage in combination with high quality seed potatoes and sustainable crop production methods will lead to higher yields of potato production in China. Results in Heilongjiang can be used as a blueprint to introduce promising technologies and know how in other parts in China, in combination with tailor-made dissemination strategies and specific demonstration farms, symposia and trainings.

So, a bright future is seen with much work to do. ToDo is one of the Chinese words for potato. So, a lot can be gained with R&D and extension to do on ToDo.

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Appendix I.
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 Corne 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)	%		$SOM \le 1.7$	Choose one of the options
			$1.7 < SOM \le 5.2$	
			$5.2 < SOM \le 10.3$	
			$SOM > 10.3$	

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 ☐ petrol	Indicate the type of fuel that is used by your tractor
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

Appendix IIA.
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

	Ningxia - Xiji	Ningxia - Yanchi	Inner Mongolia - Dalate	Heilongjiang - Keshan	Hebei	Fujian - Yutian, Changle
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

	Ningxia - Xiji	Ningxia - Yanchi	Inner Mongolia - Dalate	Heilongjiang - Keshan	Hebei	Fujian - Yutian, Changle
Slurry injection	0	0	0	0	0	0
Slurry transport	0	0	0	0	0	20
Manure spreading	1	2	0	0	0	0
Manure transport	5	2	0	0	0	0
Fertilizer spraying	1	2	5	0	15	0
Fertilizer spreading	3	2	1	1	2	1
Pesticide spraying	1	2	1	5	2	4
Irrigation						
Irrigation water (mm)		?	357	29	300	6
Depth irrigation water (m)		0.1-0.25	80	130	80	5
Horizontal transport distance (m)		1000	0	0	500	20
Type of irrigation equipment	none	Drip irrigation	Pivot	Pivot	Pivot	Flooding
Power supply for irrigation		Electricity	Electricity	Electricity	Electricity	Electricity
Foliage destruction						
Type of foliage destruction	Manual	haulm flailing	haulm flailing	haulm flailing	haulm flailing	manual
Harvesting and storage						
Type of harvest	Manual	Fully mechanical	Fully mechanical	Windrowing	Windrowing	manual
Transport distance (m)	1500	3000	350	15000	15000	300
Fresh product harvested (t/ha)	20.2	30	40	52.5	45	35
Sold product	9.1	30	40	44.6	20	33
Washing potatoes (%)	30	0	0	0	0	100
Fuel type	Electricity				Electricity	Electricity

	Ningxia - Xiji	Ningxia - Yanchi	Inner Mongolia - Dalate	Heilongjiang - Keshan	Hebei	Fujian - Yutian, Changle
Grading potatoes (%)		85	100	85	0	80
Fuel type		electricity	electricity	electricity		electricity

Storage of potatoes (%)	55	100	100	15	55	15
Energy source for loading/unloading the storage	Electricity	Diesel	Diesel	Petrol	Electricity	??
Duration of storage (months)	6	7	4.5	6	5	0
Temperature difference (°C - cooling)	0	0	0	0	0	0
Crop protection treatments	0	0	0	0	0	0
Comments			see comment 1	see comment 2	see comment 3	
			Cv Burbank	Seed tuber company	Average over varieties	
			Soil is very sandy	Product sold to south China	food, seed, french fries	
				Irrigation only once in 2012		

Storage temperature: All storage under cool conditions: no difference in temperature with outside assumed. In Fujian no storage.

Transport off-site: only for seed potatoes and slurry/manure. Not for harvested product.

Comment 1: The farm belongs to a local potato product company whose processing site is 300km away. The variety described is Burbank; they also have Shapody planted but the fertilize usage is different so we chose one as sample. Soil in Dalate is completely sand. And the average wind speed is about 3 m/second. So they make ridge for 3 times because wind will destroy the ridge in the early stage of the plant. Irrigation water is 100,000t in total life period for a 28 ha pivot irrigation circle

Comment 2: This site is run by a local seed tuber production company, 85% of its harvest was sold to south China as seed tuber, while 15% leftover for self-reproduction. The pivot irrigation was used only once (6000 tonnes for 21 ha) in the whole planting life in year 2012, for precipitation was enough in summer.

Comment 3: This questionnaire was interviewed from the Snowvalley company, whose farms in Chabei district, Zhangjiakou city, Hebei province. The data was averaged from 530 ha land. Variety were Shapody (for food process), Atlantic (Seed tuber use), Favorita (seed use), Innovator (French Fries use).

Appendix IIB.

Questionnaire responses of the provincial study in Heilongjiang

	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 and chicken manure		
2					
3					

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

Appendix III.
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 Centre (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

Appendix IV.
Protocol field testing PVY resistance in potato varieties

Derived from:

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.

Appendix V.

Protocol field testing *Phytophthora resistance* in potato varieties

Derived from:

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.

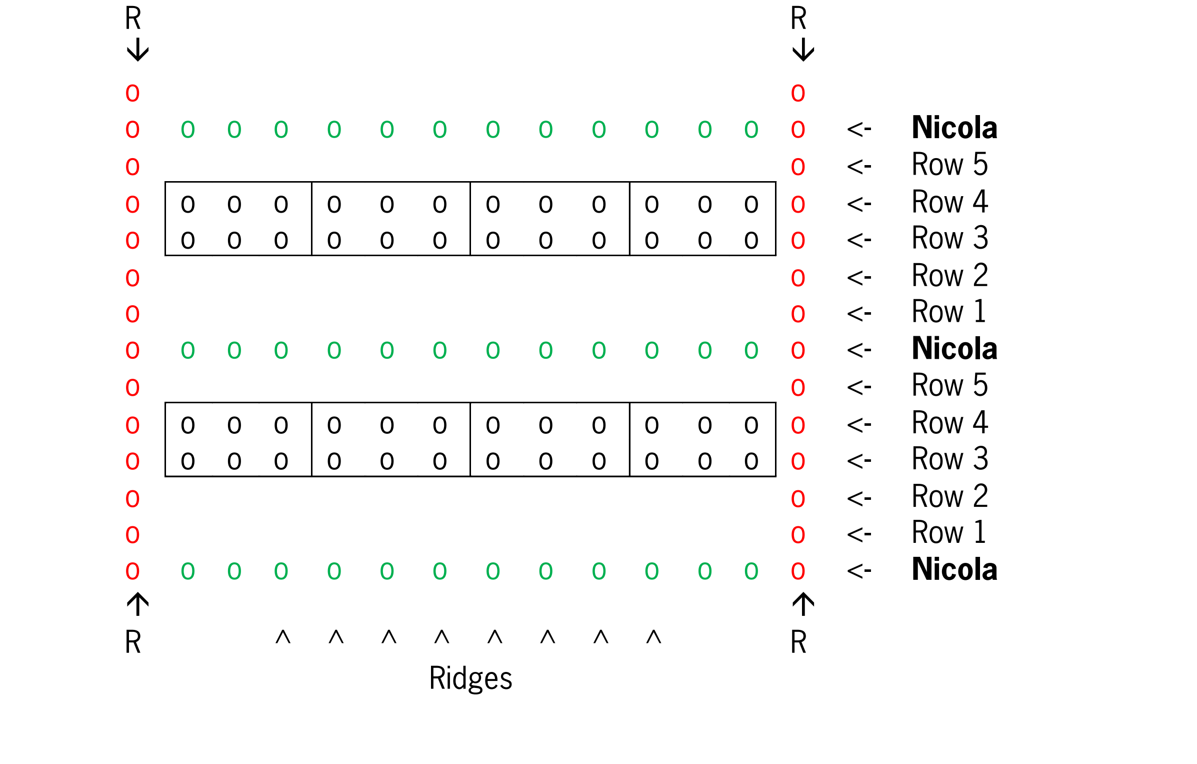

Figure 0.1. Experimental setup as described above under "Experimental setup". Variety Nicola (o) is moderately susceptible (MS). The outer two ridges are planted with a late and moderately resistant variety (o).

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.

Literature

Colon, L.T. and D.J. Budding, 1988. Resistance to late blight (Phytophthora infestans) in ten wild Solanum species. Euphytica 37: 77 - 86.

Fry, W.E., 1978. Quantification of general resistance of potato varieties and fungicide effects for integrated control of potato late blight. Phytopathology 68: 1650 - 1655.

Kessel, 2014. Protocol translated from Dutch (Protocol voor het Cultuur- en Gebruikswaarde Onderzoek van Aardappelen – 2013, Raad voor Plantenrassen, the Netherlands - March 2013) by GK, April 2014

Appendix VII.
Information on PPS partners in Potato GAP China (January 2015)

In this appendix 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, institute PPO/PRI.

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.

PPO/PRI 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, PPO/PRI serves the entire agro-production chain with scientific products, from the DNA level to production system concepts. PPO/PRI regularly has articles in the leading scientific journals and has a superb research infrastructure. PRI is short for Plant Research International, PPO Plantaardig Praktijkonderzoek (Applied Plant Research). Head office of PPO/PRI is in Wageningen, The Netherlands.

More information: www.wageningenur.nl