Muresk Institute

Supply of Affordable High Quality Potato Seed for Potato Production in the Red River Delta of Vietnam

Dang Thi Hue

This thesis is presented for the degree of
Master of Science in Agriculture
of
Curtin University of Technology

November 2008

Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University.

Signature:……………………………………………

Date:…………………………………………………

Abstract

Poor quality seed is the major constraint limiting both the productivity of potato crops and the expansion of the potato industry in Vietnam. Despite numerous attempts to establish a certified seed system, the most practical solution is to import clean foundation seed of the desired variety and physiological age. With imports from Europe and North America proving to be immature and too expensive, Western Australia (WA) has emerged as a potential source of high quality seed. While seed imports from WA are unique in that the varieties imported have been selected by researchers in Vietnam as being suited to the agro-ecological environment in the Red River Delta (RRD), no assessment of the economic benefits to smallholder potato farmers from the use of WA potato seed has been undertaken. In 2006/08, the yield and profitability of three potato varieties Eben, KT3 and Atlantic in two locations were compared where the crops had been derived from new seed imported from WA (VN0), seed derived from crops cultivated in the RRD after one generation (VN1) and two generations (VN2). There was a significant difference in the yield produced between the three different seed sources but not between the locations. For all varieties, and in both years, the yield decreased with the number of multiplications in Vietnam. Furthermore, the marketable yield declined significantly from the first crop (VN0) to the third crop (VN2). The decline in yield and tuber quality with each successive generation was associated with an increase in PVY and PVX infection. Not unexpectedly, differences in yield and marketable yield between the seed generations had a significant impact on the gross income for each variety. VN0 seed of all varieties produced the highest gross income (VND 2.4 to 4.1 M/sao) compared to VN1 (VND 1.9 to 3.1 M/sao) which was significantly higher than VN2 (VND 1.4 to 2.4 M/sao). However, while high quality seed is more productive, it is also more expensive. As a result, significant differences were observed between the seed costs. VN0 seed was almost two times more expensive (VND 10,500 – 11,000 per kg) than VN1 and VN2 seed (VND 6,000 – 6,500 per kg). Despite the higher costs, VN0 seed provided the highest net incomes compared to VN1 which was significantly higher than VN2. Farmers who retained seed received a higher net income (VND 0.13 – 0.6 M/sao) than those who did not retain seed. Ways to improve the accessibility of affordable, high quality potato seed to farmers in the RRD are discussed.

Acknowledgements

I am most grateful to my supervisors, Associate Professor Peter J. Batt, Dr. Ian McPharlin and Mr. Peter Dawson for their enthusiasm and support for my study. It is hard to express my gratitude for their continuous support, coaching and advice.

I would like to thank the Vietnamese Government for providing my scholarship and the Department of Agriculture and Food Western Australia for the financial support. Without these, this research would not have been done.

Furthermore, I wish to thank the Centre of Root and Tuber Crop Research and Development at the Food Crop Research Institute (FCRI) for giving me this precious opportunity to study at Curtin University of Technology.

I am grateful to Mr. Terry Hill and Mr. Paul Mattingley from the Department of Agriculture and Food WA for their continuous support, friendship and encouragements that make my study possible in Western Australia.

I particularly wish to thank Mr. Kon Peos from Southern Packers in Manjimup, Western Australia for providing potato seed. I also thank and acknowledge the assistance of FCRI staff, specially Dr. Truong Cong Tuyen, Ms. Vu Thi Lieu and Mr. Tran Quoc Anh, who assisted with the experiments and harvesting of potato.

I wish to thank to Mr. Dale Spencer, Mr. Andrew Taylor and Mr. Tony Shimmin from the Department of Agriculture and Food WA for their support in providing potato information and figures; and Mrs Jenny Lalor at the Centre for Educational Advancement at Curtin University of Technology for her support with the SPSS analysis.

Many thanks to my Vietnamese friends, especially Ms. Minh Tam Pham and Ms. Huong Mai who have been great sources of support and encouragement which helped me to cope with the difficulties experienced during my stay in Perth.

I am indebted to my parents for their understanding, support and encouragement during my study. I am especially grateful to my beloved husband for his incredible personal sacrifice, patience and support. For my little daughter Thuy Dung who always asked "Mum, when will you come home?", you are all a great source of inspiration which has made it possible for me to complete this thesis.

Abbreviations

ACIAR	Australian Centre for International Agricultural Research
AGWEST	Business Unit of Department of Agriculture and Food, Western Australia
AUD $	Australian dollar
AVRDC	Asian Vegetable Research and Development Center
BMP	Best Management Practice
CIP	International Potato Center
cm	centimetre
DAP	days after planting
FAO	Food and Agriculture Organization
FCRI	Food Crop Research Institute
Go	generation 0
G1	generation 1
G2	generation 2
G3	generation 3
G4	generation 4
G5	generation 5
g	gram
GSO	General Statistic Office
ha	hectare
HAU	Hanoi Agricultural University
IAS	Institute of Agricultural Science for Southern Vietnam
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
K	potassium
kg	kilograms
LSD.	least significant difference
m	metre
MARD	Ministry of Agriculture and Rural Development
mm	millimetre
N	nitrogen
NCVESC	National Centre for Variety Evaluation and Seed Certification
^{o}C	degrees Celsius
P	phosphorus
Pers.comm	personal communication
RRD	Red River Delta
t	tonnes
t.p.a	tonnes per annum
t/ha	tonnes per hectare
S.E.	standard error
TPS	true potato seed
USDA	United States Departments of Agriculture
USSR	Union of Soviet Socialist Republics
VAAS	Vietnamese Academy of Agricultural Science
VG-PPP	Vietnam –Germany Potato Production Promotion Project
VND	Vietnamese Dong

EQUIVALENTS

1 sao = 0.036 hectares

AUD 1.0 = 11.500 VND (November 2008)

Table of Contents

Appendices

List of Tables

List of Figures

Chapter One:

Introduction

1.1. Background

In Vietnam, potatoes have been cultivated for more than one hundred years after being first introduced by French colonialists. Potatoes remained a minor vegetable crop in the garden of most Vietnamese until the 1970's when population growth and the successful introduction of new short duration rice varieties enabled potatoes to fit into the winter cropping season between the two rice crops in North Vietnam (Tung 2000). Due to a serious deficiency of food at that time, potato was considered for inclusion as a staple food in the Vietnamese food system (Chung 2001).

Potato is the second most important food crop after maize in the winter cropping system in the Red River Delta (RRD) where 98% of Vietnam's potatoes are cultivated (Tung 2001). Potato is a priority crop for development by the Government because it is an alternative food crop to rice, which is capable of feeding an increasing rural population and providing both nutrition and income for many rural families (Batt 2003b).

In 1980, Vietnam was the largest producer of ware potatoes in South East Asia with more than 100,000 ha under cultivation (Batt 2002). However, in the absence of good quality seed, poor production and the introduction of other more profitable food crops, the area of potatoes cultivated has declined to about 35,000 ha and the average yield in the RRD approaches only 13 tonnes per ha.

Poor quality seed has been acknowledged as the major constraint limiting the productivity of potato crops in Vietnam (Tung 2000). Seed constraints include the unsuitability of most varieties to the agro-ecological conditions experienced in Vietnam and the poor management of seed quality (poor seed husbandry, poor seed selection and poor seed storage conditions). Under the current system of seed multiplication in Vietnam, farmer volunteers select small tubers from the harvested crop for seed which they then store for the next season nine months later (Hoa *et al.* 1995).

In Vietnam, as there is no certified seed scheme; farmers buying seed have no means of knowing whether the seed is of good quality and seed growers have no means of securing a good price for the seed they have produced (Hue 2006). Therefore, Vietnam needs to introduce an appropriate certified seed potato production system.

However, after numerous attempts to introduce a certified seed system based on European protocols, most have failed due to the unsuitability of the models to the agronomic and economic conditions in Vietnam. The schemes have been successful developed in temperate areas where there is isolation from commercial crops, a low number of aphids, good seed storage, and field multiplications can be done over many generations to defray the cost of the foundation material. This cannot be done in Vietnam. Therefore, the most practical solution may be to import good quality seed and to reduce the cost of the seed to farmers by undertaking one or more subsequent multiplications of the seed in-country (Batt 2003). With a limited number of field multiplications, the incidence of seed borne disease can be minimized. This ensures that farmers can buy good quality seed at a lower cost compared to the newly imported seed.

Seed imported from Europe and North America has been used by several projects since 1975. However, the seed is often physiologically too young to yield well in Vietnam for the main October to November planting time. Furthermore, the cost of importing seed from these countries is too expensive for the majority of small farmers to purchase (Tung 2000). In addition, the use of imported seed restricts Vietnamese farmers' choice of varieties to those which are available from the exporters (Fuglie *et al.* 2006).

With average seeding rates approaching 1,100 kg per ha, the Vietnamese potato industry needs some 38,500 tonnes of seed annually (Batt 2002; Chung 2003). Several institutions and universities including the Food Crop Research Institute (FCRI), the National Seed Company in Hanoi and Hanoi Agricultural University have attempted to produce and multiply good quality seed for the farmers by mini-tuber and tissue culture production. However, these attempts to improve seed quality have generally failed as the seed degenerated too quickly under Vietnamese cultural conditions, and the cost of this type of seed is more expensive compared to other seed sources. Furthermore, the quantity of seed produced (G1 and G2) has been unable to satisfy more than 5% of the demand.

Over recent years, a large quantity of seed potatoes has been imported from southern China by various agencies. In 1999, the quantity of imported Chinese seed was estimated to exceed 10,000 tonnes. However, this seed was derived from the small tubers harvested from the ware crop, which would ordinarily be used for animal feed (Tung 2000). Many seed lots are a mixture of varieties, and potentially there is the high risk of importing a number of pests and diseases including powdery scab *(Spongospora subterranea)* and potato cyst nematode *(Globodera rostochiensis and G. pallida).* However, this seed is widely used in the RRD as it is inexpensive and sprouts at the right time for planting (Chung 2003).

The high incidence of pests and diseases, especially viral diseases, is considered to be the most important factor causing the degeneration of seed potatoes in the RRD. Ho *et al.* (1983) indicated that the infection rate by viral disease could reach 90% after only two seasons of cultivation in the RRD.

The lack of good, locally produced seed plus the high cost of European certified seed force farmers to use the Chinese seed. The poor quality of this seed is made worse following un-refrigerated diffuse light storage that leads to low yields and poor quality potatoes. Thus, potato production in Vietnam could be improved considerably if a greater quantity of high quality seed was available to replace most of the low quality seed purchased from informal sources. The most practical solution it seems is to import affordable good quality seed and to reduce its cost by undertaking one or more subsequent multiplications in-country.

With seed imported from Europe and North America proving to be too immature and expensive, Western Australia (WA) is emerging as a potential source of affordable good quality seed. Potatoes are the largest vegetable crop cultivated in WA. From an agronomic perspective, potatoes are produced under almost ideal conditions. In WA, the seed potato production areas are free from bacterial wilt (*Ralstonia solanacearum*), potato cyst nematode (*Globodera rostochiensis* and *G. pallida*), late blight (*Phytophthora infestans*), potato virus Y *(necrotic strain)* and potato leaf miner (*Liriomyza huidobrensis*) (Schmiediche 1995; Holland and Spencer 2007).

Seed potatoes in WA are produced as registered and certified seed under the National Seed Potato Certification Standard (Dawson, McPharlin and Howes 2003). These standards were developed to facilitate more efficient interstate and international trade

(Sully 2000). The WA Seed Potato Scheme was introduced by the Department of Agriculture and Food to provide industry with an independent, government inspection service. The purpose of the scheme is to ensure the authenticity of the cultivar, the disease–free condition of the seed and to monitor seed quality (Holland and Spencer 2007).

Seed potatoes are available in WA all year round. This enables WA to provide seed of the desired physiological age for planting in Vietnam (November). When this seed is planted, it emerges uniformly and it tuberises earlier than seed imported from Europe and North America (Kustiati 2005). The geographic proximity of WA to Vietnam is beneficial in terms of the reduced transportation time and the younger chronological age of the seed. In addition, WA is unique in that the varieties imported have been selected by researchers in Vietnam as being suited to the agro-ecological environment in the RRD and market preferences in Vietnam. These aspects provide WA with a competitive advantage in the supply of seed potatoes to Asia compared to European countries (David 2001). Therefore, importing WA seed potatoes is an attractive alternative for Vietnam (Batt 2003b).

1.2. Objectives of the study

While numerous trials have been conducted to demonstrate the significant positive impacts from the use of good quality seed, no evaluation of the agronomic and economic impact on smallholder potato farmers in the RRD from the use of high quality seed imported from WA has been undertaken. Specifically, this project aims to compare the cost-benefits to smallholder potato farmers in the RRD arising from the use of potato seed:

1. sourced from WA (VN0)
2. derived from WA seed after one generation in the RRD (VN1)
3. derived from WA seed after two generations in the RRD (VN2)

The study has three major objectives:

1. to evaluate the extent to which the yield declines with each subsequent multiplication of the seed in the RRD
2. to evaluate the extent to which the decline in yield is associated with an increase in the level of selected viral disease

3. to evaluate the socio-economic impact of seed degeneration on smallholder potato farmers in the RRD.

1.3. Significance of the study

The study will examine the cost/benefit of using seed imported from WA in the RRD. This information is of great practical importance as it will greatly assist the Vietnamese potato industry to decide whether imported seed from WA should become a part of any formal seed supply system.

If imported seed potatoes are shown to provide a benefit for the Vietnamese potato industry then the Vietnamese seed certification authorities will most likely incorporate imported seed into a Vietnamese seed certification system. This will provide official recognition for the seed which is bulked by Vietnamese farmers. If imported seed potatoes are included in a Vietnamese seed scheme, the supply of improved quality seed potatoes will increase. This will lead to an immediate gain in productivity for farmers who currently have no access to good quality seed.

Potato production in Vietnam would be improved considerably if a greater quantity of high quality seed was available to replace most of the low quality seed purchased from informal sources. There is, within the RRD, the potential to cultivate 400,000 ha of potatoes if a reliable supply of good quality seed can be established.

1.4. Thesis outline

This thesis is presented in seven chapters. The first chapter has provided a brief description of potato production in the RRD of Vietnam, the research problem, the research objectives and the significance of the study.

While the focus of the research is the value created for smallholder farmers in the RRD from the use of WA potato seed, it is not possible to analyse the impact without some background knowledge of the potato industry in the study area. Thus, Chapter Two will provide a comprehensive review of the botanical characteristics of potato and the importance of potato to the human diet in Vietnam, particularly in the RRD.

Chapter Three provides a review of seed potato quality, the factors influencing the quality of a potato seed tuber, certified seed and seed certification. Further sections will describe the seed system in Vietnam, followed by an exploration of the seed supply and seed certification system in Western Australia.

Chapter Four comprises the research methodology. It begins by providing a botanical description of the three potato varieties used in the project and an explanation of the selected locations for the study.

Chapter Five investigates the performance of WA potato seed in the RRD. It presents the results achieved from on-farm experiments to investigate the tuber yield and tuber quality of WA seed through three generations under Vietnamese cultural conditions. The next section focuses on the level of virus infection for each seed generation for each variety in each study location. The final section describes the interaction between virus infection and yield reduction.

Chapter Six begins by presenting the results of the main quantitative study. It begins with a description of the potato farmers, the farmers' demand for potato seed and their attitudes towards WA potato seed. Subsequent sections provide an analysis of the respective production costs and economic returns for each generation of WA seed.

The final chapter focuses on a general discussion of the agronomic and economic impacts on smallholder farmers in the RRD from the use of WA potato seed. The chapter then discusses the main limitations of the research and provides recommendations for further research.

Chapter Two:

Potato Production in Vietnam

2.1. Chapter outline

The following chapter begins with a brief botanical overview of the potato and the importance of potato to the human diet. An overview of potato production in Vietnam is provided with particular emphasis on the Red River Delta (RRD).

2.2. Introduction

Potato *(Solanum tuberosum* L.) is one of about 2,000 species of the family Solanaceae. Potato was first cultivated in the Andes in the vicinity of Lake Titicaca near the present border of Peru and Bolivia (Horton 1987). In the 16th century, potato was introduced to Europe as a curiosity (Beukema and van der Zaag 1990; Dean 1994). Gradually it became a food crop, especially when varieties adapted to the long day conditions were selected (Beukema and van der Zaag 1990). In the 18th and 19th centuries, the potato was already an important food crop, especially for the poor in many countries in Europe. Potatoes reached most other parts of the world through the European colonial powers, rather than directly from South America. During the 19th century, the potato was introduced to several tropical and sub-tropical countries.

Potato is one of the most important food crops in the world. It is the fourth largest food crop by volume after rice, wheat and maize with global production exceeding 300 million tonnes in 2000 ("World potato situation" Agriculture Canada 2000 cited in McKinna 2001).

Due to its importance in Europe as a staple food, livestock feed and source of starch and alcohol, potato is most often thought of as a crop whose production and use is largely confined to industrial nations (Horton 1987). Although it is not a staple food in Asia, the demand for potato is increasing due to population growth and the boom in western food and the snack industries. Potato in these areas is expanding due to increasing demand for fresh and processed potato (Dowling 1995). With increasing prosperity, there is an associated increase in the consumption of processed potato products and a corresponding shift from a staple food to a snack food (van der Zaag 1990).

The relatively high carbohydrate level and low fat content of the potato makes it an excellent energy source for humans as well as livestock (Dean 1994). Potatoes contain many of the essential nutrients that dietary guidelines recommend. About 82% of the dry matter is carbohydrate, mainly starch, with some dietary fibre and small amounts of simple sugars. One medium-sized potato (150 g) eaten with the skin provide nearly half of the daily intake of Vitamin C and is one of the best sources of potassium and fibre. One medium-sized potato has 0.42 kJ and yet it provides many of the complex carbohydrates needed to fuel the human body (Kris and McCashion 2005). Although potatoes contain relatively little protein (0.6-1.2% fresh weight), their nutritional quality is better than cereals or soybeans. Potatoes contain at least 12 essential vitamins and minerals, are a rich source of Vitamin C, thiamine, iron and folic acid (Fulton and Fulton 2000).

2.3. Potato production in Vietnam

Potatoes have been cultivated in Vietnam since 1890 when they were first introduced by the French colonialists. Potato is known as "Khoai tây" which translates to "Western root" or "French tuber" (Ho 1987). Potato remained a minor vegetable in Vietnam until the 1970s when population growth and typhoon damage to the rice crop motivated farmers to use the dry season from November to February for potato production (Tung 2000; Anonymous 2006a).

2.3.1. Production trend and distribution

During the 1970s, the successful introduction of new short duration rice varieties enabled potatoes to fit into the winter cropping season between the two rice crops in North Vietnam. In the 1980s, Vietnam was the largest producer of ware potatoes in South East Asia with more than 100,000 ha under cultivation (Batt 2002). Most of this was found in the RRD at low latitude (20^{o} N), except for a few hundred hectares which were cultivated in the highlands of Dalat at an altitude of 1,500 masl, and some small areas in the mountainous regions of North Vietnam (Appendix 1) (Anonymous 1983). Nowadays, some 35,000 ha of potato are cultivated in the RRD

(Tung 2000; Chung 2006). The reduction in the area cultivated is the result of poor quality seed, poor production and the introduction of other more profitable food crops. Today, the average yield in the RRD approaches 13.4 tonnes per ha (GSO 2006) (Table 2.1).

Table 2.1: Potato yield of RRD and Vietnam (t/ha) from 1995 to 2005

Year / Region	1995	1997	1999	2001	2003	2005
All Vietnam	8.93	10.96	11.58	11.94	12.57	12.52
Red River Delta	9.36	11.16	11.51	12.49	13.42	13.44

Source: General Statistics Office of Vietnam

2.3.2. Importance of potato in the cropping system and food security

Potato is the second most important food crop after maize in the winter cropping system in the RRD (Tung 2000) and is a priority crop for development by the Government as it is an alternative food crop to rice. Potato is capable of feeding an increasing rural population and providing both a valuable source of nutrition and a valuable source of income for many impoverished rural families (Batt 2003b).

In the 1980s, due to a serious deficiency of food, potato was considered for inclusion as a staple food in the Vietnamese food system (Chung 2001). Today, however, the demand for potato is increasing due to population growth and the increasing demand for western food and convenience food as Vietnamese people lead a busier life style (Batt 2003b). At the farm level, the income from potatoes is usually used to meet family expenses during the Lunar New Year festival and for school fees (Tuyen 2001).

2.3.3. Growing condition and cropping systems

Crop duration and planting time

Vietnam's climate is characterized by an alternating monsoon and dry season. In the RRD, potatoes are generally cultivated in the dry season (winter) when temperatures fluctuate between 26°C (October) to 17°C (February) (Anonymous 1983). Typically, potatoes are grown in the RRD for only a very short period between the two rice crops (Ho 1987).

There are two potato crops in the RRD: (i) the winter potato crop (planted in November and harvested February) and (ii) the spring, or late, potato crop (planted in January and harvested in April). Most potatoes are grown during the winter season, when it is cool after the heavy rains and the rice fields are dry enough for soil preparation. The most suitable planting time for potatoes is during the first half of November but some early plantings may take place in mid October. Later plantings are possible during December in the uplands or where the spring rice is not planted. In most cases, potatoes must be harvested before the end of January, for the spring rice crop is normally transplanted during the first half of February. Therefore, the duration of a typical potato crop in the RRD is only 60 to 90 days, which frequently results in premature harvest (Tung 2000; Anonymous 1983).

Starting at the end of October or early November, the weather conditions are quite favourable for potato cultivation. Temperatures range from 17-24^{o}C with a monthly rainfall of 17 - 60 mm which enables good plant growth after emergence. Lower temperatures during the second half of the crop promote rapid tuberisation of the potatoes (Figure 2.1).

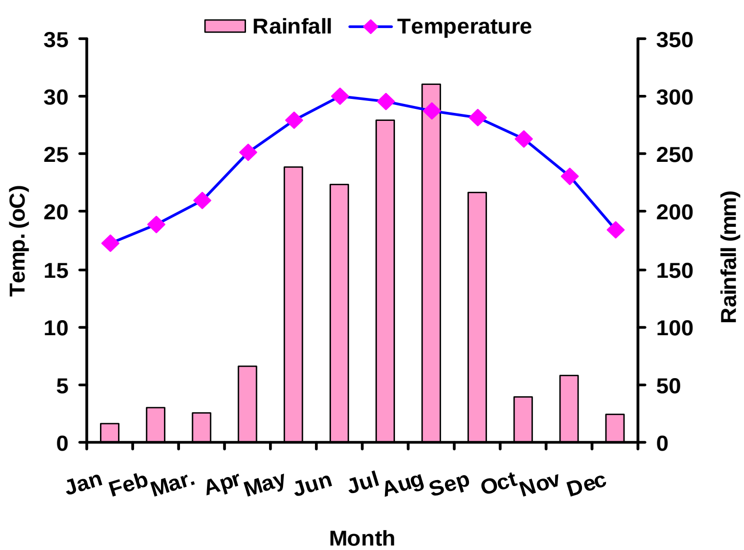


Figure 2.1: Average temperature and rainfall (mean 5 years from 2002 to 2006) in the RRD, Vietnam (GSO 2007)

The weather conditions in the RRD are less favourable for the late crop (planted in December and harvested in March) as the humidity is high and there are limited hours of sunshine. The crops at this time are often heavily infected with late blight and yield poorly (Figure 2.2).

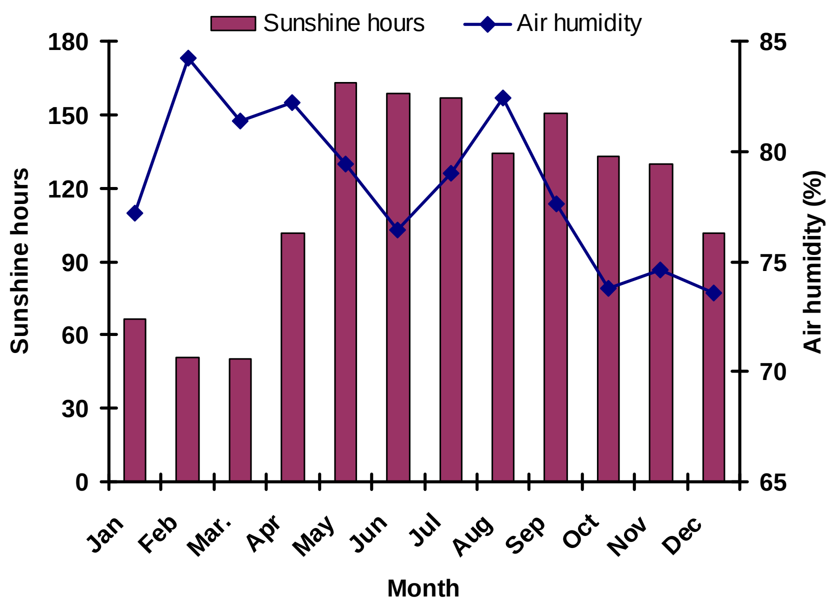


Figure 2.2: Average humidity and sunshine hours (mean 5 years from 2002 to 2006) in the RRD, Vietnam (GSO 2007)

Cropping systems

Most potatoes in the RRD are rotated with rice, where potato is cultivated in the winter between the summer and spring rice crops. The typical crop rotation is spring rice - early autumn rice - potato (Anonymous 1983). In the uplands, potato may be cultivated in cropping systems with other spring and summer crops such as corn, mungbean, soya bean, sweet potatoes and vegetables. Potato remains a winter crop with typical cropping patterns including: spring corn – mungbean – potato or sweet potato – soya bean – potato. During the growing season, potatoes are grown in small fields scattered around in patches with fields planted to sweet potato, winter corn and/or other vegetables such as cabbage, tomato, kohlrabi or onion. With potatoes, inter-cropping is not a common practice in the RRD (Tung 2000).

Soil condition and preparation

Soil compaction is considered one of the major constraints limiting yields and tuber size in the RRD (Tung 2000). Soon after the harvest of the summer rice crop, the soil is ploughed by animal or machine in a moist to wet condition due to heavy rains. Under the muddy conditions experienced in the paddy fields, the soil compacts and becomes very cloggy with cultivation (Ho 1987; Tung 2000). Much effort is then required to reduce the compaction before the potatoes can be planted, especially in soils with high clay content. A common practice to improve the emergence of potatoes is the pre-planting incorporation of organic matter and sand into the seed bed.

2.3.4. Cultivation Practices

Manure and fertilizer application

Manure (animal manure) is normally applied at the rate of 12 – 15 tonnes per ha at the time of soil preparation (Tung 2000; Anonymous 2003). Ash, rice hulls and decomposed rice or legume straw may also be applied to improve the soil texture and structure. To control white grub larvae and termites in the soil, some farmers apply lime before planting.

Chemical fertilizers used include urea, super phosphate, potassium chloride or potassium sulphate. The rates of application in most cases are: 100 - 120 kg N, 90-100 kg P_2O_5 and 110 - 150 kg K_2O per ha (Tung 2000; Anonymous 2003), depending on farmer practice and the soil type. The use of complex foliar and micronutrient fertilizers is not a common practice in the RRD.

Due to the heavy soil type, farmers normally plant potatoes at a density of 4-5 plants per m^2 to ensure they have enough soil for hilling. Other farmers leave a wide space between potato beds for walking into the crop to irrigate or to control weeds, pests and diseases.

Irrigation

In the RRD, potato fields are irrigated 2-3 times during the growing season by furrow irrigation. Water from the canals is pumped into the furrows and retained for a day or two for absorption by the soil. Excess water is then withdrawn to let the field dry until the next irrigation, which normally takes place 2-3 weeks later (Tung 2001). Periodic droughts and heavy rains have sometimes hindered irrigation due to inadequate infrastructure. Surface irrigation is also used in some locations in the RRD where the farm size is too small or canals are not available.

2.3.5. Disease and pest constraints

The RRD has a high incidence of pests and diseases that can cause considerable crop losses and contribute to the rapid degeneration of seed potatoes. The main diseases are late blight *(Phytophthora infestans)* and bacterial wilt (*Ralstonia solanacearum)*, potato virus Y and potato leafroll virus.

Late blight is the most important disease of potatoes as it occurs in all potato growing areas. It usually occurs late in the second half of the main growing season (winter crop) in late December and early January. Severe epidemics often break out during January and February when the weather is cool and wet (Tung 2000).

Unlike late blight, bacterial wilt appears under all climatic conditions and will readily attack any member of the Solanaceae. It is considered to be an important disease reducing the productivity of potatoes in the RRD, more so because the disease can not be controlled by chemicals and is spread by water, seed, equipment and humans. IPM has been introduced to minimize loss, but this is difficult to achieve as farmers often have insufficient land available to meet the requirements for crop rotation, and they have inadequate management inputs (Hue 2006).

Viral infection is high in Vietnam and seed degeneration is rapid. Potato virus X and Y have been detected and infection with potato leafroll virus (PLRV) is common. Only one or two seasons after the introduction of healthy seed potato tubers, the rate of viral infection can range from 69 to 90 percent (Ho *et al*. 1983).

2.3.6. Varieties

In the past, the main variety cultivated in Vietnam was Thuong Tin, which is thought to be the Germany variety Ackersegen, first introduced from France in 1929. This variety was adopted by the farmers because of its early bulking, long dormancy, good storability, medium sized tubers and especially good eating qualities. A big advantage of Ackersegen is that farmers can store the seed under the hot and humid ambient conditions for nine months until the following planting, although seed losses can be as high as 40% (Fuglie *et al.* 2001; Batt 2003b). Thuong Tin's disadvantage is its susceptibility to late blight, potato viruses, bacterial wilt and Fusarium dry rot resulting in low yields of 8 to 10 tonnes per ha (Anonymous 2006a).

In the late 1970s, tissue culture and rapid multiplication techniques were introduced to produce disease-free plantlets by FCRI in Da Lat where there were about 400 ha of potatoes. Opened-pollinated progenies of true potato seed (OP TPS) were introduced to farmers in the RRD in the mid 1980s. The adoption of OP TPS reached 700 ha by 1987 (Fuglie *et al*. 2001). However, poor tuber quality and low yields limited the adoption of OP TPS among the farmers.

In 1990, hybrid true potato seed (TPS) progenies from CIP and India were tested by researchers at the FCRI. The first hybrid TPS progenies were extended to farmers in 1993/94. The most popular hybrid TPS progenies used in the RRD were HPS II/67 and 7/67, which were officially released in Vietnam in 1998 as "Hong Ha 2" and "Hong Ha 7" respectively (Fuglie *et al.* 2001). By 1999, TPS had expanded to 20% of the potato area in the RRD due to the inexpensive initial cost of seed, reasonably good yield, early bulking, cheap transport cost and freedom from most soil and seed borne diseases (Tung 2000). However, the large amount of labour required, misshapen tubers and the wide variation in tuber sizes caused a significant reduction in the use of TPS in the RRD. The area planted to TPS dropped from 8% in 2003 to less than 4% in 2004 (Chung 2003; Tuyen 2008).

Since the early 1970s, there have been a number of European potato varieties introduced to Vietnam through a cooperative project between Vietnam and the Democratic Republic of Germany (GDR). Among these, the varieties, Kardia and Mariella were identified and released in 1979 as "Viet Duc 1" and "Viet Duc 2". They are well adapted to the short day conditions and produce well. However, they have not been produced at any large scale due to the poor storability of the tubers under the high ambient temperatures experienced in the RRD. Other European varieties including Diamant and Solara occupy about 14% of the planted area (Chung 2003) with other varieties imported from Korea and Australia accounting for 8% (Tuyen pers.com 2008).

Some clonal varieties KT2, KT3 and P3 were released from CIP materials in the 1990s by VASI and FCRI. They are well adapted to the local agro-ecological conditions, as they bulk up early, have good storage characteristics and a low rate of seed degeneration. However, they occupy only 8% of the total area planted to potato in the RRD (Tuyen pers.com 2008).

Potatoes from China were initially imported into Vietnam as ware potatoes, but they have been widely used as seed in the RRD as they are inexpensive and sprout at the right time for planting. At present, about 63% of the area planted to potato in the RRD is derived from Chinese seed, particularly the potato variety VT2. The remainder are CIP clones which occupy about 3% (Tuyen pers.comm 2008).

2.3.7. Seed selection and storage

Vietnamese farmers normally save between 20 to 30% of the small tubers from the harvest for seed for the next crop. Ideally, small to medium sized tubers (20–50 g) should be selected from healthy looking plants, but more often than not, small to medium tubers are simply selected from the harvest (Tung 2000).

As the seed must be stored for up to eight months, two types of seed potato storage are employed in Vietnam: diffuse light storage and cool storage. For diffuse light storage, seed potatoes are stored by farmers in their homes in areas typically characterized by low light. Most seed potatoes are stored for 8-9 months from February/March until November under the hot and humid conditions. The temperatures sometimes reach 32°C - 35°C (for up to three months) (Figure 2.1). Cockroaches, rats and mice can all damage the tubers. The long storage duration plus poor seed selection often results in considerable seed losses (45-60%). Furthermore, the seed degenerates quickly due to physiological aging (Hoa *et al.* 1995; Batt 2003a). This storage method also needs a large space and intensive labour.

Cool storage has been identified to be the best method for storing seed potatoes as losses can be minimized and the seed tubers are maintained in a better physiological state for the next planting (Tung 2000). As a result, diffuse light stores are gradually being replaced by cool stores. The cool storage capacity in the RRD has increased from 20 tonnes in 1994 to 605 tonnes in 2000 (Chien *et al.* 2000) to 2,615 tonnes in

2003 (Chung 2003). In 2005, there were 111 cool stores with a collective capacity of 3,565 tonnes (Tuyen 2008) (Figure 2.3).

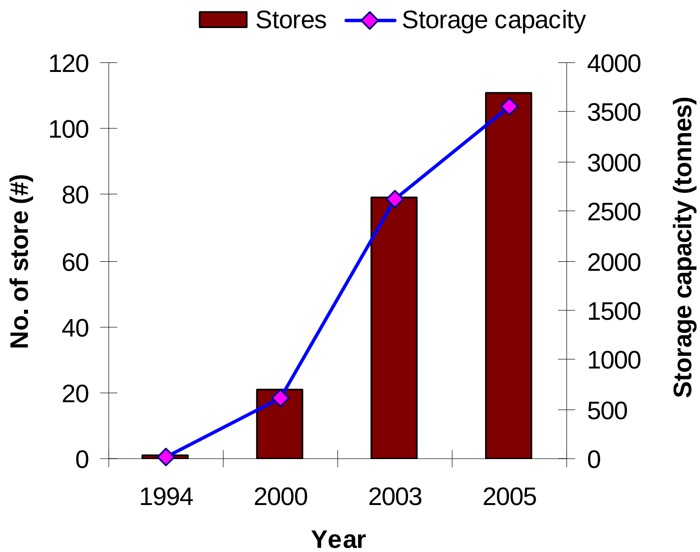


Figure 2.3: Cool stores and storage capacity for seed potato in the RRD (from 1994 to 2005)

No specific technique has been introduced for storing ware potatoes in the RRD. Generally, table potatoes are stored for only a few weeks in dark locations (under the bed or in dark sheds) on the farm. As farmers normally get low prices for their potatoes during the peak season (end of January to March), ware potatoes may be stored in the expectation of receiving higher prices when the supply declines. However, the window of opportunity is short, for ware potato imports from China recommence late March – early April (Batt 2002).

2.3.8. Consumption and marketing

Potatoes in Vietnam are usually consumed as a vegetable such as potato soup with meat (mainly pork), curries or other Vietnamese recipes with some herbs. Crisps and chips (French fries) prepared in restaurants and hotels, are considered as special dishes for reception dinners and parties. Potatoes are often harvested at the time of the Lunar New Year, a period of great festivity which greatly enhances their consumption as fried chips, or potato cakes. Potatoes are often used as pig food when they are plentiful (Tung 2000; Batt 2003b; Chung 2003).

Potatoes are sold directly to local markets or collected by wholesalers and traders. About 76% of the domestic potatoes are marketed through collector agents, 15% are sold directly to large or medium sized wholesalers, some 8% direct to retailers and about 1% are sold directly to consumers (Chung 2006).

Vietnam's population is concentrated in the two large deltas, the RRD where Hanoi is located and the Mekong Delta where Ho Chi Minh City is located. These cities are the main consumption centres for potatoes. It is believed that a higher proportion of the population consume potatoes in the north than in the south of Vietnam (Anonymous 2006b). Ho Chi Minh City is presently supplied with potatoes produced in the highland area of Dalat (Batt 2003a).

Export to some neighbouring countries may provide an attractive market for Vietnamese potatoes. Although many previous attempts have been made, only few successful shipments to the former Soviet Union took place during the 1980's and some containers were despatched to Singapore in 1997 (Tung 2000). In 2003, about 4,200 tonnes of potatoes were exported to Laos, Singapore, Malaysia and Cambodia through 4 main traders (three in the RRD and one in Dong Nai province) (Chung 2006). Poor product quality as well as plant quarantine regulations are the major barriers (Tung 2000).

It is estimated that 100,000 tonnes of potatoes per annum are imported into Vietnam from the Netherlands, Germany and China through private companies and wholesalers. It is estimated that 62% are used as table potatoes and animal feed, 30% as seed and 8% for processing (Chung 2006). Most potato imported from Germany and the Netherlands was used for seed (Tuyen pers.comm 2008). The Chinese potatoes are normally imported during the off-season (May to December) when there is a shortage of domestic potatoes in the market.

2.3.9. Opportunities

The potential for potato production in the RRD is estimated to exceed 400,000 hectares (Batt 2003b). Greater opportunities are thought to exist with the development of appropriate post-harvest technologies to store greater quantities of the harvest to increase potato consumption, develop export markets and to process greater quantities of potatoes. This will do much to improve conditions in the domestic market (Batt 2003b; Anonymous 2006b). Furthermore, an open door policy in Vietnam will attract foreign investment and encourage potato cultivation. This will enable farmers to significantly improve their income from the cultivation of potato.

There are currently five potato crisp processing companies (An Lac, Vita Food, Orion, Li Way Way and PepsiCo) operating in Vietnam. The demand for processing potatoes increased from 2,000 tonnes in 1999 to 20,000 tonnes in 2005. Demand is estimated to exceed 40,000 tonnes in 2010 (Figure 2.4) (Chung 2006).

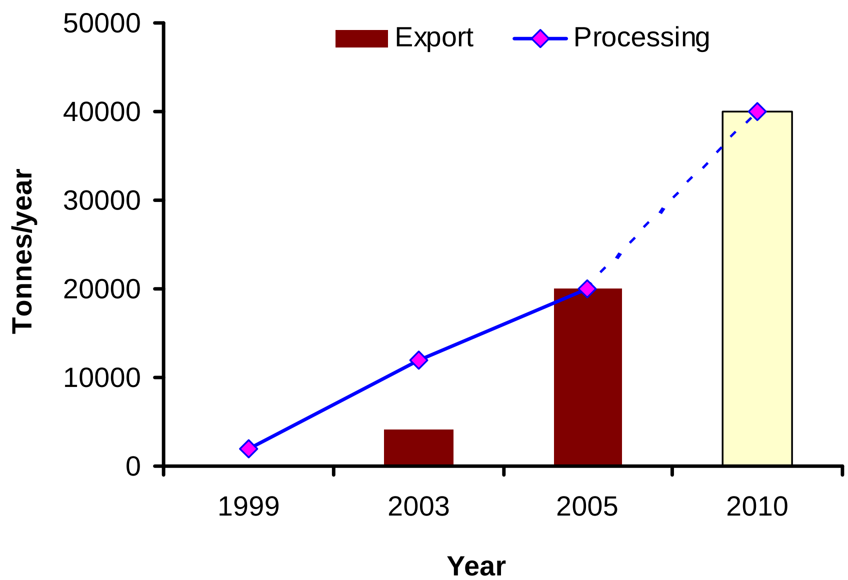


Figure 2.4: Potatoes used for processing and export in Vietnam from 1999 to 2010 (broken lines and pale column indicate projected figures).

2.4. Chapter summary and implications

The chapter has provided an overview of potato distribution, cultivation practices, constraints and opportunities for the potato industry in the RRD. The lack of good quality seed appears to be the most important constraint to increased production, efficiency and the profitability of potatoes in the RRD. High infestations of pests and disease, poor cultivation practices and unsuitable varieties also contribute to the poor yields, low quality and low stocks of clean seed for further multiplication.

Although cool storage capacity has increased significantly in the last five years, the amount of seed that can be stored is still less than 10% of the annual seed demand in the RRD. The lack of good quality seed plus the high cost of European seed has forced farmers to use the Chinese seed and diffuse light storage.

Although the demand for processing potatoes has increased significantly in recent years, the potato varieties produced locally do not meet the quality standards for processing. Vietnam needs to introduce new potato varieties that are better suited to the agro-ecological conditions and which meet the market demands.

Chapter Three:

Seed Potato Quality, Seed Certification, Seed System in Vietnam and Seed Supply from Western Australia

3.1. Chapter outline

The chapter begins with an overview of seed potato quality and the factors which influence the quality of a seed potato tuber including the biological quality, physiological age, seed size and seed purity. The next section provides an overview of the seed certification system for potato production. The chapter continues with a description of the seed system in Vietnam, followed by a description of the seed certification system in Western Australia.

3.2. Introduction

Potato is one of only a few food crops cultivated from vegetative tissue (tubers) rather than botanical seed (Dean 1994). Seed tubers have an important influence on the productivity of potatoes (Kawakami 1962). Good quality seed tubers are capable of producing healthy, vigorous plants that produce a high yield of good quality tubers within the time limits set by the growing season and the socio-economic and agronomic environment in which the seed is planted (Beukema and van der Zaag 1990; Dowling 1995; Struik and Wiersema 1999). No aspect of growing potatoes is more important than the selection of the best possible planting material, for the yield obtained from different stocks of the same variety under the same conditions of culture, depends more upon the quality of the planting stock than any other single factor (Balaoing and Lazo 1967). Moreover, the use of high quality seed improves the productivity of traditional inputs such as labour, irrigation and cultivation practices (Monares 1981).

There is a direct link between the quality of the seed used and the productivity of the crop (Struik and Wiersema 1999). The quality of the seed planted affects: (i) the number of plants and stems per unit area; (ii) the vigour of plants and stems; (iii) the length of growth cycle and; (iv) the balance between haulm and tuber growth; and (v) the number and growth rate of tubers.

A high quality seed tuber must be free of pests and diseases if it is to produce a healthy, vigorous plant with a sufficient number of strong stems (Struik and Wiersema 1999). The characteristics that most influence seed quality include the biological quality (seed tuber health), physiological age, seed tuber size and seed purity (van der Zaag 1990).

3.2. Seed potato quality

3.2.1. Biological quality (seed sanitation/seed health)

As a vegetatively propagated crop, the potato is prone to "seed degeneration", a decrease in the health status of the seed tubers from one crop to the next. Many plants and tubers carry pathogens which are easily transferred to and accumulate in the next generation when vegetatively propagated (Beukema and van der Zaag 1990; Struik and Wiersema 1999; Bus and Wustman 2007). Pathogens transferred from one generation to the next include viroids, viruses, bacteria and fungi. Insects, nematodes, weeds and other organisms can also be transferred by or with seed tubers (Rowe 1993; Struik and Wiersema 1999; Bus and Wustman 2007).

Potato pests and diseases affecting the seed biological quality

The potato is afflicted by many pests and pathogens (disease agents) wherever they are grown including many insects, nematodes, fungi, bacteria and viruses (Rowe 1993; Dowling 1995). Some of these are transported to new locations along with the tubers. Others are present in locations when the potato is introduced and then proliferate on the new host plant (Rowe 1993). The infection of the crop and the subsequent spread of the disease are influenced to a large degree by the climatic conditions, the prevailing cropping practices and the susceptibility of the cultivar (Dean 1994).

Virus diseases

More than 35 different viruses are known to affect potato (Salazar 1996). Viruses are protein-coated particles with nucleic acid cores that are visible only when viewed with an electron microscope (Ernest, Peter and Khurana 1993). All potato viruses invade developing tubers and can thus be carried over from one season to another through infected seed tubers.

Potato viruses are often designated with an internationally recognized abbreviation, derived from their English name such as potato virus X (PVX), potato virus Y (PVY), potato leafroll virus (PLRV) and potato virus A (PVA) (van Baarlen *et al* 2005).

Aphids are important vectors for the transmission of a number of viruses in a non-persistent manner (PVA and PVY) or persistent manner (PLRV). In non-persistent transmission, the virus is not multiplied in the aphid so only the virus particles present on the mouth parts of the aphid are transmitted. Aphids can be virus-free in a short period (1 to 2 hours) after acquisition of the virus. With persistent transmission, the virus is first ingested by the aphid whereupon it multiplies inside the aphid body; it is then exuded with the saliva on the next occasion that the aphid feeds. It usually takes over 24 hours before an aphid transmits a persistent virus for the first time. This enables the aphid to infect plants for the rest of its life (Cuperus and de Bokx 2005c; Struik and Wiersema 1999).

Virus infection can be further divided into primary and secondary infection. Plants infected during cultivation are referred to as primary infection, whilst diseased plants originating from infected tubers have secondary infection. Potato plants with primary and secondary infections from the same virus often show significantly different symptoms (Cuperus and de Bokx 2005c).

Virus diseases, although seldom lethal, reduce plant vigour and thus the yield potential (Hooker 1981; Burrows and Zitter 2005). Plants grown from virus-infected seed tubers are less productive than those cultivated from healthy ones (Beenster and de Bokx 1987). Virus infection can affect the plant’s metabolism, leading to a diseased plant and corresponding disease symptoms. However, the effects of viruses on potato growth and yield vary with the virus and the virus strain, the genetic resistance of the potato cultivar, and the growth stage of the plant at the time of infection (Ernest, Peter and Khurana 1993). The extent to which the yield decreases due to viruses depends on the conditions during the growing period: the worse the growing conditions (e.g. as a result of hail or nematode attack), the greater the yield loss due to viruses (van Baarlen *et al.* 2005).

+ Potato virus Y (PVY)

Potato virus Y (PVY) is a well known and well studied potato virus. PVY is one of the most important viruses infecting potatoes because it is easily transmitted and causes serious crop losses (Cuperus and van de Haar 2005; Dean 1994; German 2001; van Baarlen *et al*. 2005). PVY, together with potato leafroll virus (PLRV), are the most significant causes of what is described as the "degeneration of potato" (Cuperus and van de Haar 2005). According to Zitter and Gallenberg (1984) and German (2001), PVY can causes yield reductions from 10 to 80%.

Symptoms in potato vary widely with virus strain and cultivar, ranging from mild mosaic to severe foliar necrosis (dead spots on leaves) to death of infected plants (de Bokx 1981; German 2001; Burrows and Zitter 2005). Primary symptoms of PVY infection include necrosis, mottling, yellowing of the leaflets, leaf dropping and premature death. PVY is tuber-borne and can interact with other viruses such as PVX and PVA to result in heavier losses (Zitter and Gallenberg 1984; German 2001; Hooker 2001; Cuperus and van de Haar 2005).

Several strains of PVY have been identified that differ by the symptoms caused in potatoes. There are three main groups of potato virus Y (Jones, Kumar and Mackie 2003); PVY^O is the common strain that causes mosaic symptoms; PVY^C causes stipple streak; while PVY^N causes the necrotic strains (dead spots both on leaves and in tubers) (Jones; Kumar and Mackie 2003; Burrows and Zitter 2005).

PVY is readily spread by aphids in a non-persistent manner (Zitter and Gallenberg 1984; Burrows and Zitter 2005). Besides potato, PVY infects other solanaceous crops (tomato, pepper) and weeds (nightshade, ground cherry) (de Bokx 1981; Zitter and Gallenberg 1984). Control depends on the use of disease-free seed, isolation from infection sources, insecticides to reduce aphid populations, and mineral oil sprays to interfere with the aphid's feeding process, which must be re-applied at frequent intervals to be effective (Zitter and Gallenberg 1984; Burrows and Zitter 2005). Furthermore, PVY can be managed by not planting potatoes next to weedy ditches and practicing good weed control within the field (Burrows and Zitter 2005).

+ Potato leafroll virus (PLRV)

Potato leafroll virus (PLRV) affects the quantity and quality of production. PLRV was the first virus disease of potatoes to be studied (Cuperus and de Bokx 2005a). PLRV occurs in all locations where potatoes are grown. Its severity depends on the virus strain, potato variety and climatic conditions (Zitter and Gallenberg 1984). Foliar symptoms of PLRV can be divided into primary and secondary infection (Peters and Jones 1981). Primary symptoms appear mainly in the young leaves, which usually stand upright, roll and turn slightly pale (Zitter and Gallenberg 1984). Secondary symptoms become evident soon after shoots emerge from an infected tuber. Because the virus damages the phloem (sometimes seen as dead spots along the underside of leaf veins), sieve tubes are blocked through the formation of callose. Sugar transport is severely inhibited which leads to starch being partially deposited in the foliage, causing leaflets to roll, stiffen and dry, to be thicker than normal and to make a crisp, somewhat paper-like sound when touched (Ragsdale *et al.* 1994; Rich 1983; Cuperus and de Bokx 2005a; Burrows and Zitter 2005).

PLRV is transmitted persistently by several aphid species, the most important of which is the green peach aphid *(Myzus persicae)* (Munro 1981; Bantarri *et al.* 1993, Radcliffe *et al.* 1993; Slack 2001a). In addition, the virus infects other solanaceous crops and weeds (tomato, tobacco, jimsonweed, etc.). Yields of plants with secondary infection are often reduced by more than half, while in highly sensitive varieties, yield losses can be as much as 90% (Cuperus and de Bokx 2005a; Cuperus and de Bokx 2005c).

As the transmission of PLRV from the aphid to the plant takes longer time than PVY, insecticide application can be effective if the aphid populations are closely monitored (Burrows and Zitter 2005).

+ Potato Virus X

Potato virus X (PVX) is one of the most widely distributed viruses of potatoes, often completely infecting commercial stocks (Cuperus and de Bokx 2005c). It produces weak symptoms which are often barely perceptible (Munro 1981; Cuperus and de Bokx 2005c). In the field, PVX is only transmitted by contact, even through wounds caused when an infected leaf rubs against a healthy leaf, via humans, animals and machines moving through the crop; by biting insects such as grasshoppers and beetles; and through contamination during seed cutting, but not by aphids.

PVX usually causes only small yield reductions (Zitter and Gallenberg 1984). Depending on the variety and virus strain, maximum yield losses are between 10 and 15% (van Baarlen *et al.* 2005; Zitter and Gallenberg 1984; de Bokx 2005). However, mixed infections of PVX with other viruses like PVY and PVA usually cause more damage and yield loss than PVX alone (Burrows and Zitter 2005; Zitter and Gallenberg 1984; Beukema and van der Zaag 1990). Tobacco, pepper and tomato are additional hosts for this virus. PVX can be controlled by using certified seed, sanitising all tools, and limiting within-field movement (Burrows and Zitter 2005).

+ Potato Virus A

Potato Virus A (PVA) causes mild mottling in the leaves (mosaic) and has a number of characteristics in common with PVY (Cuperus and de Bokx 2005b). Symptoms and severity depend upon the strain, potato variety and environmental factors. It is transmitted non-persistently by aphids. Primary infections may be symptomless, while secondary symptoms are chlorotic mottle (mosaic) and quite distinct, yellow or pale green irregular spots in the leaflets, alternated with dark green. Control of this aphid-transmitted virus is through the use of disease-free seed, insecticides and resistant varieties (Thurston and Schultz 1981).

+ Phytoplasmas and viroids

Phytoplasmas are small organisms with sizes between those of virus particles and bacteria. Phytoplasmas are transmitted in a persistent manner by different species of leafhoppers. Phytoplasmas disrupt the plant’s hormone balance and cause the large scale production of aerial tubers instead of lateral shoots. Seed tubers infected by phytoplasms do not sprout, or form only a few weak sprouts which soon die (Turkensteen 2005a). Phytoplasma infection can be avoided by ensuring that potatoes are not the only green crop in the field as leafhoppers transmitting the disease do not like potatoes and will not feed on them if there are other host plants available.

Viroids resemble virus but are even smaller. The most important threat is potato spindle tuber viroid (PSTVd). PSTVd can be efficiently transmitted in true potato seed as well as in seed tubers (Slack 2001b; Turkensteen 2005a). The symptoms may not be visible in the season of infection but the severity increases with each successive generation as the viroid persists from generation-to-generation in infected seed tubers. Infected plants are stunted and upright with abnormally elongated and cylindrical or spindle-shaped tubers. The pathogen is easily transmitted by contact such as mechanical injury and cutting in particular (e.g. stem cutting for rapid propagation) and even chewing insects. Using certified seed without cutting is the best way to avoid disease infection.

Fungus diseases

Among the potato pathogens, a number of fungi form an economically significant group. Fungi are organisms generally characterized by the formation of mycelium consisting of tubular filaments, which contain many cells with a rigid cell wall of chitin (Turkensteen and Flier 2005). The economically significant fungal diseases of potato include late blight and early blight.

+ Late blight

Late blight *(Phytophthora infestans)* is the most famous and important disease of potatoes worldwide (Zitter and Gallenberg 1984). This is a greatly feared disease because of the speed with which it may spread through a crop. From the first infection, it can destroy a susceptible crop within 2 weeks (Thurston and Schultz 1981). Under cool, wet conditions, sporangia produce zoospores (Zitter and Gallenberg 1984) and the leaf or stem is colonized quickly. Large portions become necrotic as the pathogen advances. At the lesion's margin, new sporangia emerge through the stomata to continue the disease cycle. Under favourable conditions, the pathogen can complete one cycle in as little as 4 days.

In the field, plants severely infected with late blight give off a distinctive odour. This odour actually results from the rapid breakdown of potato leaf tissue (Dean 1994; Turkensteen and Flier 2005). If potatoes with late blight are stored, the disease can directly and indirectly damage tubers. Indirect damage occurs when secondary infection by soft rot bacteria invades the tuber, which then spreads to other tubers in the pile. Direct damage happens when the tubers contact with spores through soil cracks, harvesting or other means. The tubers show irregular, slightly depressed brown to purplish areas on the skin (Dean 1994; Turkensteen 2005e). Secondary organisms may then infect partially rotted tubers and result in extensive losses.

+ Early blight

Early blight *(Alternaria solani)* is a fungal disease found in all potato growing regions, especially in irrigated crops (Rotem 1981). It is most severe in areas of high humidity, frequent rainfall and especially in sandy soils. The disease organism survives on the plant debris, in the soil, on the potato tubers and on other host plants. Infection is particularly visible after flowering (Turkensteen 2005c).

If plants are maintained in a vigorous growing state by proper fertility and water application, early blight is seldom a problem. However, in susceptible varieties, it can lead to early defoliation and premature death of the haulm and consequently to a significant reduction in yield (Ernest, Peter and Khurana 1993).

Bacterial diseases

Bacteria are present in large numbers in the soil, water and on plants. However, both the degree of contagiousness and the long period of latency make it very difficult to control these diseases adequately in the field (Wicks 2004).

Several bacterial diseases are particularly important in potato production (Kelman 1981; Allen, Kelman and French 2001; Turkensteen 2005b), but the two most significant bacterial diseases of potato are bacterial wilt and soft rot.

+ Bacterial wilt

Bacterial wilt (or brown rot) is caused by the soil-borne bacterium *Ralstonia solanacearum* (Dean 1994; Turkensteen 2005d). This disease affects potatoes in almost every warm, temperate, semitropical and tropical zone of the world (Kelman 1981; Dean 1994). The disease is more prevalent in wet seasons and where excess nitrogen has been applied.

In the field, the first symptoms are the wilting of leaves at the top of a single stem. This wilting is irreversible and soon all the leaves hang down along the stem. Wilting may be present without any colour change (Wicks 2004). Tubers may not show any external symptoms, however, greyish-white droplets of bacterial slime may be squeezed from the vascular tissue when cut in half (Wicks 2004; Turkensteen 2005d). Tubers damaged by bacterial wilt are more susceptible to soft rot (Erwinia) (Powelson and Ranc 2001).

Bacterial wilt is perhaps the most difficult disease to control because of the soil-borne nature of its causal organism (Kucharek 1998). However, the incidence of disease can be reduced by integrated crop management including: (i) planting healthy seed in clean soil; (ii) planting tolerant varieties; (iii) rotation with non-susceptible crops; (iv) not planting in fields that receive water runoff from infested fields (Salmond 1992; Kucharek 1998); (v) rotation with non-host plants such as cereals, legumes, cucurbits and brassicas; (vi) avoiding other Solanaceous crop such as groundnut, tomato and ginger; and (vii) flooding fields (Priou *et al.* 1994).

+ Blackleg and bacterial soft rot

Blackleg, aerial stem rot and tuber soft rot are all similar diseases caused by *Erwinia* spp. These diseases are found wherever potatoes are grown (Dean 1994). It is a common bacteria causing rot in many vegetables including potatoes and affects both stems and tubers. Soft rot can occur at any temperature above 10^{o}C, but the optimum temperature range for disease development is 25 – 30^{o}C.

The disease begins from a contaminated seed piece, but the symptoms can occur at several stages of plant development. In severe cases, entire seed pieces and developing sprouts may rot in the ground prior to emergence (Mulder and Brinkman 2005a).

Pests

There are many pest species damaging potatoes that influence the yield, quality and productivity of the crop (Dean 1994). For seed tuber production, pests are especially important as vectors of viral disease or when they attack the tubers (Struik and Wiersema 1999). In certified seed schemes, crops and seed tubers can be rejected if insect damage exceeds maximum tolerances. The important pests influencing seed tuber quality include; nematodes, aphids and potato tuber moth.

Nematodes

Nematodes are described as small microscopic roundworms that attack potato roots and tubers (Dean 1994). There are several types of nematodes that may cause direct damage to roots and tubers resulting in yield or quality loss, or which provide entry points for other diseases (MacGuidwin 1993; Dean 1994). There are two common nematodes attacking potatoes: root-knot nematode (RKN) and the potato cyst nematode (PCN).

+ Potato cyst nematode (PCN)

Potato cyst nematode (*Globodera rostochiensis* and *G. pallida)* gets its name from the hard round cysts (mature females) it produces which encapsulate the eggs. The larvae hatch in warm weather when stimulated by potato root exudates, then move to and enter the potato roots, feed and develop until they enlarge enough to rupture the root tissue (Dean 1994; Mulder and Brinkman 2005b). Cysts containing viable eggs can survive in soil which has not been planted in potatoes for up to 20 years. Infected plants are stunted and may wilt; leaves turn yellow or display a dull colour. Damage to the crop varies from small patches of poor growing plants to complete crop failure. Light infestations can reduce the tuber size, whereas, heavy infestations reduce both the number and size of tubers (Knoxfield 2006b).

Hooker (1981) stated that PCN can be controlled by: (i) crop rotation (minimum 5 years); (ii) the application of high rates of soil fumigants and chemical treatments; (iii) restricting the shipment of seed tubers and plants of other types from PCN infected areas; and (iv) combining different control methods. However, Dean (1994) advised that potatoes should not be planted in soil having PCN.

+ Root-knot nematode (RKN)

Root-knot nematode (*Meloidogyne spp.*) is a pest of potato and a large number of other crops worldwide (Dean 1994). The larvae emerge from the egg, travel through a film of water to the potato root or tuber and enter through natural openings or cracks in the cuticle or periderm. Once in the plant, RKN retards the growth, delays flowering and causes the plants to produce giant cells which appear as galls on the root and tuber surfaces giving the tubers a warty appearance (Dean 1994; Brinkman and Mulder 2005; Knoxfield 2006a). RKN reduces the quality, size and number of tubers. Infected plants can become more susceptible to bacterial wilt *(Ralstonia solanacearum).* Damage is more severe when plants are also infected with fungal pathogens (Knoxfield 2006a).

RKN is difficult to control by rotation as it is able to infect a large variety of plants including cereals and grasses (Dean 1994; Knoxfield 2006a). It may be controlled only by integrated management including: (i) monitoring crops for symptoms; (ii) practising good farm hygiene; (iii) avoiding planting susceptible crops in paddocks contaminated with root knot nematodes; (iv) rotating crops with resistant, immune or non-host crops (Knoxfield 2006a) and (v) nematicides (Ingham, Dick and Sattell 1999).

Aphids

Aphids are small insects only a few mm long with mouthparts adapted for piercing and sucking plants. Aphids are the most dangerous insects as they are such efficient transmitters (vectors) of plant virus (Mulder and Stolte 2005; Struik and Wiersema 1999).

Aphids may cause direct and indirect damage to the potatoes. For direct damage, aphids pierce plant cells to feed on the phloem, remove sap and even introduce toxic substances that can cause abnormal plant growth (Mulder and Stolte 2005). Indirect damage happens when aphids act as a vector for many important potato viral diseases including PLRV, PVY, PVA, PVS and PVM.

For the production of seed potatoes, the transmission of viruses is the most threatening aspect of aphids. Therefore, they should be treated with approved chemicals as soon as locally derived action thresholds are reached. Virus transmission by aphids can also be reduced considerably by early roguing of infected plants.

Tuber moth

Potato tuber moth, *Phthorimaea operculella (Zeller)* is considered one of the most economically damaging pests affecting potato seed tubers in the tropical and subtropical areas (Das 1995; Struik and Wiersema 1999; Mulder and Turkensteen 2005a). Tuber moth may persist on various nightshades and other members of the Solanaceae.

The caterpillars (larvae) mine into leaflets, leaf veins and stems but generally cause only minor damage. However, damage is far more substantial when the caterpillars tunnel into tubers. Tubers may be invaded both during cultivation and storage. Affected tubers will often rot and are rejected during inspection (Davidson *et al*. 2006).

Tuber moth can be prevented by proper hilling whereby tubers are not exposed. Chemicals can be used to kill moths and caterpillars if necessary (Mulder and Turkensteen 2005a).

3.2.2. Physiological quality (physiological age)

The crop performance of potatoes is closely related to the physiological age of the seed tubers. The physiological age of the seed tuber influences the potential of the tubers to produce new sprouts (Kumar and Knowles 1996; Hartmans and van Loon 1987). In the field, the physiological age of the seed tuber affects the rate of plant emergence, crop vigour and growth, the number of stems produced per plant, the time of tuber initiation, dry matter distribution and tuber yield (Horton 1987; Caldiz, Fernander and Struik 2001; Reust 1986).

According to Reust (1986), the term “physiological age” is defined as “the physiological state of the tuber, which influences its productive capacity”. Physiological age is defined by Struik and Wiersema (1999) as “the state of development of a seed tuber, which is modified progressively by increasing chronological age, depending on growth history and storage conditions”.

The chronological age is calculated from the time of tuber initiation to sprouting and is expressed in days, weeks or months, without regard to the environmental conditions (Reust 1986). However, tubers with the same chronological age can have very different physiological ages due to the effect of different environmental and management conditions during growth (van der Zaag and van Loon 1987) and storage (Hartmans and van Loon 1987). For example, seed stored in diffuse light storage conditions is physiologically older than seed stored in a cool store; a whole round seed tuber without bruising or damage will be physiologically younger than a cut seed tuber.

Different growing conditions also influence the physiological age of the potato tubers. This may have an effect on the performance of the seed tuber in the next season (Struik and Wiersema 1999). Potatoes planted under high temperatures will advance the physiological age of the tubers produced (Caldiz, Fernandeza and Struik 2001). Physiological age is also influenced by the length of the growing period as plants harvested earlier produce physiologically younger tubers than late harvested tubers (Struik and Wiersema 1999).

Kumar and Knowles (1996) stated that the physiological age also influences the sprouting behaviour of potato tubers. Starch is the principal storage form of carbohydrate in tubers which is used during storage through respiration. Physiologically old seed tubers contain less carbohydrate than physiologically young seed, and over time, this can reduce sprout growth. Young seed tends to be more vigorous and produces a later maturing crop with a higher yield (Struik and Wiersema 1999).

Seed tubers perform best when they are planted at the appropriate physiological age. The reduction in yield caused by the unsuitable age of seed tubers is termed "physiological degeneration". There are two types of physiological degeneration including juvenile degeneration (where seed is planted less than 4 months after harvest - physiologically young seed) and senile degeneration (where seed is planted after more than six months after harvest - physiologically old seed) (Kawakami 1962). Ideally, tubers chosen for seed production should be neither senile nor juvenile but of an appropriate physiological age to suit the market requirements of the crop.

Physiological age of the seed also affects haulm growth and the number of stems because the number of eyes that sprout from a seed tuber depends on the physiological age of the seed tuber when planted. Physiologically old seed usually emerges earlier than physiologically young seed, but with a greater number of sprouts and potentially more small tubers (Bohl *et al.* 1995; Kawakami 1980; Kumar and Knowles 1993). There is a linear relationship between stem number and seed age. In the field, the older the seed, the more stems are produced (Knowles and Botar 1991; Knowles and Botar 1992). This stimulates competition between emerging shoots for light, water and nutrients and yields are often lower than physiologically young seed (Struik and Wiersema 1999; Fulton and Fulton 2000).

The effects of physiological age differ between varieties (Caldiz *et al.* 1996; Struik and Wiersema 1999), as tuber dormancy may last from one month to several months. These effects are important because farmers often practice multiple cropping, seed tubers are planted in different zones of the same country or are shipped to overseas countries which require seed of different physiological age (Struik and Wiersema 1999).

Seed age can be modified by crop and storage management to make it suitable for different conditions (van Ittersum 1993). For example, storing seed at 4ºC overcomes dormancy and enables the seed tuber to produce the optimum number of sprouts and to yield well (Kustiati 2005). There is general agreement that physiologically young seed produces higher yields in longer growing seasons, while old seed produces higher yields in a short growing cycle (Wurr 1979).

3.2.3. Seed size

Seed size influences the emergence, seedling vigour, subsequent plant growth and final yield (Struik and Wiersema 1999). The size of seed tubers or seed pieces affects the number of eyes. It can be defined by weight (in grams) or by diameter (in mm). The number of eyes is directly related to the physiological status of the tuber: smaller tubers are generally physiologically younger.

Seed size will influence the number of sprouts and thus the number of stems produced per seed tuber. More stems per tuber will result in crowding and thus reduced vigour unless the seed tubers are planted further apart (Fulton and Fulton 2000). Small seed tubers require a longer growing period to reach their yield potential. As a consequence, killing the haulm will reduce the yield of crops grown from small seed tubers more than the yield of crops grown from large seed tubers. However, small seed tubers have a higher value per unit weight than large seed tubers because small tubers produce more stems per unit of weight than large tubers (Hartmans and van loon 1987; Caldiz, Fernandez and Struik 2001).

3.2.4. Seed purity

The majority of potato varieties cultivated commercially throughout the world have been bred and selected under temperate growing conditions (Beukema and van der Zaag 1990). As agro-climatic conditions vary between and within countries, the performance of a particular cultivar may vary in different locations (Bleasdale 1965). Therefore, most countries carry out testing programs in order to identify cultivars that are the most suitable for growing in specific local situations (Panda and Mohanty 1981).

Variety is an important determinant of the number of stems produced from a seed tuber because the number of stems determines the numbers of tubers and their size distribution (Alvin and Richard 1993). With the same seed treatments and planting methods, tubers of different varieties will produce a different number of stems per tuber.

Alvin and Richard (1993) found that each variety has an unique requirement for optimum performance. For good crop health and maximum profit, a variety must be well adapted to the local soils, weather and cultural conditions and meet the demands of the intended market. To yield well in the tropics, a variety must be able to cope with higher temperatures, a higher humidity, a shorter day length, a shorter growing period, higher levels of pests and diseases and grow well with only limited inputs (Batt 2003b). The variety must also have a good storage capability and fit into the length of the cropping season (Horton 1987).

3.3. Certified seed and seed certifications

Early in the 20^{th} century, it was widely believed that the propagation of potatoes by tubers was responsible for the degeneration of seed which led to decreased yield (Steven 1993). In the 1900s, agriculturists in the Netherlands and Germany found that certain symptoms of degeneration could be transmitted from plant-to-plant and persisted from one crop to another as a result of tuber-borne diseases, particularly viruses (Steven 1993; Bus, van Loon and Veerma 1996). They discovered that the spread of virus diseases could be reduced by roguing and early haulm killing. These findings are still used in seed production and field inspection today (Jones, Munro and Darling 1981; Struik and Wiersema 1999).

Historically, the detection of disease has been accomplished primarily through field inspections conducted two or three times during the growing season (Shepard 1975; Zink 1991). The first field inspection and certification of seed potatoes was carried out in Europe in the 1900s. It was then applied in the USA and North America between 1913 and 1915 (Steven 1993). Seed inspection started in response to the demand from seed buyers for greater reliability in the quality of the seed potatoes purchased as well as the origin of the seed (Oosterveld 1987; Steven 1993). At that time, inspection and certification was on a voluntary basis and seed growers used this system to increase the value of their crop.

Many seed-borne pathogens can remain latent and symptom expression is frequently influenced by the environment and subject to differences in varietal response (Callison 1982). Therefore visual field inspections and field diagnoses are inadequate. Furthermore, only a relatively small sample of the field or seed lot can be observed. These problems have been overcome with the introduction of molecular techniques to seed potato schemes. ELISA (Enzyme-Linked Immunosorbent Assay) and c-DNA hybridization are now used to test for viruses and viroids in seed potatoes from *in vitro* to greenhouse to field production. A combination of the sensitivity of monoclonal antibodies with the flexibility of ELISA made it feasible to do large scale screening for bacterial ring rot. These pathogen detection techniques eliminate much of the guesswork that used to be involved in the seed certification process (Zink 1991).

Seed certification provides seed buyers with a guide to the quality of the seed produced by seed growers (Ulmer and Stuber 1997; Holland and Spencer 2007). Certification does not constitute a warranty or a guarantee that the seed potatoes are disease free; rather, certification means that the seed potatoes have met the standards of the certification agency (Oosterveld 1987; Bohl, Nolte and Thornton 1992; Dehaan 1994; Holland and Spencer 2007). This means that the seed has been produced, inspected, graded and handled according to the regulations of the agency. Certification provides high quality seed to commercial growers by ensuring that diseases are not present at levels which will affect yield or marketability of the subsequent crop (Oosterveld 1987).

“Certified seed” is seed of a known variety produced under strict seed certification standards to maintain varietal purity (Bohl *et al.* 1995). Seed lots must also meet specified standards for other crops, inert matter, weed seeds and germination. Potato seed is usually produced in areas that are isolated from commercial potatoes, with the intent of preventing disease contamination by insects, animals or humans (Dean 1994). To restrict the spread of virus diseases, the number of disease infected plants should be kept low or removed from the field as they are the main sources of mechanically transmitted viruses.

Certification schemes differ from country-to-country, but all have certain elements (tuber size, physiological age, disease level) in common. The choice of these elements depends on the conditions of production and the infrastructure (the way organizations involve in seed potato production cooperative) of the seed potato business in a given country (Oosterveld 1987). In Asian countries, for example, small round seed potatoes (20-55 g) are required to meet the farmers’ demand (Arpiwi 2003) as seed is rarely cut in the tropics because of high humidity and high temperatures, which increase the likelihood of diseases infecting the wound (Batt 2002).

3.4. The potato seed system in Vietnam

The current seed supply system in Vietnam can be divided into two main schemes: informal and formal seed schemes (Hue 2006).

3.4.1. Informal seed scheme

Farmer saved seed

Traditionally, potato farmers save between 20 to 30% of their harvest for seed to plant the next crop. Small to medium tubers weighing from 10 to 50 gram are either harvested from healthy looking plants that have been selected in the field before haulm killing, or selected at harvest (Tung 2000). Some growers in the highlands, however, sell most of their crop for seed, retaining just a minor portion for their own consumption (Batt 2003b). Seed is sold freely on the open market or exchanged among farmers in the village (Figure 3.1). Seed from other provinces can also be distributed through seed traders.

Chinese potatoes

Over the last ten years, a large quantity of seed potatoes has been imported from southern China by various agencies. In 1999, the amount of Chinese seed imported was estimated to exceed 10,000 tonnes (Tung 2000). This seed was derived from the small tubers harvested from the ware crop, which would otherwise be used for animal feed (Tung 2000; Chung 2003). Many seed lots contained a mixture of varieties and there was a high risk of introducing a number of pests and diseases including powdery scab *(Spongospora subterranea)* and potato cyst nematode (PCN). Chinese seed was imported to Vietnam by middle men (seed companies), private enterprises or wholesalers in Northern Vietnam, or through the open market direct to farmers (Figure 3.1).

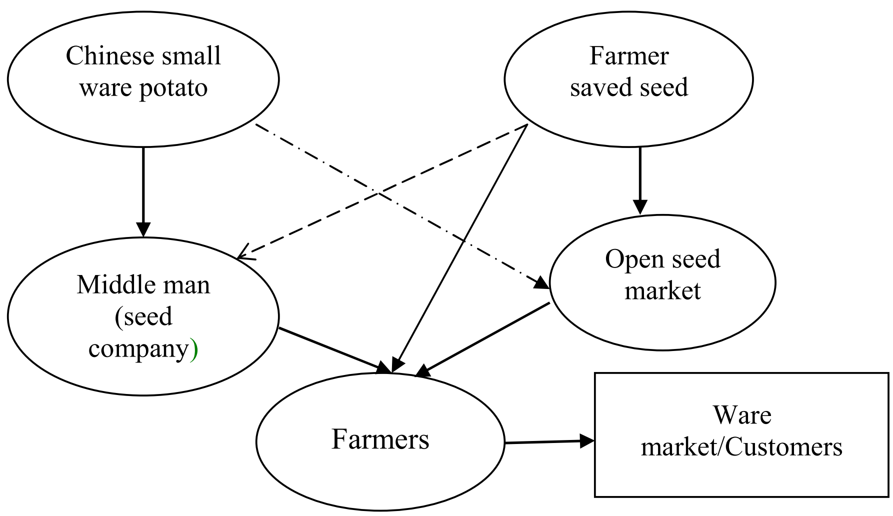


Figure 3.1: Current supply chains of informal seed in the RRD, Vietnam

Although there is no guarantee of the seed quality, Chinese seed is widely used in the RRD as it is inexpensive and sprouts at the right time for planting. In 2003, about 66% of the potatoes planted in the RRD were derived from Chinese seed (Chung 2003).

3.4.2. Formal potato seed scheme

Imported seed

The "formal" seed scheme is derived from imported seed or seed produced in Vietnam under a quality control system. Seed from Europe has been used by several projects since 1975. Recently, some 300 to 400 tonnes of seed from the Netherlands, Germany and France has been imported into Vietnam through FCRI, HAU, NSC and GTZ (Tuyen pers.comm 2008).

Generally, the cost of imported seed remains too high for the majority of small farmers to purchase (Tung 2000). Only more skilful farmers with the financial capacity or farmers in the project area have been able to purchase the seed. Seed is then multiplied in Vietnam one or more times before being sold to small farmers at a more affordable cost (Figure 3.2).

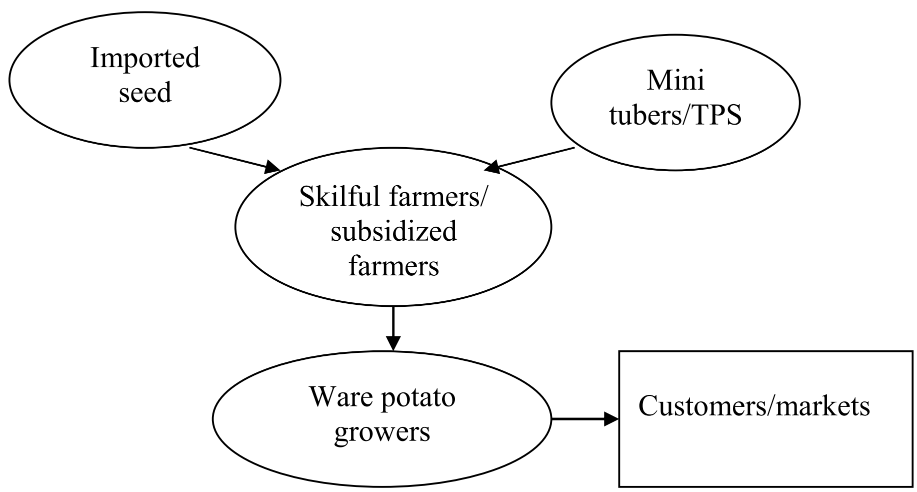


Figure 3.2: Current supply chains of formal seed scheme in the RRD, Vietnam

The cultivation of imported seed follows the general guidelines for potato seed multiplication developed by NCVESC. Importers are responsible for selecting the site and managing the seed quality as most of the small tubers are collected and cool stored as seed by the importers and then sold back to the farmer for the next crop. Most of these varieties are attractive to Vietnamese farmers as they have a yellow skin and yellow flesh colour. The tubers can be easily sold in the fresh market because they meet the customer's expectations (e.g. Diamant, Solara, Mariella, Sinora, Nicola and Granola). Because seed is imported from temperate areas such as the Netherlands and Germany, the varieties cultivated are seldom suited to the agro-ecological conditions experienced in the RRD due to their susceptibility to pests and diseases and low tolerance of poor storage conditions under a hot and humid climate. In addition, the seed is physiologically too young (harvested in August in Europe then planted November in the RRD) for planting in the RRD. For those reasons, the quality of the seed degenerates quickly after only one or two crops.

Seed produced in Vietnam

Seed produced in Vietnam can be divided into two types: (i) mini tubers produced from tissue culture; and (ii) true potato seed (TPS).

Mini tubers are produced from tissue culture by several institutions and universities such as the Food Crop Research Institute (FCRI) and the National Seed Company (NSC) in Hanoi and Hanoi Agricultural University No.1 (HAU) and the Institute of Agricultural Science for Southern Vietnam (IAS). As these are government organizations, 40 – 60% of the costs of the seed are subsidised by the government. The seed goes to skilful or government/project supported farmers before going to ware potato growers (Figure 3.2). The seed used initially is of good quality, but it degenerates quickly in only a few field multiplications. Farmers report that the multiplication rate declines from 4 to 5 fold for generation 1 (G1) planted seed to under two for generation 2 (G2) planted seed (Table 3.1).

Table 3.1: Performance of Vietnamese mini tubers in Trong Quan cooperative, Thai Binh province (Mr. Yen and Mr. Bang pers.comm. 2008)[1]

Seed source	Seed rate per sao	Yield (kg/sao)		Saved seed (kg/sao)	Seed multiplication rate
		Big tubers	Seed size tubers		
Mini tubers (G0)	2.500 – 2.800 tubers	280 - 300	150 - 160	150 - 160	5-6
G1	20 kg	200 - 220	130 - 140	130 - 140	4-5
G2	25 – 30 kg	150 - 160	30 - 50	40 - 60	1.5–2

[1] Mr Yen and Mr. Bang are leaders of Trong Quan cooperative. They both have wide experience in cultivation and marketing of potatoes in the RRD.

While the demand for this superior quality seed is high, the quantity produced is negligible fulfilling just 5% of the demand (Tuyen pers.comm 2008). Furthermore, if farmers had to pay full price, they would not be able to afford to buy this seed (Mr. Yen and Mr. Bang pers.comm 2008).

TPS was used widely in the RRD from the late 1970s to late 1990s as it was inexpensive, there was a low risk of seed-borne diseases and low transportation costs (Tung 2000). The method used to produce TPS in the RRD is described in Figure 3.3.

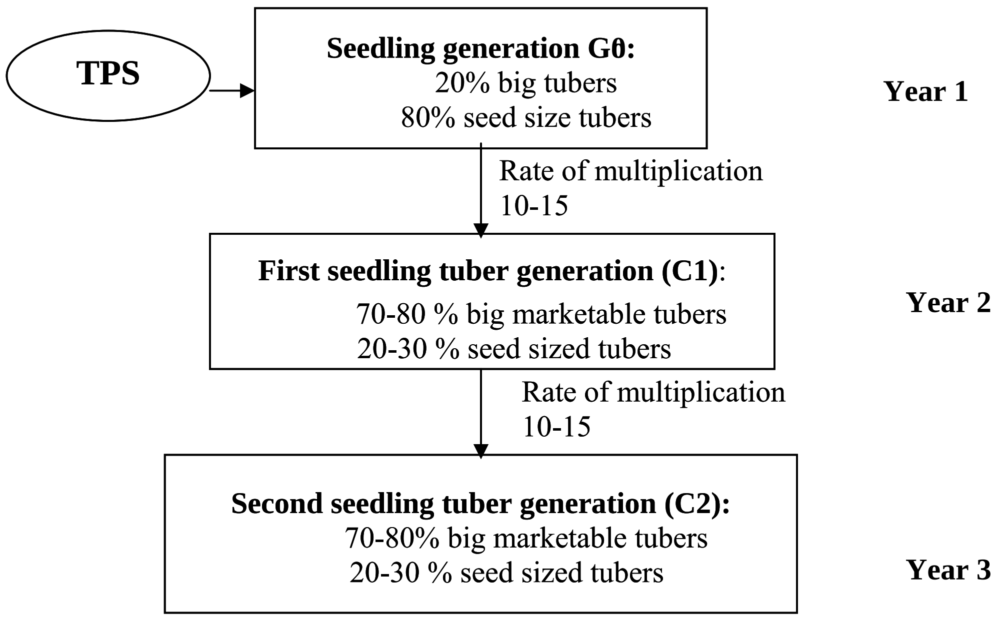


Figure 3.3: Method of use of TPS in the RRD (adapted from Tung 2000)

However, the area planted to TPS dropped sharply from 30% in 1999 to less than 8% in 2003 and 4% in 2004 (Chung 2003; Tuyen 2008). The reason for the reduction in the use of TPS was because it was too labour intensive for the cultivation of the "C1" generation plus the variability in tuber size and shape that did not meet the market expectations.

3.5. Seed potato production in Western Australia

Western Australia (WA) occupies an area of 2.5 million km^2 and is the largest of the Australian states. WA is isolated from the rest of the world by ocean and from eastern Australia by the Great Australian desert. The nearest potato cropping area to

WA is 2,000 km away across the arid Nullarbor Plain (Dawson 2000). From its tropical north to temperate areas in its south-west corner, WA experiences a range of climatic conditions (Western Australia facts).

Potato growing in WA began with European settlement in 1827. Small plots of potatoes were cultivated on the site of what is now the Albany Bowling Club (Western Potatoes 2004). Potato production in WA is based on about 110 enterprises; some of which comprise several families. Some potato producers specialise in intensive horticulture with year round production of other vegetable crops, others run grazing enterprises. The average area is estimated to be about 20 ha ranging from 60 ha for large producers to about 10 ha for smaller producers. Most producers grow potatoes for several markets which include; fresh, processing (crisp and French fry), export (mostly crisp potatoes) and seed (WA, interstate and export) (unpublished journal 2007).

The area of potatoes cultivated has increased gradually from 1,778 ha in 2000 to almost 2,000 ha in 2005 (Table 3.2). In 2007/2008, there were some 2,200 ha of potatoes planted in WA with 380 ha of potatoes planted for producing both certified and registered seed (Spencer pers.comm. 2008).

Table 3.2: Potatoes and potato seed production area (ha) in WA from 2000 to 2005

Year / Crop	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
Potatoes seed (ha)	589	346	259	496	456
Potatoes (ha)	1,778	1,724	1,819	1,898	1,920

Source: Australian Bureau of Statistics (ABS) and Department of Agriculture and Food Western Australia (DAFWA) 2008.

In WA, potatoes are mainly grown in the southwest of the state (Appendix 2). The main potato growing areas include Albany (2% area grown in potatoes), Manjimup (43%), Busselton (22%), Myalup (17%), Gingin and the Perth Metropolitan (14%) and Donnybrook (2%) (Potato Marketing Corporation of Western Australia 2004).

Although, WA produced over 90,000 tonnes in 2004/2005, this was only 7% of the Australian potato crop (Table 3.3). Most of the ware potatoes produced in WA are used for domestic consumption, crisp and French fries (Dawson 2000).

Table 3.3: Productivity of potatoes (tonnes) in WA and Australia from 2000 to 2005

Year	2000/2001	2001/2002	2002/2003	2003/2004	2004/2005
WA	87,107	88,102	82,953	84,581	91,291
Australia	1,413,123	1,442,472	1,350,948	1,408,026	1,397,356

Source: Australian Bureau of Statistics (ABS) and Department of Agriculture and Food Western Australia (DAFWA) 2008.

In WA, the export of potato seed has risen sharply in the last eight years. In 2007/08, some 13,000 tonnes of seed potatoes were produced. Most were used for domestic consumption, but more than 2,000 tonnes were exported to Mauritius, Thailand, Indonesia and other countries. This amounted to 32% of the total seed potato exports from Australia (Table 3.4).

Table 3.4: Potato seed export in WA and Australia from 2000 to 2008

Year / Country	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08
Mauritius	1,013	800	599	660	272	1,017	696	1,587
Indonesia	15	30	152	85	670	308	634	353
Thailand	162	83	100	0	189	210	24	94
Sri Lanka	0	20	711	565	0	0	0	0
Vietnam	0	0	0	24	0	0	30	0
Other countries	113	643	92	87	18	3	84	29
WA	1,303	1,576	1,654	1,421	1,149	1,538	1,468	2,063
Australia	**14,694**	**17,145**	**19,554**	**21,814**	**15,647**	**14,603**	**7,391**	**6,447**

Source: Australian Bureau of Statistics (ABS) and Department of Agriculture and Food Western Australia (DAFWA) cited in Anonymous 2008

WA has traditionally produced potato seed in the Albany region. WA is unique in that it is free from many potato pests and major infectious diseases (Schmiediche 1995) (Appendix 3). Natural advantages such as climate, a clean environment, soils and water, make WA an ideal place to cultivate seed potatoes for both domestic and international markets (Dawson, McPharlin and Howes 2003). The potato production areas in WA are free from bacterial wilt (*Ralstonia solanacearum*), potato cyst nematode (*Globodera rostochiensis* and *G. pallida)*, late blight (*Phytophthora infestans*) and potato virus Y (all strains) which are common in the tropics (Schmiediche 1995; Dawson, McPharlin and Howes 2003). WA is also free from potato leaf miner (*Liriomyza huidobrensis*) (Holland and Spencer 2007).

In being close to Asian countries like Vietnam, WA is also able to reduce the shipping time (Batt 2003b) compared with Europe and North America. Furthermore, seed growers in WA have introduced and multiplied potato varieties that have been selected by the national potato programs in Asia as being suited to the agro-ecological conditions and market preferences.

Seed scheme and seed certification in Western Australia

There are two seed schemes operating in WA: (i) a Certified Seed Scheme (for use in both domestic and export markets) and (ii) a Registered Seed Scheme (for the domestic market only). The Certified Seed Scheme limits seed to G5 while the Registered Seed Scheme allows growers to multiply seed up to G7.

In WA, the Seed Potato Certification Scheme is a cooperative industry scheme which uses the National Standard as a minimum. The scheme is administered by the Department of Agriculture and Food, Western Australia, through its Plant Laboratory Business Unit (PLBU). The PLBU is responsible for undertaking inspections of both the growing crop and harvested tubers, providing advice and certifying those seed lots which meet the quality standard. The National Standard began in 1997 when five separate state-based standards were replaced by a National Standard (Anonymous 2001). The National Standard also ensures that irrespective of the state of origin, buyers in Australia will receive seed which is certified according to a single nationally agreed standard (Holland and Spencer 2007).

In comparison to other countries such as the Netherlands, Canada and Scotland, the WA Certified seed scheme produces seed with the lowest number of field generations. For example, the final product of the Certified seed scheme in WA is Generation 5 (G5) compared to Class C certified seed (G7) in the Netherlands, G7 certified seed in Canada and class A (G11) in the Scottish seed certification scheme (Anonymous 2005; Holland and Spencer 2007; Anonymous 2006c).

Seed quality quarantine rules

All potato stocks (existing and new cultivars) acquired from whatever source for use as starting material (plants or tubers) must be visually free from all diseases before being pathogen tested for the presence of blackleg, bacterial wilt, ring rot, powdery scab, black scurf, silver scurf, gangrene, wilt and dry rot, black dot, potato leafroll virus, potato virus A, potato virus M, potato virus S, potato virus X, potato virus Y, tomato spotted wilt virus, and potato spindle tuber viroid, calico (potato aucuba virus), late blight and common scab. The aim of this scheme is to ensure that the stock provided for further multiplication has been tested and found to be free from these diseases.

Procedure of the seed certification for Certified Seed

+ Field inspections and tolerances

Growers are responsible for notifying PLBU when their crops reach a suitable stage of growth for inspection. Inspectors must be able to see the base of the plant four rows away when looking across the crop. Seed potato crops must be inspected at least two times during their growth. The inspector will look at each of the following aspects:

- Crop growth status: the crop may be rejected if it shows poor emergence, unthrifty plants, undue growth of weeds, severe hail or frost damage, severe damage caused by or suspected to be caused by chemicals, or is too advanced for inspection. Crops may be rejected if the inspector is satisfied that the incidence of one or more diseases or weeds is such as to adversely affect the quality of the seed tuber regardless or whether the weed or disease is specifically listed in the rules.
- Foreign plants
- Samples of plants may be required for laboratory testing of pathogens at the grower's expense. The result of these diagnostic tests can be used as the basis for crop rejection.
- Crop rating: crops will be rated from 1 to 3 according to the tolerances for foreign varieties, virus and other diseases. Any seed having a field rating of 3 cannot be further multiplied as certified seed.

+ *Virus testing:* All Generation 2 sown plots (G3 harvested) are tested for tomato spotted wilt virus, potato leafroll virus, potato virus S, potato virus X and potato virus Y. A minimum of 50 leaves per variety and a total at 500 leaves per grower are tested. Samples may be taken at the first or second inspection at the grower's preference. First inspection samples detecting virus must have a second set of samples taken at the grower's expense.

+ *Roguing:* Undesirable plants (self-sown, variety off-types and diseased) must be removed from the crop prior to inspection if they are sufficiently advanced to be identified as such. The whole plants, tops and tuber pieces must be removed from the paddock.

+ *Handling and packing:* Seed potatoes are to be harvested, graded, packed, transported and stored in such a way as to preserve their identity and prevent any contact with other potatoes. Containers in which seed is stored and/or sold must be new or clean and not pose a disease or toxicity risk.

+ *Tuber inspection:* Tuber inspection may be required before packing. The PLBU inspector will inspect the tubers for diseases and defects by examining random samples of each lot of produce presented for inspection. This inspection is based on prepared models.

Any generation of seed up to generation 5 may be sold as "certified" provided it meets the minimum rating. Seed that does not meet the minimum rating of 3 can be certified but not multiplied further in the Certified Seed Scheme. The seed from generation 0 (G0) must be produced by an accredited laboratory and may be sold directly for commercial use or for subsequent multiplication (G1 to G4) through one or more field generations. This material is produced in the field for a maximum of five generations (Table 3.5).

Table 3.5: Generation of certified seed in WA

Seed planted and growing crop	Year	Seed harvested
Mini tubers, micro tubers or plantlets (G0)	1	G1
G1	2	G2
G2	3	G3
G3	4	G4
G4	5	G5

Source: Holland and Spencer (2007)

+ *Labelling:* PLBU issues a purple label for registered seed lots and a red label for certified seed lots. Growers must contact the certifying authority before packing to request certified labels for the seed lots to be certified. Labels must be attached to each container of seed intended for certification at the time of grading and packing.

Each sack of seed potato must be sealed by sewing an official label into the mouth of the sack. When the seed is packed into bulk containers, the following conditions apply: (1) each container of seed potatoes must be labelled with an official label prior to tuber inspection; (2) the truck should be treated as a bulk bin and have a signed cleanliness declaration certificate; (3) on loading the truck, the labels are to be removed from the containers and only one label is to be given to the driver to represent that lot of seed. The seed grower keeps a record of the label numbers used; (4) all labels removed from the containers must be cut in half and retained for audit purposes. Official labels must be securely attached to prevent loss during transport and these labels must be destroyed after use.

3.6. Chapter summary and implications

Batt (2003b) and Tuyen (2008) consider that in the absence of a sustainable formal seed system and limited imports from Europe (300 to 400 tonnes per annum), plus the negligible amount of good quality seed produced locally, 90% of the seed used in the RRD comes from the farmers' saved seed and Chinese imports. Seed from both seed sources are contaminated by seed-borne diseases and suffer from seed degeneration. According to Batt (2003b), the annual seed requirement in the RRD is calculated to be 6,300 tonnes per annum. This is based on a production area of 35,000 ha with a seed rate of 1.2 tonnes per ha and a seed renewal rate of one time every six years (0.15). With such a high degeneration rate in the RRD, the current replacement of 0.15 is very low and is one of the most important reasons for the low yield in the RRD. A significant improvement in the yield can be expected if the replacement rate was to increase.

Seed quality is the most important factor influencing the yield and productivity of the potato crop. Therefore, an appropriate solution to improving the health and yield of potato crops in Vietnam, where the seed degeneration rate is very high, is the use of certified seed.

Numerous attempts to introduce a certified seed system based on European protocols have failed due to the unsuitability of the models to the economic and agronomic conditions in Vietnam. The models have been unsuitable because the schemes have been developed in temperate areas where there is isolation from commercial crops, low number of aphids, good storage facilities and field multiplication can be done over many generations to defray the cost of the expensive foundation material. These conditions do not occur in Vietnam. Therefore, the most practical solution may be import good quality seed and to reduce the cost of the seed to farmers by undertaking one or more subsequent multiplications of the seed in-country. With a limited number of field multiplications, the incidence of seed-borne disease can be minimized. This ensures that farmers can buy good quality seed at a lower cost compared to newly imported seed.

In addition, WA has a better seed certification scheme than competitors from Europe and North America as it provides seed with fewer field multiplications (David 2001). Furthermore, the availability of seed potatoes all year round enables WA to provide seed of the desired physiological age which corresponds with the planting time in the RRD (end of October and November).

Furthermore, WA is unique in that it provides varieties which have been selected as being suitable to the Vietnamese cultural conditions and market preferences. These aspects provide WA with a competitive advantage in the supply of seed potatoes to Vietnam compared with other seed suppliers.

There is a Vietnamese Government directive to identify and develop areas where imported seed can be multiplied prior to sale to growers. Such areas, whilst never completely free from pest and diseases, will provide better growing conditions than those normally found in the RRD. Areas identified include Thai Binh, Van Don Island, and the highlands of Sapa (Tuyen, Chuc and Mentz. 2003). An efficient seed multiplication and supply system needs to be developed to provide a continuous supply of affordable and high quality seed to smallholder farmers in the RRD. In order to implement such a scheme, Vietnam will need to formalize standards for crop care and management through a Seed Certification program.

Chapter Four:

Research Methodology

4.1. Outline

This chapter describes the research methodology used in this project in two parts: (i) the field trials and the virus testing; and (ii) the farmer's survey. It begins with a botanical description of the three potato varieties used in the project, followed by a description of the selected project locations. The chapter concludes with a justification for the study design.

4.2. Varietal selection

Three potato varieties: KT3, Eben and Atlantic were used in the experiments associated with this project. Two of these varieties, KT3 and Eben have been found to be suitable for cultivation in the RRD. With the growing demand for potato crisps for the snack food industry, Atlantic is being evaluated to determine its suitability for processing in the RRD.

Atlantic

Atlantic is a processing variety with a high specific gravity which makes it suitable for crisp production. It was bred and selected by the USDA from the cross of B5141-6 (Lenape) x Wauseon in 1969 for cool temperate regions. It was first released in 1976 and introduced into Australia in 1986 (Love *et al.* 1993). It is a medium to large, upright and open plant, with purple pigmented stems and slightly swollen nodes with conspicuous wings. Leaves are large, closed and of medium green with ovate terminal leaflets. Flowers are numerous, of medium size, with light red-purple petals (Webb *et al.* 1978). Tubers are round to oval, with scaly, buff coloured skin, a creamy white flesh with well distributed eyes of medium depth and purple pubescent sprouts (Love *et al* 1993; Pavlista 2003).

The seed has a dormancy of 3 to 4 months at $4^{o}C$ (Pavlista 2003). The crop is of medium maturity and on average is cultivated for 100 – 115 days. The yield is medium to high, with a high proportion of large tubers (>112 g), although there may be a high incidence of hollow heart in the larger tubers.

Seed is stored at 3-5^{o}C for 3 to 4 months to provide plants which produce tubers of the best crisping quality. Atlantic is susceptible to *Verticillium* wilt, early and late blight, common scab and most storage rots. However, it is resistant to potato virus X; potato leafroll virus induced net necrosis and some strains of *Globodera rostochiensis* (Pavlista 2003).

KT3

KT3 is a hybrid (Serrana x I.1035) bred by the International Potato Center (CIP) and evaluated in Vietnam by the Vietnam Agricultural Science Institute (VASI). KT3 has been multiplied in the farmers' fields since 1996 and was officially released as a variety in 2000 (Fuglie *et al.* 2001). It has tall to medium stems with dark green to green leaves. In the RRD, it produces high yields, small to large tubers that are round in shape, golden yellow flesh and a yellow skin. The tuber contains many eyes that are deep and dark pink (Love *et al*. 1993).

Eben

This potato variety was first released by Mariano Marcos State University (MMSU) and originally called "Raniag" (ray of light). It was the result of eight years trials in the Philippines. It is well adapted to the hot lowlands of Ilocos Norte and Abra where it yields from 17 to 24 t/ha and up to 35 t/ha at higher elevation (Perez 2001). It has good crisping quality and storability, and is profitable for Vietnamese farmers to grow (Tuyen, Hue and Thoai 2003). It is an early maturing variety, capable of harvest after only 75 - 85 days. The tubers are round with a brown skin colour and shallow eyes. Processors have found the variety acceptable because of its high dry matter content and strong potato flavour (Perez 2001).

4.3. Selection of study location

The study was undertaken in the Red River Delta which is the flood plain formed by the Red River and its tributaries in northern Vietnam. The delta, measuring some 15,000 square km and is well protected by a network of dykes. The RRD is an agriculturally rich area where most of the land is devoted to rice cultivation and food crops. The RRD is comprised of eight provinces together with two municipalities:

the capital Hanoi and the main International port Hai Phong. The RRD is the major potato production area of Vietnam where 98% of the potato crop is planted. Four locations were selected for the field experiments and farmer surveys including Hai Duong, Thai Binh, Hai Phong and Ha Tay. These locations are close to Hanoi which is the biggest market for fresh potatoes in North Vietnam (see Appendix 1).

Hai Duong province is located half way between Hanoi and Hai Phong. With a total land area of 1,648 km^2 and a population of 1,670,800, it is bordered by Bac Ninh and Bac Giang to the north, Thai Binh to the south, Hai Phong province to the east and Hung Yen in the west. Hai Duong is one of the main locations where fresh fruit and vegetables are cultivated for the market in Hanoi; and some 3,762 ha of potatoes are cultivated. The Food Crop Research Institute (FCRI), located in Gia Loc district, was selected for the field experiments in Hai Duong province.

FCRI is the national food research institution belonging to the Vietnamese Academy of Agricultural Science (VAAS) under the Ministry of Agriculture and Rural Development (MARD). Established in 1968, FCRI is responsible for: (i) conducting research and development on food crops including rice, vegetables and legumes, root and tubers crops; (ii) developing improved production technologies for food crops and transferring those technologies to farmers; and (iii) producing foundation and certified seed for food crops. FCRI has many collaborative research programs with other national research institutions, universities, provincial agencies and several international organizations including IRRI, ICRISAT, CIP, AVRDC, FAO and ACIAR.

Thai Binh province is on the coast in the RRD. With a land area of 1,540 km^2 and a population of 1,865,000 (GSO 2006), Thai Binh has the largest area of potatoes planted in the RRD (4,360 ha). It is about 18 km from Nam Dinh, 70 km from Hai Phong, and 110 km from Hanoi. Most of the potatoes produced in Thai Binh are sold to HCM City or exported to Laos and Cambodia. Trong Quan cooperative, located in the west of the province, was selected for both field experiments and the farmer survey. Trong Quan is an agricultural cooperative with 160 ha planted in potatoes. The cooperative is an experimental and demonstration location for research and development on food crop projects conducted by FCRI, VASI, HAU and NCVESC. The agro-ecological conditions experienced at Trong Quan are typical of the agro-ecological conditions found in the RRD. Moreover, Trong Quan is one of three coastal locations that are believed to be suitable for clean seed potato multiplication in the RRD as it has a lower incidence of aphids and pathogens compared to other locations in the RRD (Tuyen, Chuc and Mentz 2003).

Ha Tay province is the gateway to Hanoi. It is surrounded by Hanoi and Hung Yen province to the east, Vinh Phuc province to the north, Ha Nam province to the south, and Hoa Binh and Phu Tho provinces to the west. Ha Tay has a land area of 2,198 km^2 and a population of 2,543,500 (GSO 2006). Ha Tay is the main source of fresh vegetables for Hanoi including potato with 1,859 ha under cultivation. Ha Hoi cooperative has some 235 ha under production with some 52 ha planted in potatoes.

Hai Phong is another coastal province, 100 km east from the capital Hanoi. It occupies an area of 1,507 km^2 and supports a population of 1,803,000. The total area planted in potatoes is 1,405 ha (GSO 2006). Hai Phong is the gateway to the world for it is the national port of Vietnam where all imports and exports of potato take place. Viet Tien cooperative has a total of 429 ha devoted to agricultural production with 24 ha planted in potatoes.

4.4. Justification for study

This project is a combination of three parts: field trials, farmer surveys and a formal laboratory based analysis of selected viral diseases in potatoes. The methodology has been designed with a view towards ensuring an accurate investigation of the agronomic and economic impacts arising from the use of WA potato seed for smallholder farmers in the RRD of Vietnam.

Since smallholder farmers are unlikely to keep any formal records, on-farm field trials were undertaken to provide an accurate measure of the yields and the yield composition for each of the three WA seed potato generations for each variety in two locations in the RRD.

The high incidence of pests and diseases has been acknowledged as the major constraint limiting the yield and the quality of potatoes in the RRD. Virus tests were undertaken to explore the correlation between virus infection and yield and the yield components for each seed generation. This should also show the interaction between virus infection and the rate of seed degeneration for each variety.

Although farmers are unlikely to provide any accurate information on crop performance, they are the best sources of information on production costs and economic returns because they have been working directly on the farm and they undertake the marketing of the crop. Farmer surveys were conducted to explore the economic impact on smallholder potato farmers in the RRD from the use of WA potato seed and the opportunities for WA potato seed in Vietnam.

All observations were conducted in the farmers' field and surveys were undertaken in potato growing areas which were representative of the agro-ecological conditions experienced in the RRD. This was done to ensure that the results achieved from the project would be of direct benefit to the smallholder potato farmers in the research area.

Chapter Five:

The Agronomic Impact of WA Potato Seed in the RRD[2]

5.1. Chapter outline

Chapter Five investigates the performance of WA potato seed in the RRD. It begins with a determination of the tuber yield and tuber quality derived from three generations of WA seed under Vietnamese cultural conditions. The next section focuses on the level of virus infection for each seed generation for each variety in each location. The final section describes the interaction between the level of virus infection and the reduction in yield for each variety.

5.2. Introduction

Many factors influence the tuber yield and quality of the potato crop such as climate, soil types, the incidence of pests and diseases, on-farm practices and variety. However, Rex (1990) and Struik and Wiersema (1999), consider that the performance of a potato crop is directly related to the quality of the seed tuber planted. Good quality seed tubers are capable of producing healthy, vigorous plants that produce a high yield of good quality tubers within the time limits set by the growing season and the socio-economic and agronomic environment (Beukema and van der Zaag 1990; Dowling 1995; Struik and Wiersema 1999).

Potato plants are liable to coincident infection by more than one virus (Burton 1966). The disease, although seldom lethal, reduces plant growth and the yield potential of seed tubers (Hooker 1981). However, the extent to which the yield is reduced depends on the conditions experienced during the growing period (Mulder and Turkensteen 2005b). The high incidence of pests and diseases in the RRD, specifically virus, has been acknowledged as the major constraint reducing the yield and productivity of potato crops.

---

[2] The chapter is drawn from Hue D.T, Batt P.J, McPharlin I.R and Dawson P. (2008a). Performance of Western Potato Seed in Vietnam. Fifth biennial workshop of Horticulture Program. Mandurah Quay Resort, Western Australia 8-9 May.

However, no assessment of the agronomic impact of viral infection on the productivity or quality of WA potato seed cultivated in the RRD has been undertaken. Over two years, 2006/07 and 2007/08, the yield and level of virus infection for three potato cultivars KT3, Eben and Atlantic, in two locations were compared where the crops had been derived from new seed imported from WA (VN0), seed derived from crops cultivated in the RRD after one generation (VN1) and seed derived from crops cultivated after two generations in the RRD (VN2).

5.3. Methodology

5.3.1. Field experiments

Experimental design

A randomized block design was used with two varieties (KT3 and Eben) in the first year and three varieties (KT3, Eben and Atlantic) in the second, factorised with three seed treatments (VN0, VN1 and VN2). The plot size was 24 m^2 with 2 beds of 12 m^2 and 4 replications for each treatment. The total size of the experimental area was 576 m^2 for the first crop and 864 m^2 for the second crop (excluding boundaries).

Experiments were conducted in both locations (Hai Duong and Thai Binh provinces), in 2006/07 and 2007/08. Crops were planted in early November and harvested in late January in both years.

Seed preparation

The VN0 seed was certified G4 seed grown at Manjimup, WA, harvested in May and cool stored at 2.5^{o}C and 95% humidity until September. The seed was then graded and packed for export into 25 kg hessian bags. The seed was treated with Tecto Flowable SC fungicide® (500 g/L thiabenzadole) at 2 L/tonne in a solution of 1 L of Tecto® /22 L of water for the control of dry rot (Fusarium). The seed was then loaded into a refrigerated sea container and transported to Hai Phong harbour. The seed was unpacked from the refrigerated container and transported to FCRI where it was stored at room temperature to promote sprouting one week before planting.

VN1 and VN2 seed was derived from VN0 seed grown for one and two generations in the field respectively in the RRD. Small tubers (30-50 g/tuber) were selected from healthy looking plants of the previous crop (VN0 or VN1). These were laid on the floor in the cool store at ambient conditions for one week before cool storage at 4^{o}C and 95% humidity for 8 months at FCRI and Trong Quan. One week to ten days before planting, VN1 and VN2 seed was taken from the cool store, unpacked from the refrigerated bag then laid on the floor at room temperature to promote sprouting. No seed treatment was applied either before or after storage.

On-farm practices

On-farm practices for each of the experiments followed the procedures developed by the Root Crop Research and Development Centre of the FCRI.

Planting and fertiliser application

In all experiments, seed was planted at a density of 5 plants per m^2, 5-7 cm deep, in a bed 1.2 m wide with double line spacing of 40 cm between lines and 30 cm between plants in the line. The rates of manure and fertilizer application per ha was 15.0 tonnes of composted manure (pig manure), 120 kg N, 110 kg P_2O_5 and 130 kg K_2O, applied: (1) before planting: 100% of composed manure, 100% of the phosphorus (P); 40% of the nitrogen (N) and 20% of the potassium (K); (2) at the first hilling time: (15-20 DAP): 50% of the N and 30% of the K; and (3) 10% of N and 50% K applied at the second hilling (40-45 DAP).

Crop protection and irrigation

Sherpa (15-20 ml/ 10L) or *Confidor* (10-20 ml/10 L) was applied for the control of leaf miner and aphids, and *Dipterex®* (500 g/L trichlorfon) for the control of cutworm. *Daconil®* (750 g/L chlorothalonil) and *Ridomil MZ 720* (25-30 g/10 L) were applied alternately each week to control early and late blight. Furrow irrigation was applied to provide water to 2/3 the height of the ridge, which was released the following day. Weeds were removed by hand hoe at hilling times.

Harvest

Potatoes were prepared for harvest when the leaves turned yellow, which was about 85 days after planting. The haulms were cut by sickle one week to ten days before harvest to prevent disease infection spreading from the foliage to the tubers. Tubers were dug from the middle 4 m of two beds (40 plants) in each plot then laid in bamboo and plastic buckets for grading.

Data collection and measurement

In the field, the total yield of fresh tubers (tonnes/ha) for each plot was recorded. After counting and weighing rejected tubers (i.e. tubers showing damage, greening, second growth, cracks or rots), all the remaining tubers were counted and weighed. The percentage of tubers was determined in each of the following weight grades: large (>50 g), medium (30 – 50 g), and small (< 30 g). Marketable yield was the total yield minus the yield of small and rejected tubers.

Data analysis

For the field experiments, analysis of variance (ANOVA) was carried out on total yield, marketable yield and the yield of each tuber size category versus the seed tuber generation (VN0, VN1, VN2) using Genstat version 10 (Lawes Agricultural Trust, Rothamsted Experimental Station) for a completely randomized design. Differences between the treatment means were compared using LSD (least significant differences) at $p= 0.05$.

5.3.2. Virus testing

To evaluate the rate of tuber degeneration, virus testing was done in both the 2006/07 season and the 2007/08 season. The virus tests were conducted by the National Centre for Variety Evaluation and Seed Certification (NCVESC) in Hanoi, Vietnam. Four major viruses were tested for including potato virus A (PVA), potato virus Y (PVY), potato leafroll virus (PLRV) and potato virus X (PVX).

Sampling and data collection

The leaves were collected 60 to 70 DAP. Samples were collected in the early morning, placed in plastic bags and labelled. One young fully expanded green leaf with no dead/ damaged tissue was randomly collected from fifty plants (one leaf per plant) in each plot then arranged into five groups of ten leaves. All leaf samples were stored in cool containers to ensure leaves were fresh when they reached the laboratory at NCVESC on the same day. ELISA (Enzyme-linked immunosorbent assay) tests were used to determine the percent of virus infection in the potato plants in each plot.

Data analysis

ANOVA (Genstat version 10) was carried out on the yield data (total yield, marketable yield and yield in each weight grade) for each variety at each location and in both years for Eben and KT3 and in 2007/08 for Atlantic. Significant differences in yield between the seed source treatments (VN0, VN1 and VN2) were reported at the 95% level in all cases.

The percent of virus infection was estimated using the formula of Gibbs and Gower (1960). The raw virus data (percent infection) were transformed to angles (ASIN ($\sqrt{(\% \text{ incidence}/100)}$)* 360/2л)); and percentage values of 0 or 100 were converted to 0.1 or 99.9, respectively. ANOVA was performed on the transformed data using Genstat version 10. Differences between the treatment means were compared using LSD at p=0.05. The mean data on percent virus infected plants were then back-transformed for presentation.

Where there was no significant difference between years or locations from the ANOVA, the relative yields of each variety were combined to allow an investigation of virus infection across each year. Relative yields (%) for each variety were calculated by dividing the yield in each seed source treatment by the maximum yield measured at each location each year. Linear regressions (y = a + bx, where y = relative yield (%), *x* = % virus infection, a: constant and b = the slope) were then fitted to relative yield and percent virus infection for each variety and seed treatment using Genstat version 10. Linear regressions (Thackray *et al.* 2000) were chosen over the more complex models used by van der Zaag (1987) as being appropriate to evaluate any relationship between percent of virus infected plants and yield only one strain of PVY and PVX were identified and the percent virus infection was moderate.

5.4. Results

5.4.1. Yield and quality of WA potato seed in the RRD

There were highly significant differences in the total yield produced by the three different seed generations in the RRD. In 2006/07, for Eben, VN0 seed produced the higher total yield of 26.3 t/ha compared to VN1 (20.3 t/ha) in Hai Duong. In Thai Binh, Eben produced 27.5 t/ha (VN0 seed) compared to 20.3 t/ha for VN1 (Figure 5.1)[3]. Similar differences were observed for KT3, where the total yield declined sharply from 32.9 t/ha for VN0 to 25.5 t/ha for VN1 and 22.1 t/ha for VN2 in Hai Duong and from 33.1 t/ha to 27.5 t/ha and 24.5 t/ha for VN0, VN1 and VN2 respectively in Thai Binh. There was no significant difference between total yields of each variety by location.

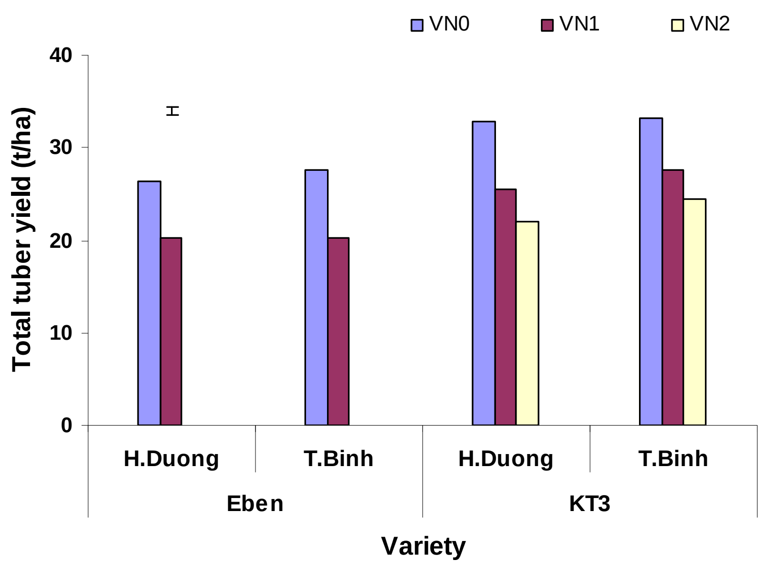


Figure 5.1: Total tuber yield of three different WA seed generations for Eben and KT3 in Hai Duong and Thai Binh during the winter season 2006/07. Vertical bar is l.s.d. value at p=0.05 for total tuber yield between seed generations

In 2007/08, the total yield for Atlantic decreased from 24.4 t/ha for VN0 to 21.4 t/ha for VN1 and 16.6 t/ha for VN2 in Hai Duong and from 24.9 t/ha for VN0 seed to 21.6 t/ha for VN1 and 16.7 t/ha respectively for VN2 in Thai Binh. For Eben, VN0 seed produced the highest total yield of 26.2 t/ha compared to 21.7 t/ha (VN1) and VN2 (16.5 t/ha) in Hai Duong and 26.0 t/ha (VN0) compared to 21.3 t/ha (VN1) and 16.9 t/ha for VN2 respectively in Thai Binh. For KT3, the total yield declined from

[3] Data table of tuber yield and quality for three different WA seed generations of Eben and KT3 in Hai Duong and Thai Binh during the winter season 2006/07 is to be found in Appendix 4.

26.3 t/ha for VN1 seed to 22.5 t/ha for VN2 in Hai Duong and from 26.9 t/ha for VN1 compared to 23.6 t/ha for VN2 in Thai Binh (Figure 5.2)[4].

There was no significant difference between yields of variety by location.

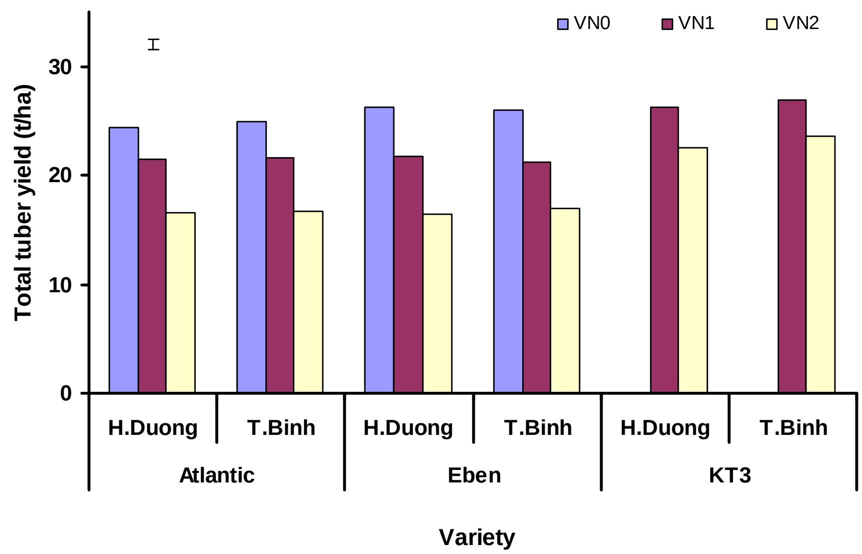


Figure 5.2: Total tuber yield of three different WA seed generations for Eben and KT3 in Hai Duong and Thai Binh during the winter season 2007/08. Vertical bar is l.s.d. value at p=0.05 for total tuber yield between seed generations

However, there were highly significant differences found in marketable yields (tubers > 30g) for the three different seed generations in the RRD. For Eben, in 2006/07, VN0 seed produced the higher marketable yield of 88.5% compared to VN1 (78.3%) in Hai Duong and 84.7% (VN0 seed) compared to 75.9% (VN1) in Thai Binh (Figure 5.3). Similar differences were observed for KT3, where the marketable yield declined sharply from 90.5% for VN0 seed to 82.1% for VN1 and 74.6% for VN2 in Hai Duong; and from 89.7% to 81.8% and 79.2% for VN0, VN1 and VN2 respectively in Thai Binh. For Atlantic, in 2007/08, the marketable yield of VN0 seed declined from 90% to 86.6% for VN1 and 77.4% for VN2 in Hai Duong. In Thai Binh, it decreased from 90.7% to 87.1% and 79.9% respectively. For Eben, VN0 seed produced the highest marketable yield of 88.0% compared to VN1

[4] Data tables of tuber yield and quality for three different WA seed generations of Atlantic, Eben and KT3 in Hai Duong and Thai Binh during the winter season 2007/08 is to be found in Appendix 5.

(85.1%) and VN2 (76.7%) in Hai Duong and 86.6% compared to 78.2% and 74.3% respectively in Thai Binh. For KT3, the marketable yield declined from 83.1% for VN1 seed to 76.8% for VN2 in Hai Duong and from 82.8% for VN1 compared to 78.9% for VN2 in Thai Binh (Figure 5.3).

No significant difference was found between the marketable yields (tubers > 30g) by location.

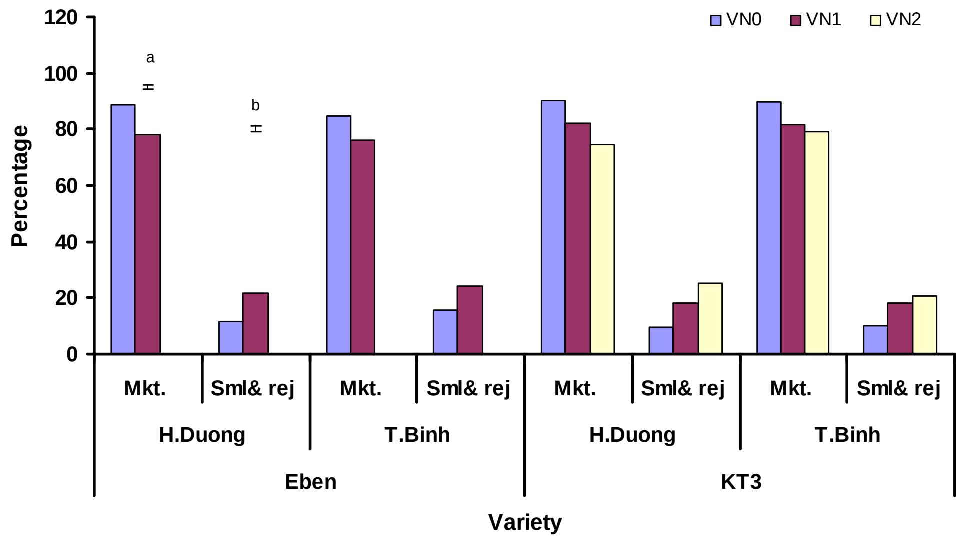


Figure 5.3: Tuber quality of three different WA seed generations for Atlantic, Eben and KT3 in Hai Duong and Thai Binh during the winter crop 2006/07. Vertical bars are l.s.d. values at p=0.05 for marketable yield (a) and small and rejected tubers (b) between seed generations

There were highly significant differences in small and reject tubers (<30g and damaged tubers) for each of three different seed generations. In 2006/07, for Eben, VN0 seed produced the lower quantity of small and rejected tubers (11.5%) compared to VN1 (21.7%) in Hai Duong. A similar result was achieved in Thai Binh, where the proportion of small and rejected tubers was 15.4% for VN0 compared to 24.1% for VN1 (Figure 5.1 and 5.2). Similar differences were observed for KT3, where the proportion of small and rejected tubers increased considerably from 9.6% for VN0 seed to 17.9% for VN1 and 25.4% for VN2 in Hai Duong. In Thai Binh, the figures were 10.3% to 18.2% and 20.8% for VN0, VN1 and VN2 respectively.

In 2007/08, for Atlantic, the yield of small and rejected tubers increased from 9.4% (VN0) to 12.4% for VN1 and 20.7% for VN2 in Hai Duong and from 8.9% to 12.0% and 18.4% respectively in Thai Binh. For Eben, VN0 seed produced the lowest proportion of small and rejected tubers (11.7%) compared to VN1 (14.1%) and VN2 (21.6%) in Hai Duong and 13.1% compared to 21.1% and 23.8% respectively in Thai Binh. For KT3, the yield of small and rejected tubers increased from 16.3% for VN1 seed to 22.1% for VN2 in Hai Duong and from 16.6% for VN1 compared to 20.2% for VN2 in Thai Binh (Figure 5.4).

There was no significant difference between small and rejected tubers (<30g and damaged tubers) by location.

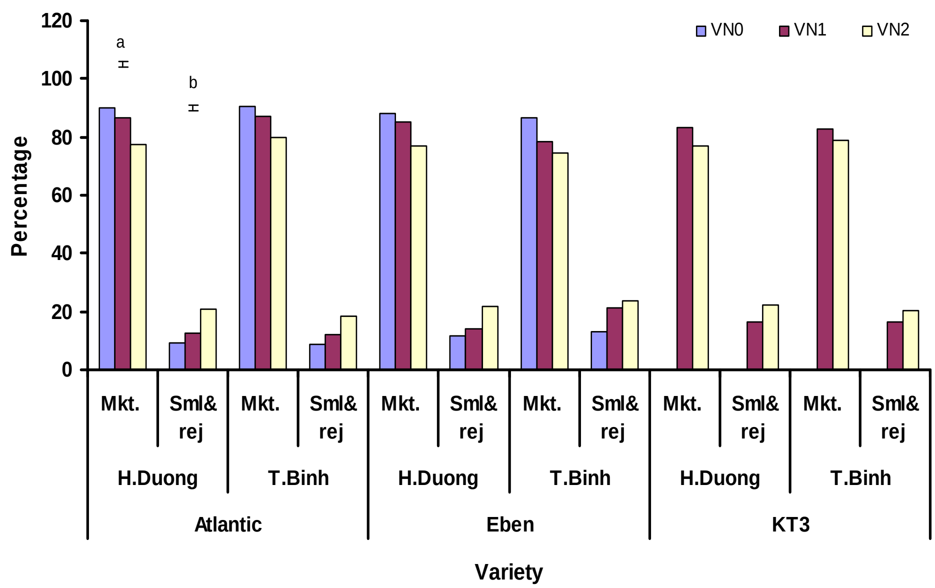


Figure 5.4: Tuber quality of three different WA seed generations for Atlantic, Eben and KT3 in Hai Duong and Thai Binh during the winter crop 2007/08. Vertical bars are l.s.d. values at p=0.05 for marketable yield (a) and small and rejected tubers (b) between seed generations.

5.4.2. Virus infection

During both years (2006/07 and 2007/08), no infection of either PVA or PLRV was detected by ELISA testing of potatoes grown in the RRD experiments. However, the percent of both PVX and PVY were found to increase significantly from VN0 seed to VN1 and VN2 for all three varieties.

In 2006/07, viral infection was lowest in crops grown from VN0 seed and highest in crops grown from VN2 seed for both Eben and KT3 (Figure 5.5 and Figure 5.6)[5]. Mean PVX infection increased from 0.0 % for VN0 seed to 10.5% for VN1 for Eben and from 0.0% to 5.0% and up to 11.7% respectively for KT3 in Hai Duong. In Thai Binh, mean PVX infection increased from 0.1% for VN0 seed compared to 12.7% (VN1) for Eben and from 0% for VN0 seed to 6.9% (VN1) and 22.2% (VN2) respectively for KT3. PVY infection in Hai Duong (Figure 5.5) increased significantly from 3.6% for VN0 seed to 15.4% for VN1 for Eben and from 5.0% (VN0) to 12.1% (VN1) and up to 19.4% (VN2) for KT3. In Thai Binh, VN0 seed had the lowest rate of PVY infection (4.2%) compared to 17.2% (VN1) for Eben (Figure 5.6). For KT3, the incidence of PVY increased from 6.1% for VN0 seed to 7.4% (VN1) and 23.1% (VN2) respectively.

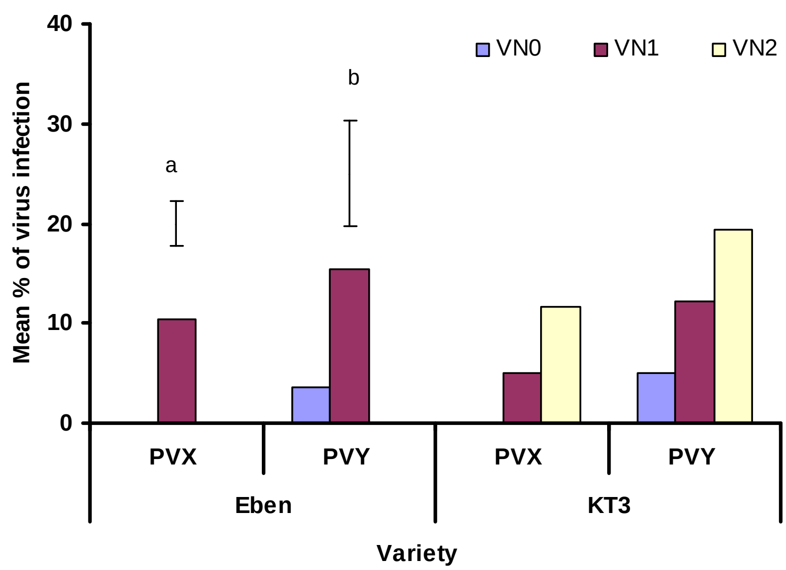


Figure 5.5: Virus infections of three different WA seed generations for Eben and KT3 in the Hai Duong during the winter season 2006/07. Vertical bars are l.s.d. values for PVX infection (a) and PVY infection (b) at p= 0.05

[5] Data table of virus infection for three different WA seed generations of Eben and KT3 in Hai Duong and Thai Binh during the winter season 2006/07 is to be found in Appendix 6.

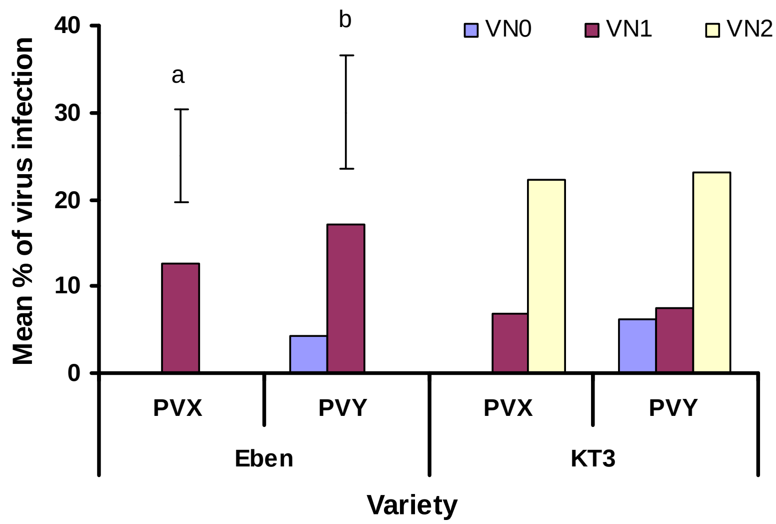


Figure 5.6: Virus infections of three different WA seed generations for Eben and KT3 in the Thai Binh during the winter season 2006/07. Vertical bars are l.s.d. values for PVX infection (a) and PVY infection (b) at p=0.05

Similar differences in virus infection were observed for the 2007/08 crop (Figure 5.7 and Figure 5.8)[6]. The incidence of PVX increased significantly from VN0 seed to VN1 and VN2 for Eben and KT3. PVY infection also increased significantly from VN0 to VN1 and VN2 for all three varieties in both locations. No PVX was found in Atlantic at either location.

In Hai Duong, mean PVX infection for Eben increased from 0.0% for VN0 seed compared to 0.9% (VN1) and 3.5% (VN2) and for KT3, 4.4% for VN1 seed compared to 10.3% (VN2), respectively. For PVY, in Atlantic, VN0 seed had the lowest infection (0.6%) compared to 0.9% for VN1 and 9.0% for VN2. The PVY infection in Eben increased from 0.1% (VN0) compared to 5.0% for VN1 and 13.2% for VN2 and for KT3 PVY increased from 0.6% (VN1) to 9.9% for VN2.

In Thai Binh, mean PVX infection for Eben increased from 0.1% (VN0) to 0.9% (VN1) and reached 5.2% (VN2). For KT3, the incidence of PVX increased from 1.7% (VN1) to 6.1% (VN2). For PVY, the infection in Atlantic increased significantly from 2.8% (VN0 and VN1) to 15.8% (VN2). For Eben VN0 seed had

[6] Data table of virus infection for three different WA seed generations of Eben and KT3 in Hai Duong and Thai Binh during the winter season 2007/08 is to be found in Appendix 7.

the lowest infection (0.1%) compared to 4.2% for VN1 and VN2 and for KT3 PVY infection increased from 1.3% (VN1) compared to 6.1% (VN2).

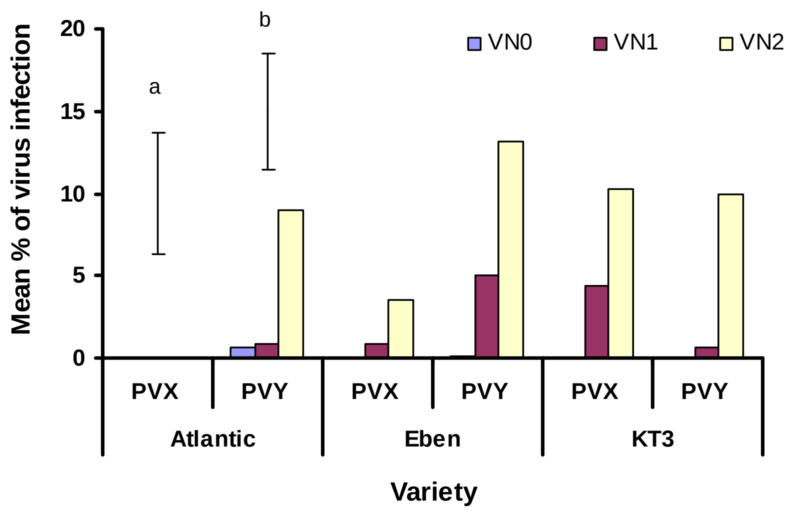


Figure 5.7: Virus infections of three different WA seed generations for Eben and KT3 in the Hai Duong during the winter season 2007/08. Vertical bars are l.s.d. values for PVX infection (a) and PVY infection (b) at p= 0.05

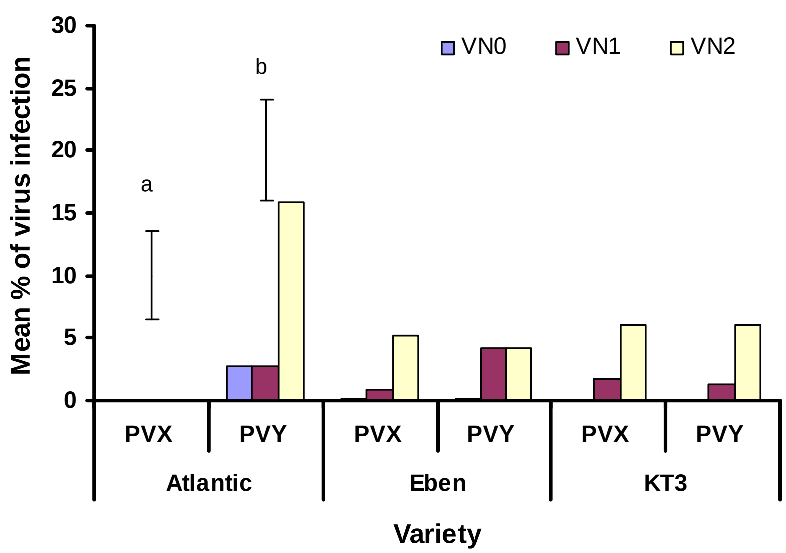


Figure 5.8: Virus infections of three different WA seed generations for Eben and KT3 in the Thai Binh during the winter season 2007/08. Vertical bars are l.s.d. values for PVX infection (a) and PVY infection (b) at p=0.05.

5.4.3. Relationship between virus infection and yield[7]

ANOVA showed there was no significant difference between years or locations for PVY infection and so the relative yields of each variety were combined. Relative yields (%) for each variety were calculated by dividing the yield in each seed source treatment by the maximum yield measured at each location and year. The reduction in relative tuber yield associated with increasing percentage PVY infection was linear (r^2=0.41) and was similar for each variety (Figure 5.9). The yield of crops grown from VN2 seed was 30% less than crops grown from VN0 seed in the RRD. PVY infection increased from 2.8% (VN0) to 24.1% in the VN2 crop over both sites and years.

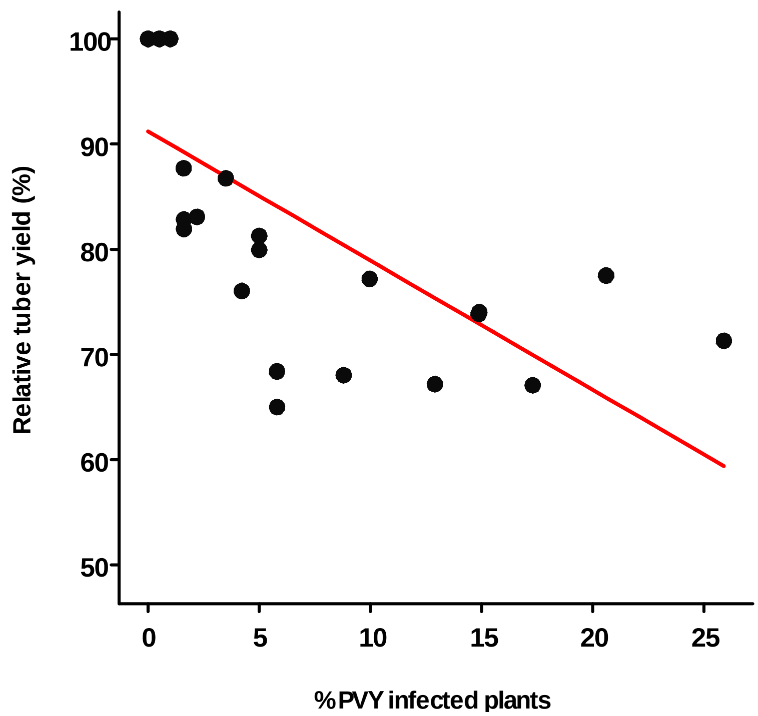


Figure 5.9: Relationship between relative tuber yield (%) and PVY infected plants (%) of three different WA seed generations for three varieties, Atlantic, Eben and KT3 in two locations during two potato crops from 2006 to 2008 in the RRD. The equation for the regression is: Y= 92.95 – 1.1x (p< 0.001; r^2= 0.41)

PVX was not detected in any samples of Atlantic leaves. However ANOVA showed there was no significant difference between years or locations for PVX infection

---

[7] Figures of regression for interaction between PVX and PVY infection and relative tuber yield reduction of WA seed generations for individually variety in two locations during two potato crops can be found in appendices.

between Eben and KT3 and so their relative yields were combined. The relative tuber yield for KT3 and Eben decreased linearly (r^2= 0.4) with a increase in the number of PVX infected plants from 0.3% (VN0) to 8.7% (VN2), where the VN2 crop yielded about 70% of the VN0 crop over both sites and years (Figure 5.10).

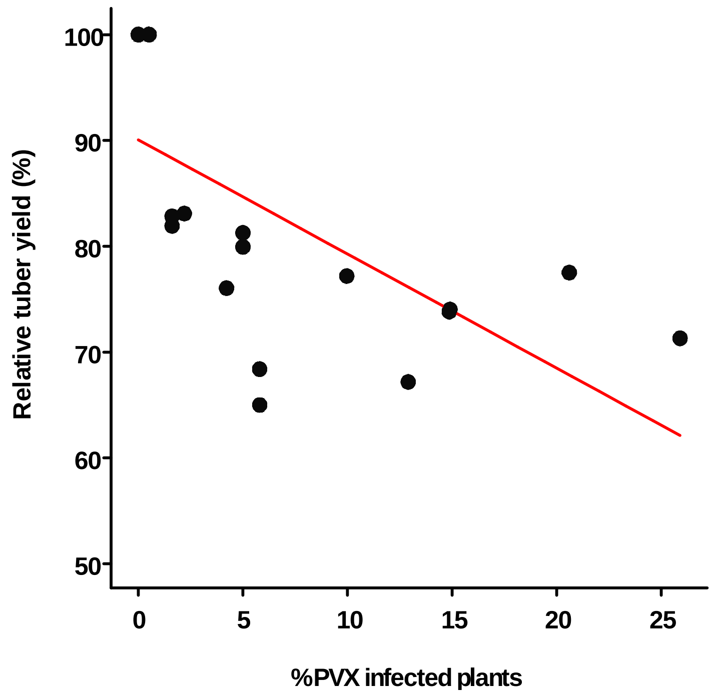


Figure 5.10: Relationship between relative tuber yield (%) and PVX infected plants (%) of three different WA seed generations for two three varieties, Eben and KT3 in two locations during two potato crops from 2006 to 2008 in the RRD. The equation for the regression is: Y= 90.06 – 1.1x ($p<0.002$; r^2= 0.40)

5.5. Chapter summary

These results identified the important relationship between seed tuber quality and the yield of the potato crop. There was a significant difference in yield produced between the three different seed sources but not between locations. For all varieties, and in both years, yield decreased with the number of multiplications in Vietnam from first crop (VN0) (24.4 to 33.1 t/ha) to the third crop (VN2) (16.5 to 24.5 t/ha). Similar results were observed for tuber quality, whereby the VN0 seed produced the highest marketable yield (82.8 to 90.7%) compared to VN2 crop (74.0 to 80%). The yield decline was associated with an increase in PVY (0 to 23.1%) and PVX (0 to 22.2%) infection with each subsequent multiplication of the seed in the RRD.

The reduction in tuber yield associated with increasing PVX and PVY infection was linear and similar for each variety with yield of crops grown from VN2 seed being 30% less than the crops grown from VN0 seed in the RRD.

Chapter Six:

Economic Impact on Smallholder Potato Farmers from the Use of WA Potato Seed[8]

6.1. Chapter outline

Chapter Six explores the economic impact on smallholder farmers from the use of high quality WA potato seed based on survey information over two years (2006/2008). The chapter begins with a description of the respondents, baseline information on their potato farms and the intended market for the tubers they have produced. The next section explores the seed demand, followed by information on farming practices in the RRD, including an assessment by the farmer of the pest and disease status of each seed generation. Further analysis is carried out to investigate the farmer's attitude towards each alternative source of seed and the reasons for their preference. The final section deals with information on post-harvest management and marketing, and a calculation of the production costs and economic returns for each seed generation for each variety.

6.2. Methodology

6.2.1. Location selection

Sampling

In 2006/07 and 2007/08, one hundred and twenty growers of WA potato seed in three provinces (Thai Binh, Ha Tay and Hai Phong) were randomly chosen. In the first year, sixty farmers from two cooperatives in two different provinces (Thai Binh and Ha Tay) were surveyed to collect baseline data on the economics of growing potatoes. From each province, fifteen potato growing households were interviewed from two different villages (Table 6.1). In the second year, the surveys were repeated

[8] The chapter was taken from Hue DT, Batt PJ, McPharlin IR and Dawson P (2008b). The Economic Impact on Smallholder Potato Farmers in the Red River Delta, Vietnam from the Use of Superior Quality Seed. In: Batt, PJ (ed) Proceedings of an International Symposium on the Socio-Economic Impact of Modern Vegetable Production Technology in Tropical Asia. Acta Horticulturae. Chiang Mai, Thailand, 3-6 February 2008 (in press).

with WA potato growers in two provinces (Thai Binh and Hai Phong) with the same number of growers for each group.

Table 6.1: Survey sample

Province	Thai Binh		Ha Tay	
District	Dong Hung		Thuong Tin	
Cooperative	Trong Quan		Ha Hoi	
Group	Group 1	Group 2	Group 1	Group 2
Number of farmer households surveyed	15	15	15	15

6.2.2. Questionnaire format

According to Malhotra *et al.* (2002), questionnaires are designed to fulfil three objectives: (1) to translate the information into a set of specific questions; (2) to motivate the respondents to complete the interview; and (3) to minimize response error. In order to obtain accurate information, a well structured questionnaire was developed based on prior knowledge of potato production in Vietnam, on-farm practices and the marketing of fresh potatoes in the RRD (Appendix 8 and 9). The questionnaire was prepared with careful consideration to the content, wording and the order of the questions.

The questions were adapted from a combination of questionnaires used previously by Embry (2003), Batt (2003c) and Chung (2003), after discussion with supervisors and in consultation with project stakeholders. The questionnaire was prepared in English and translated into Vietnamese.

The questionnaire was divided into nine sections that began with simple questions seeking general information about potato production at the household level and ending with questions about the respondent.

Section One: General information

This section contained four simple questions to gather baseline information on the size of the farm, the area of the farm cropped in potatoes, when the potato crop was planted and the intended market for the output.

Section Two: Potato seed history and demand for seed renewing

Section Two sought to collect information on the seed used through eight questions that dealt with: the frequency (N) with which the seed was renewed and the reason for renewing seed, the method of seed storage (including the type of store), the amount of seed lost and the cost of each storage method. The two last questions in this section focused on information relating to seed purchase and the number of times the seed had been used under Vietnamese cultural conditions.

Section Three: seed selection and seed preparation for the crop

Section Three contained four questions that focused on seed selection and seed preparation prior to planting and to quantify the seed demand of the farmers in the RRD. In this section, farmers were asked about their preferred seed size, the type of seed, seed treatment and the cost of any seed treatment.

Section Four: On farm practice during the crop

Section Four sought to collect information on the agronomic practices that were employed from soil preparation until haulm killing. The two first questions collected data on manure and fertilizer application: the type, origin and cost. Other questions sought to collect information on crop protection and the assessment by the farmer of the incidence of pests and diseases for each seed generation. The last question was concerned about how the farmer dealt with disease infected plants and the percent of infected plants found in each crop.

Section Five: Seed supply

This section contained 8 questions and was a combination of unstructured open-ended questions, multiple choice questions and questions that used a four point semantic scale. For two questions, respondents were asked to rate the extent to which they agreed or disagreed with each statement on a 4 point semantic scale where 1= “not at all well” and 4= “very well” or where; with 1= “not at all important” and 4= “very important”. Section Five aimed to collect information on the attitude of the farmer towards each alternative source of seed and the reasons for their preference.

Section Six: Harvest and post harvest practices

This section contained four questions designed to collect information on harvest and post-harvest practices. Information was collected on the yield obtained, the grades of tubers harvested and how the harvested potato were utilized for each generation of seed.

Section Seven: Marketing, production costs and economic returns

Section Seven aimed to collect information on the marketing of potato including the marketing time and the price obtained for each grade of potato. The last question sought to collect data on the production costs and economic returns from the use of seed selected from each generation.

Section Eight: Demographic details of the respondents

The final section was designed to provide demographic information on each respondent. Information was sought on the gender, age and household details, including the number of occupants. This information was used to estimate the extent to which the characteristics of the sample generally met those of the population.

6.2.3. Data collection

During January to March 2007 and from January to February 2008, 120 growers of WA potato seed were interviewed. Under the circumstances, personal interviews were considered the best means of obtaining the desired information.

After making contact with the local leaders and farmers themselves, a suitable time for the interview was arranged. Interviews were conducted in the farmer's home and/ or the meeting hall of the village or cooperative by FCRI staff who were fluent in both English and Vietnamese. Most of the interviews were conducted at night as farmers were busy in the fields during the day.

At the commencement of the interview, the farmers were advised that their responses would be used only for research purposes. On average, interviews took up to one and one half hours to complete. Recognizing that the respondents did not expect such a long questionnaire, the interviewers offered the farmer a cigarette, sweets and/ or tea and coffee. The interviews were also interrupted by some informal issues that related to crop production or marketing.

6.2.4. Data preparation and analysis

Each questionnaire was checked for completeness and then coded in preparation for data entry into the SPSS program. The selection of statistical procedures was influenced by the research objectives, the characteristics of the data, sample size and the properties of the statistical techniques. Both univariate and multivariate analyses were undertaken to summarize the data, determine whether there were any significant differences between groups and examine the relationships among the variables.

Evaluation of the data was undertaken to check for the normality of data distribution. Normal probability plots were prepared and examined for both kurtosis and skewness. In this study, two of the fixed-response questions (where farmers had been asked to respond on a scale of 1 to 4), were not normally distributed. Most farmers responded to the various statements by choosing their responses at either end of the scale, choosing either a 3 or 4 or a 1 or 2).

An analysis of frequency and percentage distributions were calculated for each question. This basic procedure provides insights and guides the rest of the data analysis as well as the interpretation of the results (Leedy and Ormrod 2001).

Analysis of variance (ANOVA) was used to examine the difference in the mean values of the dependent variable for several categories of a single independent variable (Malhotra *et al.* 2002). For this purpose, one way ANOVA was used to determine whether there was any significant difference between various statements on the farmers' attitudes towards alternative seed sources, crop managements, the variety, yield and the quality of the potatoes harvested in different locations.

Post-hoc analysis, using Scheffe's test, was used to locate the source of these differences at $p=0.05$ for two questions; Question 22 (the criteria to assess farmer's satisfaction with their seed supplier) and question 27 (variables influencing the farmer's choice of variety). A number of post-hoc procedures are available to determine whether there was any significant difference between the means including Scheffe's method. Tukey's extension of the Fisher least significant difference (LSD) and Duncan's multiple range tests. Hair *et al.* (1998) suggests that Scheffe's method is the most conservative with respect to Type 1 errors.

ANOVA was carried out on the production costs and economic returns for each seed source and variety. Significant differences in production costs and economic returns between the seed sources (VN0, VN1 and VN2) were reported at the 95% level in all cases.

6.3. Results

6.3.1. General information of the respondent

The majority of the respondents who participated in the survey were female (69%) (Table 6.2). This suggests that the task of growing potatoes for the household in the RRD is still predominantly undertaken by women. During the winter, males in the village often go to work in the city as there is less irrigable land available for cropping in the RRD. Moreover, they want to earn extra money for the lunar New Year festival which occurs towards the end of the winter crop.

Table 6.2: Gender of survey respondents

Gender	N	%
Male	37	30.8
Female	83	69.2
TOTAL	120	100.0

Of the surveyed respondents; the largest group (44%) were aged 36-45 years; 30% were aged 46-55 years; 13% were aged 26-35 years; 8% were aged over 56 years and only 4% were aged 18-25 years (Table 6.3). Generally, young people in the village prefer to work off-farm as they can earn more money compared to what they can earn from farming.

Table 6.3: Age of survey respondents

Age group (years)	N	%
18-25	5	4.2
26-35	16	13.3
36-45	53	44.2
46-55	36	30.0
55 +	10	8.3
TOTAL	120	100.0

The average household size was 4.0 people. Households of one individual made up only 1% of the sample, while households of five people accounted for 24% (Table 6.4).

Table 6.4: Number of people in household of the respondent

People in household	N	%
1	1	0.8
2	23	19.2
3	17	14.2
4	33	27.5
5	29	24.2
6	14	11.7
7	3	2.5
TOTAL	120	100.0
Mean	4.0	

The average farm size was 5.5 sao (0.20 ha) per household with a maximum of 14 sao per household and minimum of 2 sao. The majority of potato farmers (53%) cropped between 3-5 sao (Table 6.5).

Table 6.5: Total area of the farm per household in the RRD

Area of farm		N	%
(sao)	(Approx ha)		
< 3	< 0.11	3	2.5
3-4	0.11 – 0.14	37	30.8
4-5	0.14 – 0.18	27	22.5
5-6	0.18 – 0.22	14	11.7
6-7	0.22 - 0.25	20	16.7
>7	>0.25	16	15.7
TOTAL		120	100
Mean area		5.5 sao (0.20 ha)	

In the absence of any sustainable irrigation systems in some areas of the RRD, the average area of the farm planted in potatoes was 2.8 sao (0.10 ha) per household, just 50% of the farm (Table 6.6).

Table 6.6: Total area of the farm planted in potatoes in the RRD

Potato farm			
(sao)	(Approx ha)	N	%
< 1	< 0.03	3	2.5
1-2	0.03 -0.06	21	17.5
2-3	0.07 – 0.11	40	33.3
3-4	0.11 – 0.14	27	22.5
4-5	0.14 – 0.18	22	18.3
5-6	0.18 - 0.22	4	1.7
> 6	> 0.25	3	4.2
TOTAL		120	100
Mean area		2.8 sao (0.10 ha)	

6.3.2. WA potato seed planted in the RRD

Most farmers in the surveyed area of the RRD rotated potatoes with two rice crops (spring rice - early autumn rice – potato). Most farmers (88%) grew only one potato crop a year, while 12% grew two crops (Table 6.7).

Table 6.7: Number of potato crops planted a year in the RRD

Crop number	N	%
1	106	88.3
2	14	11.7
3	-	-
TOTAL	120	100

Farmers reported that the spring potato crop was more susceptible to pests and disease pressure, especially late blight and aphids, which can cause considerable yield losses. Therefore, the majority of potatoes were planted in November (77%) (Table 6.8). Farmers in Thai Binh were found to plant potato earlier than Hai Phong and Ha Tay where 77% and 100% of the potatoes were planted in November, respectively.

Table 6.8: Month the main potato crop is planted in the RRD by location

Location	T.Binh		H.Tay		H.Phong		All	
Month	N	%	N	%	N	%	N	%
October	21	35	7	23.3	0	0	28	23.3
November	39	65	23	76.7	30	100	92	76.7
TOTAL	60	100	30	100	30	100	120	100.0

Most farmers in Thai Binh and Ha Tay (74%) planted potatoes for both ware and seed, whereas farmers in Hai Phong planted potatoes only for the ware market (Table 6.9).

Table 6.9: Target market for crops from WA potato seed by location

Market / Location	T.Binh		H.Tay		H.Phong		All	
	N	%	N	%	N	%	N	%
For ware	0	0	1	3.3	30	100	31	25.8
For both seed and ware	60	100	29	96.7	0	0	89	74.2
TOTAL	60	100	30	100	30	100	120	100

Of the surveyed sample, the majority of farmers (97%) had been growing WA potatoes for only 1- 4 years. Only 3% of farmers had grown WA seed potatoes for more than 6 years (Table 6.10).

Table 6.10: Number of year's farmers have planted WA potato seed

Year number	N	%
1	24	20.0
2	20	16.7
3	60	50.0
4	12	10.0
5	-	-
6	1	0.8
7	3	2.5
TOTAL	120	100.0

Most farmers in the RRD (75%) saved some proportion of the harvest from the previous crop for the next year. Conversely, some 25% of potato farmers purchased seed every year (Table 6.11).

Table 6.11: Number of years farmers retain WA potato seed by location

Year / Location	T.Binh		H.Tay		H.Phong		All	
	N	%	N	%	N	%	N	%
0 (not retained)	-	-	-	-	30	100	30	25.0
1	22	36.7	-	-	-	-	22	18.3
2	34	56.7	12	40.0	-	-	46	38.3
3	1	1.7	9	30.0	-	-	10	8.3
>3	3	5.0	9	30.0	-	-	12	10.0
TOTAL	60.0	100	30	100.0	30	100.0	120	100.0

All of the farmers in Thai Binh and Ha Tay retained seed while the majority of farmers in Hai Phong chose not to save seed. Only 18% of the farmers retained seed for one year; 38% retained seed for two years; 8% retained seed for three years; and 10% retained seed for more than three years.

As the high incidence of pests and diseases is the major reason for the rapid degeneration of seed potatoes in the RRD, the majority of the farmers (68%) wished to renew seed every year (Table 6.12); 14% would like to renew seed after two years and 17% would like to renew after 3 years (Table 6.12).

Table 6.12: Number of year's farmers seeks to renew seed

Number of years	N	%
1 (every year)	82	68.3
2	17	14.2
3	20	16.7
>3	1	0.8
TOTAL	120	100.0

However, most of the WA potato seed (68%) has been multiplied for more than two generations in-country, while only 5% was newly imported seed (Table 6.13) Given that newly imported seed is generally too expensive for the majority of smallholder farmers to purchase, most continue to use seed produced in-country.

Table 6.13: Number of generations WA seed had been multiplied in Vietnam

Number of generations	N	%
None, newly imported	6	5.0
One generation	9	7.5
Two generations	16	13.3
Three generations	21	17.5
More than four generations	44	36.7
Unknown	24	20.0
TOTAL	120	100.0

All the farmers in Thai Binh and Ha Tay stored WA potato seed in cool stores whereas in Hai Phong, none of the farmers surveyed saved seed as they did not have any cool storage capacity.

All farmers have to store seed in cool stores owned by cooperatives or privately owned stores. The storage cost was VND 1,100 per kg (charged on the weight of potato tubers before storage) in both Ha Tay and Thai Binh.

Seed losses increased significantly with each seed generation in the RRD. VN0 seed had a lowest seed loss (7%), compared to 9% for VN1 and 11% for VN2 (Table 6.14).

Table 6.14: Mean seed losses during cool storage for each WA seed generation in the RRD (% of seed losses per original weight)

Seed source	Mean (%)	S.D.
VN0	7.0^{c}	1.40
VN1	8.8^{b}	1.97
VN2	11.1^{a}	1.39

Where those mean values with the same superscript are not significantly different at p=0.05.

Some 49% of the farmers surveyed reported that seed losses were due to water loss and respiration during storage (loss in weight), while some 31% considered tuber losses in storage to come primarily from damaged and rotten tubers. Some 20% suspected that losses occurred due to both reasons (Table 6.15).

Table 6.15: The major reasons for the seed losses in cool storage in the RRD

Reason	N	%
Loss in weight	44	48.9
Loss in number	28	31.1
Both reasons	18	20.0
TOTAL	90	100.0

6.3.3. The seed demand

Most of the surveyed farmers used round seed (76%), while some 21% used both cut seed and round seed; and 3% used only cut seed (Table 6.16).

For cut seed, the majority of the farmers treated the seed before planting (88%). After cutting, the cut surfaces of the tubers were treated with cement powder to promote curing then planted on the same day. This cost VND 17,000 per sao.

Table 6.16: WA potato seed types farmers used to plant in the RRD

Seed type	N	%
Round seed	91	75.8
Cut seed	4	3.3
Both cut and round seed	25	20.8
TOTAL	120	100.0

More farmers in Hai Phong were found to use cut seed than farmers' in both Thai Binh and Ha Tay. To avoid unexpected risks from seed cutting, most farmers in the RRD intended to plant small round seed (82%), sized between 21-40 tubers/kg (Table 6.17).

Table 6.17: Seed size of the WA potatoes farmers preferred to use and seed rate farmers actually planted

Tubers per kg	Weight per tuber (g)	Preferred seed size		Actual seed size used	
		N	%	N	%
10 – 20	50-100	2	1.7	16	13.3
21 – 30	33- 48	25	20.8	76	63.3
31-40	25-32	73	60.8	22	18.3
41-50	20-24	19	15.8	5	4.2
51-60	17-19	1	0.8	1	0.8
60+	<14	-	-	-	-
TOTAL		120.0	100.0	120	100.0

Farmers reported that by using this seed size they would be able to minimize the seed cost per sao. Seed of this size would go on to produce high yields under the cultural conditions experienced in the RRD. However, for 61% of the farmers who intended to plant seed from 25 - 32 g, only 18% were actually able to do so, as seed suppliers could not provide the large amount of small round seed required.

While 32% of farmers would like to purchase WA seed from research institutions, 66% wanted to buy seed from their cooperative. Only 2% preferred to buy seed from neighbours and the open market (Table 6.18).

Table 6.18: The preferred supplier and the provider farmers actually purchased WA potato seed in the RRD

Supplier	Preferred supplier		Actual provider	
	N	%	N	%
Cooperative	79	65.8	109	90.8
Research institute	39	32.5	7	5.8
Neighbour	1	0.8	3	2.5
Open markets	1	0.8	1	0.8
Seed companies	-	-	-	-
TOTAL	120	100.0	120	100.0

Irrespective, most farmers rated the service that they received from their preferred seed suppliers very well (Table 6.19). The seed provided was of an appropriate physiological age and did not contain a mix of varieties. Seed was visually free from the major pests and diseases (e.g. bacterial wilt, scab, fungus rot) and was available at the time of planting. Furthermore, as the seed degenerated at a slower rate compared to seed sourced from alternative suppliers, there was less variability in production from year-to-year. Having dealt with the seed supplier on at least one other occasion and having had a favourable experience, most preferred seed suppliers had a good reputation among other potato farmers.

However, seed of the desired variety was not always available and most farmers suspected that there was no official pathogen testing undertaken by their seed supplier. Furthermore, there was no guarantee that having purchased superior quality seed that the farmer would receive a higher price for their produce. Not unexpectedly, the major complaint was the inability of the seed supplier to provide enough small round seed of the desired size to meet the farmers' demand.

Table 6.19: How well the most preferred source of seed meets each of the following criteria

Criteria	Mean	S.D.
Seed from my preferred seed supplier does not contain a mix of varieties	3.6[a]	0.53
There is less variability in production from year to year using seed from my preferred seed supplier	3.5[a]	0.54
Seed from my preferred seed supplier is free from the major pests and diseases	3.5[a]	0.68
Seed was available from my preferred seed supplier at the time of planting	3.5[a]	0.57
Seed from my most preferred seed supplier has a good reputation among the other potato farmers	3.4[a]	0.49
I have had many favourable prior experiences using seed obtained from my preferred seed supplier	3.3[a]	0.56
There is a substantial difference in the productivity of the seed that I purchase from my preferred seed supplier and that seed which I retain of my own	3.3[a]	0.50
Seed from my preferred seed supplier degenerates at a slower rate than seed sourced from alternative suppliers	3.2[a]	0.53
Seed from my preferred seed supplier is expensive relative to the alternatives	3.2[a]	0.59
Seed from my preferred seed supplier is of the desired physiological age	3.1[a]	0.50
Seed of the variety I require for planting is available from my preferred seed supplier	3.0[b]	0.83
I obtain a high market price for the potatoes grown from seed I have obtained from my preferred seed supplier	3.0[b]	0.65
Seed from my preferred seed supplier is pathogen tested	3.0[b]	0.47
Seed is available from my preferred seed supplier in the sizes I require for planting	2.8[c]	0.85

Where 1 is “not good” and 4 is “very good”
Where those items with the same superscript are not significantly different at $p=0.05$

Most farmers (88%) wanted to purchase seed produced in WA as it had the potential to produce a high yield, it was of the desired physiological age, the seed grew quickly and had a relatively slow rate of degeneration (Table 6.20). However, most farmers reported that the big seed size (95%) was the major limitation for them in their decision to purchase WA seed.

Table 6.20: The attributes farmers most liked about sourcing seed from WA

Attribute	N	%
High yield	106	88.3
Good physiological age	101	84.2
Fast and good growth	99	82.5
Low degeneration rate	95	79.2
Less diseases	56	46.7
Suitable seed size	6	5.0

Furthermore, the major complaint was the skin and flesh colour of the WA tubers (93%). Farmers preferred potatoes with a yellow flesh colour and skin colour (Table 6.21). Some of the farmers complained about the marketing problems associated with attempting to sell WA potato varieties (Atlantic and Eben) in the ware market, as buyers did not like white skin and white flesh tubers. These varieties could only be sold to crisp processors or the ware market when other varieties were not available.

Table 6.21: What farmers most disliked about sourcing seed from WA

Criteria	N	%
Skin and flesh colour	107	89.2
Difficult to sell	6	5.0
Long growth characteristic	5	4.2
High price	2	1.7
Not come at the right time	-	-
Not good quality seed	-	-
TOTAL	120.0	100.0

6.3.4. Variety

Not surprisingly, most of the respondents liked the potato varieties KT3 (38%) and Solara (26%) which had a yellow skin and yellow flesh (Table 6.22). The Dutch variety Diamant was found to degenerate too quickly. Both KT3 and Solara were long duration crops with a high yield, good quality tubers and low degeneration rate, as they were more adapted to the agro-ecological conditions in the RRD.

Table 6.22: Potato varieties preferred by location in the RRD

Location / Variety	T.Binh		H.Tay		H.Phong		All	
	N	%	N	%	N	%	N	%
Solara	19	31.7	10	43.5	-	-	29	25.7
KT3	13	21.7	-	-	30	100	43	38.1
Eben	13	21.7	-	-	-	-	13	11.5
Atlantic	9	15.0	13	56.5	-	-	22	19.5
Diamant	6	10.0	-	-	-	-	6	5.3
TOTAL	60	100.0	23	100.0	30	100.0	113	100.0

Although Atlantic was first introduced into the RRD in 2005 (except Ha Tay province) (Tuyen per.com 2008), it had been adopted by 57% of the surveyed farmers in Hai Phong and 15% in Thai Binh. For Eben, it was introduced to Vietnam in 1999 and released by the Vietnamese National Potato Program in 2008 (Tuyen *et al.* 2007). Eben had been planted by the farmers in Thai Binh and Hai Phong where 22% of the farmers liked it because of its long duration and high yield characteristics. All of the farmers in Ha Tay preferred KT3 as it produced a high yield and had a slow degeneration rate. Furthermore, KT3 tubers had a long dormancy which enabled farmers to store seed under diffuse light conditions and to store ware potatoes longer than other varieties.

Good crop performance and marketability were the two most frequently cited characteristics of the potato variety that farmers most preferred to grow (Table 6.23).

Table 6.23: The attributes farmers most liked about their preferred variety

Attribute	N	%
High yield	100	83.3
Fast and good growth	90	75.0
Easy to market	88	73.3
High percentage of large tubers	55	45.8
Nice skin and flesh colour	26	21.7
Good eating quality	26	21.7
Long dormancy	26	21.7
Low degeneration rate	20	16.7
Resistant to diseases	13	10.8
Short growth duration	5	4.2
Tolerant to drought and high temperature	2	1.7
TOTAL of the respondents	451	

Some 83% of the respondents valued the high yield characteristics while 75% liked the variety because it produced a good crop (healthy looking and high yielding). Some 73% of farmers believed that the variety they had chosen would be easy to sell in the market. A high percentage of large tubers (46%) was the next most frequently cited attribute. Conversely, good eating quality was considered by only 22% of farmers.

In selecting a potato variety, the most important group of variables influencing the farmers' decision to purchase seed included the productivity of the crop, the suitability of the variety to the growing environment and the growth of the crop (Table 6.24).

Table 6.24: Attributes influencing the farmer's choice of variety

Attributes	Mean	S.D.
Productivity per ha	3.9^{a}	0.30
New variety	3.4^{a}	0.69
Suitability to growing environment	3.4^{a}	0.49
Vigorous growth	3.3^{a}	0.54
Eating characteristics	3.2^{b}	0.72
Resistance to disease	3.2^{b}	0.68
Storage characteristics	3.1^{b}	0.68
Flesh colour	3.1^{b}	0.63
Available of seed at planting	3.1^{b}	0.48
Skin colour	3.0^{b}	0.77
Fast maturing	3.0^{b}	0.70
Tuber size	2.9^{b}	0.84
Heat tolerance	2.9^{b}	0.79
Drought tolerance	2.9^{b}	0.71
Processing qualities	2.6^{c}	0.70
Price of potatoes at ware market	2.5^{d}	0.77
Tuber shape	2.3^{e}	0.96
Variety traditionally grown	2.2^{f}	0.67

Where 1 is not important and 4 is very important.
Where those items with the same superscript are not significantly important at p=0.05

Farmers in the RRD believed that most new varieties would produce higher yields and superior tuber quality than the existing varieties. The next group of attributes was concerned with the eating quality of the tuber, the resistance to disease, tolerance to difficult conditions, good storage characteristic and fast maturity. As most potatoes are used for fresh consumption in the RRD, the colour of the tuber skin and tuber flesh also influenced the farmers' decision to purchase a variety, whereas the processing quality was less important. As prices in the market for potatoes were determined more by supply and demand, the choice of variety was not so important.

6.3.5. On-farm practice for WA potatoes in the RRD

Some 40% of the farmers in the RRD still use cattle (buffalo or cow) to cultivate the soil prior to planting; 23% used a machine and 2.5% used a hand-hoe (Table 6.25). The average cost for soil preparation was VND 67,000 per sao with a minimum cost of VND 15,000 per sao and a maximum cost of VND 210,000 per sao. Extra costs were incurred in preparing heavier soil types for planting.

Table 6.25: Method of soil preparation for potato cultivation in the RRD

Method	N	%
Cattle	48	40.0
Machine	28	23.3
Hand-hoe	3	2.5
All of method	41	34.2
TOTAL	120	100

While all farmers applied manure in the RRD, most of them used composted manure (81%), with only 19% using fresh manure (Table 6.26).

Table 6.26: Manure application for potato production in the RRD

Type	N	%
Composted manure	97	80.8
Fresh manure	23	19.2
TOTAL	120	100.0

For both kinds of manure, farmers in the RRD applied an average of 543 kg per sao with a minimum of 200 kg per sao and maximum of 1,000 kg per sao. Most of the farmers (93%) used manure from their own farm while 7% of farmers bought manure from their neighbours. The average cost was VND 63,000 per sao (Table 6.27).

Table 6.27: Quantity and cost of manure applied per sao for potato production in the RRD

Criteria	Min	Max	Mean ± S.E.
Quantity (kg/sao)	200	1000	542.9±13
Costs (VND/sao)	20,000	120,000	63,500±1,870

With the high incidence of pests and diseases that has been reported in the RRD, most farmers (81%) seek to control more than three or more pests and diseases in their potato crop (Table 6.28).

Table 6.28: Number of pests and diseases farmers seeks to control in WA potatoes

Number	N	%
1	-	-
2	19	16.1
3	47	39.8
4	49	41.5
5	3	2.5
TOTAL	118	100.0

Most farmers (57%) believed that late blight was the most important disease, followed by bacterial wilt (18%); caterpillars (17%); and aphids/thrips (4%) (Table 6.29).

Table 6.29: Pests and diseases potato farmers seek to control in the RRD

Disease or pest	N	%
Late blight	67	56.8
Bacterial wilt	21	17.8
Caterpillar	20	16.9
Aphids/thrips	5	4.2
Rhizoctonia	2	1.7
Fusarium	2	1.7
Early blight	1	0.8
Leaf miner	-	-
Others	-	-
TOTAL	118	100.0

Most potato farmers (77%) identified the pests and diseases by themselves. Among the 118 surveyed respondents, 61% of the farmers could remember the name of the chemicals that they had used to protect their potato crop, while another 39% could not remember. The majority (79%) of the farmers followed the instructions on the label of the chemical packages, while 14% of the farmers followed the guidelines given by plant protection workers in the village (Table 6.30).

Table 6.30: Criteria the farmer used to determine chemical rate to control pests and diseases in their potato crop

Criteria	N	%
The instruction on the label	93	78.8
Guidelines of PP workers	16	13.6
Own experience	8	6.8
Applied double rate	1	0.8
TOTAL	118	100

All farmers sprayed at least two times during the season at an average cost of VND 22,750 per sao, with a minimum cost of VND 8,000 per sao and a maximum cost of VND 100,000 per sao (Table 6.31).

Table 6.31: Number of applications and cost of chemical application during the potato season in the RRD

Criteria	Min	Max	Mean ±S.E.
Time of spraying	1	4	2.5±0.07
Cost (VND/sao)	8,000	100,000	22,750 ±1,187

Farmers reported that the percent of disease infection in plants grown from each generation of seed increased from VN0 seed to VN1 and VN2. A significant increase in the incidence of late blight, bacterial wilt, virus, leaf miner and scab was found with increasing generation (Table 6.32).

Virus infection was the most serious problem in the RRD where the infection level increased sharply from a mean of 1.5 for VN0 to 2.3 for VN1 to reach to 3.8 for VN2.

Table 6.32: Means of the pests and diseases incidence level in different WA seed generation in the RRD

Pest or disease	Generation		
	Means of incidence (non-parametric scale)*		
	VN0	VN1	VN2
Late blight	1.3[b]	1.5[b]	2.0[a]
Bacterial wilt	1.6[b]	1.7[b]	2.7[a]
Virus	1.5[c]	2.3[b]	3.8[a]
Leaf miner	1.1[c]	1.8[b]	2.1[a]
Scab	1.4[c]	2.0[b]	2.8[a]
Others	1.5[c]	1.8[b]	2.5[a]

Where those mean values with the same superscript are not significantly different at p=0.05

* Incidence scale used

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

The level of bacterial wilt increased gradually from a very low infection rate (1.6) for VN0 and VN1 to an infection rate of 2.7 for VN2.

Similar differences were observed for common scab, where VN0 seed had the lowest mean infection level of infected tubers (1.4) compared to 2.0 for VN1 and 2.8 for VN2.

No difference in the mean incidence of late blight was observed between the VN0 (1.3) and VN1 crop (1.5). However, the incidence of disease increased up to 2.0 for VN2.

The incidence of leaf miner was the lowest for the first generation VN0 (1.1) and the highest in the third generation (2.1).

Similar results were observed for other pests and diseases in the three seed generations where the VN0 crop had the lowest incidence (1.5) and the highest in the VN2 crop (2.5).

Bacterial wilt can be controlled by removing infected plants from the field to reduce disease transmission or using composted manure. In this study, most farmers in the RRD (94%) rogued the crop to remove infected plants (Table 6.33).

Table 6.33: Potato farmers in the RRD who rogue the crop to remove diseased plants from the potato field

Answer	N	%
Yes	112	94.1
No	7	5.9
TOTAL	119	100.0

During the potato season, diseased plants were normally rogued twice at a cost of VND 17,500 per sao. Most farmers (85%) brought the rogued plants home to feed domestic animals or disposed of the diseased plants properly. However, 15% of farmers still left them in the field or threw them into the water source (Table 6.34).

Table 6.34: Method farmers used to dispose the diseased potato plants after roguing

Method	N	%
Brought home to feed animals	81	72.3
Threw in to water source	15	13.4
Burnt/buried	14	12.5
Left in the field/roads	2	1.8
TOTAL	112	100.0

There were significant differences in the number of disease infected plants rogued between the three different seed generations in the RRD. For the VN0 crop, the number of rogued plants was almost zero compared to the 6-10% of plants removed from seed derived from VN2 (Table 6.35).

Table 6.35: Number of diseased plants farmers rogue for each WA seed generation in the RRD

Generation	Mean (non-parametric scale)*
VN0	1.1^{c}
VN1	1.9^{b}
VN2	2.8^{a}

Where those mean values with the same superscript are not significantly different at p=0.05
* Incidence scale used:

1. None
2. 1-5 % of total plants rogued
3. 6-10% of total plants rogued
4. 11-15 % of total plants rogued
5. > 16% of total plants rogued

6.3.6. Harvest, post-harvest and marketing

Most farmers in the RRD (79%) harvested their potato crop (winter potato crop) in January, while the remaining 21% of farmers harvested the potatoes in February (Table 6.36).

Table 6.36: Time of harvest of the main potato crop in 3 provinces in the RRD

Location / Month	T.Binh		H.Tay		H.Phong		All	
	N	%	N	%	N	%	N	%
January	55	94.8	8	26.7	29	100.0	92	78.6
February	3	5.2	22	73.3	-	-	25	21.4
TOTAL	60	100.0	23	100.0	30	100.0	117	100.0

Farmers in Thai Binh and Hai Phong harvested potato earlier than farmers in Ha Tay. The second potato crop (spring crop) which was normally planted for seed and it was harvested in early March.

Most farmers (68%) harvested potatoes less than 3 months after planting when the leaves turned yellow (Table 6.37). Some 29% harvested potato because they needed the field to be ready for the spring rice crop. Only 1% of the farmers harvested potato to catch a good price.

Table 6.37: Why farmers harvested potato

Harvest decision	N	%
Need land for rice crop	35	29.2
Maturity of the crop	82	68.3
Follow other farmer	2	1.7
Higher price	1	0.8
Others	-	-
TOTAL	120	100.0

There was a significant difference in yield between Ha Tay (717.8 kg/sao or 19.9 t/ha) and Hai Phong (661.8 kg/sao or 18.4 t/ha), but there was no significant difference found between Ha Tay and Thai Binh or between Thai Binh and Hai Phong (Table 6.38). While there was no difference between the proportion of large tubers and small tubers by location, Ha Tay produced a significantly larger proportion of medium sized tubers compared to that produced in Thai Binh and Hai Phong.

Table 6.38: Total yields and tuber quality produced by location during two years 2006/08 in the RRD

Variables	Ha Tay	Thai Binh	Hai Phong
Total tuber yield			
Yield (kg/sao)	717.8[a]	708.5[ab]	661.8[b]
Yield (t/ha)	19.9[a]	19.7[ab]	18.4[b]
Proportion of each tuber size per total yield (%)			
Large tubers	58.5[a]	58.0[a]	55.8[a]
Medium tubers	30.9[a]	27.8[b]	27.3[b]
Small and rejected tubers	14.5[a]	14.2[a]	13.3[a]

Those items with the same superscript are not significantly different at p= 0.05

There were highly significant differences in the yield reported by the survey respondents between the three different seed generations in the RRD. VN0 seed produced the highest yield of 853 kg/sao (23.7 t/ha) which was significantly higher than the tuber yield achieved from VN1 (746 kg/sao or 20.7 t/ha) and VN2 (627 kg/sao or 17.4 t/ha) (Figure 6.1).

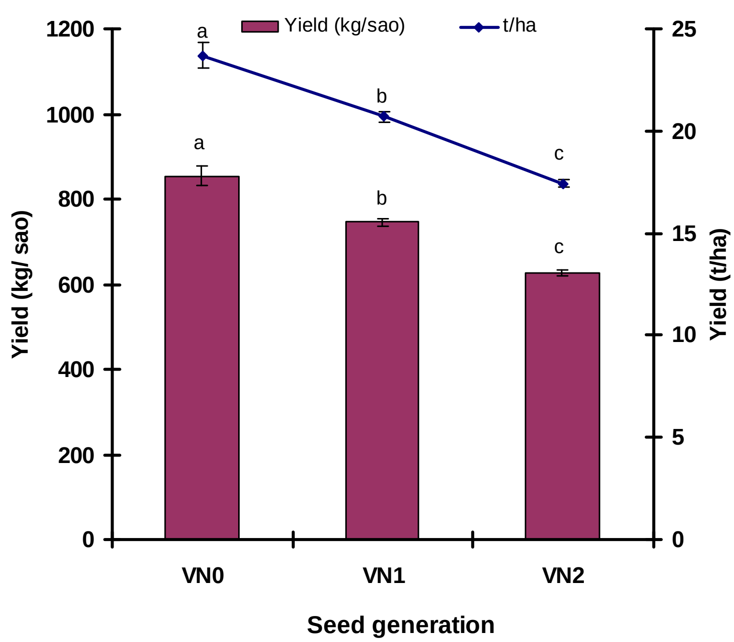


Figure 6.1: Tuber yields produced by three WA seed generations for all WA potato varieties in the RRD during two years 2006/08 as reported by survey respondents. Vertical bars are S.E. values at p=0.05 for yield of each seed generation

Similar significant differences were observed for the yield components reported by farmers for the different seed generations in the RRD. The proportion of large tubers decreased sharply from VN0 (70%) to VN1 (61%) and VN2 (51%), whereas the proportion of medium tubers increased from VN0 (21%) to VN1 (26%) and 32% for VN2 (Figure 6.2) [9].

The farmer survey also showed differences between generations for the proportion of small and rejected tubers: VN0 crops produced the least proportion of small and rejected tubers (9%), compared to 12% for VN1 and 17% for VN2.

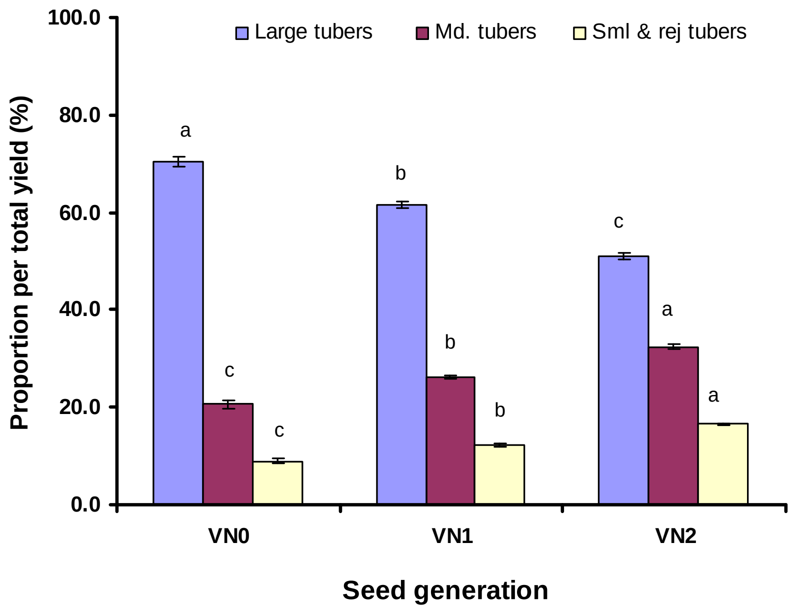


Figure 6.2: Yield components produced by three WA seed generations for all WA potato varieties in the RRD during 2006/08 as reported by survey respondents. Vertical bars are S.E. values at p=0.05 for each yield component

6.3.7. Sale of produce

In the RRD, the majority of the large tubers were sold as table potato; less than 10% were used for family, stock feed and for gifts. None of the large tubers were used for seed (Table 6.39).

[9] Total yields and tuber quality of three different WA seed generations reported by farmers during two years 2006/07 and 2007/08 in the RRD is in Appendix 15.

There were significant differences in the use of medium and small tubers by location. In Thai Binh, the proportion of medium tubers saved for seed decreased from 99% for VN0 to 61% for VN1 and 51% for VN2. Similarly, the proportion of small tubers saved declined from 24% or more for VN0 and VN1 to less than 2% for VN2 (Table 6.40).

In Ha Tay, the proportion of medium tubers retained for seed decreased from 100% for the VN0 crop to 69% for the VN1 and the VN2 crop. Because the VN0 crop in Ha Tay produced fewer small tubers than the VN1 and VN2 crop, farmers retained 55% of the small tubers from the VN0 crop compared to 70% for VN1 and only 31% from the VN2 crop (Table 6.41).

In Hai Phong, none of the harvest was retained for seed (Table 6.42) because of the lack of any cool storage capacity.

Table 6.39: Means for the disposal of different size grades of WA seed potatoes by generation in the RRD

Proportion use for different purposes	Mean ± S.E (%)		
Seed generation	VN0	VN1	VN2
Large tubers			
Sold	91.5±2.2	89.6±1.2	90.7±1.2
Retain for family consumption	7.2±2.9	7.4±1.0	6.8±0.9
Retain for stock food	0.4±0.4	1.8±0.4	0.6±0.2
Retain for seed	0.0±0.0	0.0±0.0	0.2±0.1
Retain for giving away	1.0±0.7	1.1±0.3	1.6±0.4
Medium tubers			
Sold	49.1±10.2	32.8±1.7	34.7±1.7
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	3.6±1.8	9.6±2.0	13.3±2.2
Retain for seed	99.1±0.9	65.6±1.4	57.8±1.7
Retain for giving away	0.0±0.0	0.0±0.0	1.6±1.8
Small and rejected tubers			
Sold	0.0±0.0	0.0±0.0	0.0±0.0
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	84.6±4.4	62.7±3.1	90.0±1.5
Retain for seed	38.9±5.6	54.4±2.3	30.9±1.2
Retain for giving away	0.0±0.0	0.0±0.0	0.0±0.0

Table 6.40: Means for the disposal of different size grades of WA seed potatoes by generation in Thai Binh province

Proportion use for different purposes	Mean ± S.E (%)		
Seed generation	VN0	VN1	VN2
Large tubers			
Sold	93.9±2.9	88.0±1.6	90.2±1.7
Retain for family consumption	5.0±2.4	8.8±1.3	7.5±1.4
Retain for stock food	1.1±1.1	2.5±0.7	0.6±0.3
Retain for seed	0.0±0.0	0.0±0.0	0.4±0.3
Retain for giving away	0.0±0.0	0.9±0.4	1.4±0.5
Medium tubers			
Sold	0.0±0.0	29.4±2.3	33.9±2.4
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	1.1±1.1	9.2±2.7	13.9±3.1
Retain for seed	98.9±1.1	63.9±2.0	57.3±2.2
Retain for giving away	0.0±0.0	0.0±0.0	1.6±1.10
Small and rejected tubers			
Sold	0.0±0.0	0.0±0.0	0.0±0.0
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	76.0±6.7	74.5±3.0	98.2±1.0
Retain for seed	34.3±6.1	40.2±2.0	30.0±5.8
Retain for giving away	0.0±0.0	0.0±0.0	0.0±0.0

Table 6.41: Means for the disposal of different WA seed size grades of potatoes by generation in Ha Tay province

Proportion use for different purposes	Mean ± S.E (%)		
Seed generation	VN0	VN1	VN2
Large tubers			
Sold	85.0±15.0	91.7±2.1	92.1±2.1
Retain for family consumption	10.0±10.0	5.3±1.6	5.5±1.6
Retain for stock food	0.0±0.0	0.5±0.4	0.5±0.4
Retain for seed	0.0±0.0	0.0±0.0	0.0±0.0
Retain for giving away	5.0±5.0	1.8±0.7	1.9±0.7
Medium tubers			
Sold	0.0±0.0	30.8±6.7	30.8±6.7
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	0.0±0.0	0.0±0.0	0.0±0.0
Retain for seed	100.0±0.0	69.2±6.7	69.2±6.7
Retain for giving away	0.0±0.0	0.0±0.0	0.0±0.0
Small and rejected tubers			
Sold	0.0±0.0	0.0±0.0	0.0±0.0
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	45.0±7.1	29.9±6.5	69.0±6.7
Retain for seed	55.0±7.1	70.1±6.5	31.0±6.7
Retain for giving away	0.0±0.0	0.0±0.0	0.0±0.0

Table 6.42: Means for the disposal of different WA seed size grades of potatoes by generation potato in Hai Phong province

Proportion use for different purposes	Mean ± S.E (%)		
Seed generation	VN0	VN1	VN2
Large tubers			
Sold	90.8±3.3	91.0±3.8	90.0±3.1
Retain for family consumption	8.3±3.0	7.0±2.6	7.1±2.2
Retain for stock food	0.0±0.0	0.0±0.0	0.0±0.0
Retain for seed	0.0±0.0	0.0±0.0	0.0±0.0
Retain for giving away	1.0±1.00	0.0±0.0	1.9±0.9
Medium tubers			
Sold	94.2±3.1	56.0±5.4	41.7±5.1
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	5.8±3.1	40.0±6.3	30.2±5.8
Retain for seed	0.0±0.0	0.0±0.0	0.0±0.0
Retain for giving away	0.0±0.0	0.0±0.0	0.0±0.0
Small and rejected tubers			
Sold	0.0±0.0	0.0±0.0	0.0±0.0
Retain for family consumption	0.0±0.0	0.0±0.0	0.0±0.0
Retain for stock food	100.0±0.0	100.0±0.0	100.0±0.0
Retain for seed	0.0±0.0	0.0±0.0	0.0±0.0
Retain for giving away	0.0±0.0	0.0±0.0	0.0±0.0

No significant difference was found in the pricing of the ware potatoes by seed generation and location in the RRD. Large tubers were sold at the highest average price of VND 3,000 per kg compared to VND 2,500 per kg for medium tubers and VND 1,700 per kg for small tubers (Table 6.43). The average price for reject tubers was VND 760 per kg. As most surveyed farmers raised animals, mainly pigs, the rejected tubers were either used to feed their own animals or sold to other farmers.

Table 6.43: Average prices (VND/kg) by quality for ware potato in the RRD

Tuber quality	Range (VND/kg)	Mean (VND/kg)	S.E.
Large tubers	2,500 - 3,200	2,915	19
Medium tubers	2,100 - 2,867	2,501	14
Small tubers	1,100 - 2,300	1,724	30
Rejected tubers	600 - 1,000	763	18

6.3.8. Production costs and economic returns

The respective income for each seed generation by variety and location were derived from the yields and the prices paid for potatoes sold either as ware potatoes by tuber size (large, medium, small and reject tubers), or potatoes retained for seed or sold as seed to other farmers after cool storage. The production costs included the cost of seed, fertilizer, labour and seed storage (where farmers retained seed).

Based on the prevailing marketing practice, the production costs and economic returns for potatoes in the RRD can be divided into two options: (i) farmers who did not retain seed (all potatoes were sold as ware potatoes immediately after harvest) and (ii) those farmers who retained some seed. There were no significant differences observed in the costs of applying manure, fertiliser or chemical between the seed sources and variety. Conversely and not unexpectedly, labour costs decreased with the reduction in yield as the farmers spent less time harvesting and grading potatoes.

There was some difference in the seed cost for those farmers who purchased seed every year and farmers who retained their own seed. The cost for seed purchased was VND 6,000 per kg compared to VND 3,800-4,000 per kg for seed retained from the VN0 crop (VN1 seed) and seed retained from the VN1 crop (VN2 seed). For those farmers who chose to retain seed, three factors contributed to the cost of that seed; (1) the return that farmers could have received if the tubers had been sold as ware potatoes rather than retained for seed (VND 2,200 per kg); (2) the cost of cool storage (VND 1,100 per kg); and (3) the cost of labour for seed grading (VND 500 to 700 per kg for VN1 and VN2 seed respectively (Table 6.44).

Table 6.44: Cost of the different WA seed source in the RRD

Seed source	Cost (VND/kg)
New imported (VN0)	10,500 – 11,000
VN1+ (in the market)	6,000 – 6,500
VN1+ (at farm gate level)	3,800 – 4,000
Costs contributing to the seed cost produced in the RRD (at farm gate level)	
Ware price	2,200
Cool storage cost (8 months)	1,100
Seed grading cost VN1+	500 - 700

Farmers did not retain seed

The survey income data across locations was combined as no significant difference was found between locations.

There was a significant difference in the gross income achieved for each variety. For Atlantic, VN0 seed produced the highest gross income of VND 2.4 M/sao, which was significantly greater than VN1 (VND 2.0 M/sao) and VN2 (VND 1.5 M/sao).

For Eben, VN0 seed produced a gross income of VND 2.5 M/sao compared to VND 1.9 M/sao for VN1 and VND 1.4 M/sao for VN2. Similar results were observed for KT3: VN0 seed produced the highest gross income of VND 3.2 M/sao, which was significantly higher than the gross income achieved from VN1 (VND 2.4 M/sao) and VN2 (VND 2.0 M/sao) (Figure 6.3)[10].

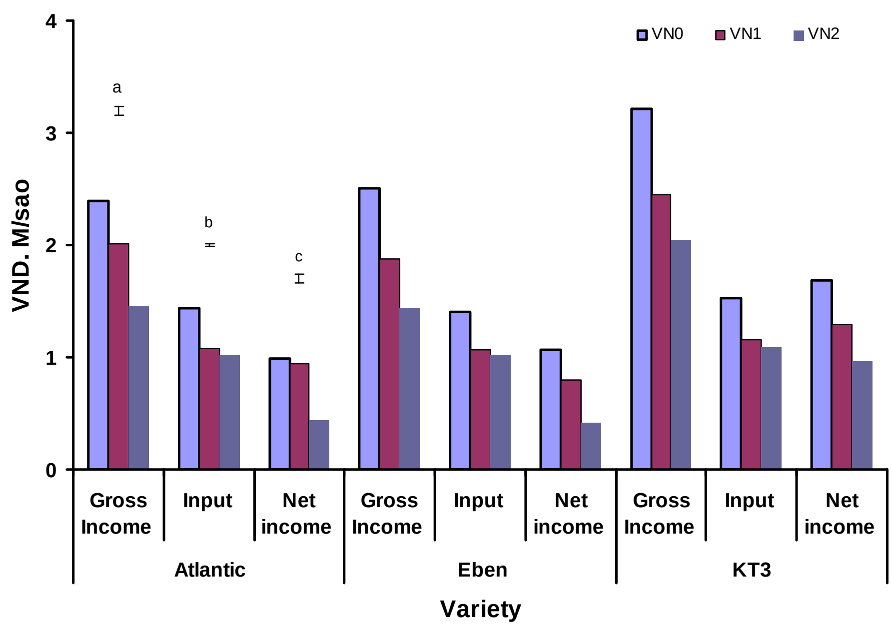


Figure 6.3: Production costs and economic returns for different seed generations for Atlantic, Eben and KT3 in the RRD. Vertical bars are are l.s.d. values at p=0.05 for gross income (a), total input (b) and net income (c) between seed generations

As high quality seed is more productive, it is also more expensive for the farmer to purchase. As a result, marked differences were observed between the production

[10] Production costs and economic returns of different seed generation for Atlantic, Eben and KT3 are found in Appendix 16.

costs of the seed generations. VN0 seed was almost two times more expensive for the farmers to purchase than seed which had been bulked up for just one and more generations in the RRD (Table 6.44).

The profitability, or net income, of potato production in the RRD was derived from the gross income minus input costs. Despite the higher costs, VN0 seed provided the highest net income compared to VN1 and VN2, except for Atlantic. For Atlantic, there was no significant difference in the net income between the VN0 crop of VND 1.0 M/sao and the net income of the VN1 crop of VND 1.0 M/sao. However, for VN2, the net income decreased significantly to VND 0.4 M/sao.

For Eben, the net income decreased significantly from VND 1.1 M/sao for VN0 to VND 0.8 M/sao for VN1 and only VND 0.4 M/sao for VN2. A similar result was observed for KT3. VN0 seed produced the highest net income of VND 1.7 M/sao, which was significantly higher than the net income achieved from VN1 (VND 1.3 M/sao) and VN2 (VND 1.0 M/sao).

Farmers retained seed

It is the practice of farmers in Ha Tay and Thai Binh is to select some proportion of the medium and small tubers from the harvest to retain as seed for the next crop. The amount of tubers retained for seed decreased significantly from the VN0 crop to VN1 and VN2 (Table 6.45).

Table 6.45: Proportion (%) of medium and small tubers saved for seed by tuber quality and seed generation in Ha Tay and Thai Binh province

Generation	Min	Max	Mean ± S.E. (%)
Medium tubers			
VN0	90	100	99±0.9
VN1	30	80	58±1.4
VN2	20	60	39±1.7
Small tubers			
VN0	20	100	66±5.6
VN1	5	80	54±2.3
VN2	20	45	31±1.2

The proportion of medium tubers saved for seed was highest for the VN0 crop (99%) compared to 58% for VN1 and less than 40% for VN2. Similar results were observed for the proportion of small tubers saved for seed which was observed to decrease sharply from 66% for VN0 to 54% for VN1 and 31% for the VN2 crop. Selected tubers which were retained for seed were cool stored from February to November and then sold to other farmers in the village or to the open market at an average price of VND 6,000 per kg.

With the inclusion of seed sales, there was a significant difference in the gross incomes achieved for each variety, although there was no significant difference by location. For Atlantic, VN0 seed produced the highest gross income of VND 3.0 M/sao, which was significantly greater than VN1 (VND 2.4 M/sao and VN2 (VND 1.7 M/sao). For Eben, VN0 seed produced a gross income of VND 3.5 M/sao compared to VND 2.5 M/sao for VN1 and VND 1.7 M/sao for VN2. Similar results were observed for KT3, where VN0 seed produced the highest gross income of VND 4.1 M/sao, which was significantly higher than the gross income achieved from VN1 (VND 3.1 M/sao) and VN2 (VND 2.4 M/sao) (Figure 6.4)[11].

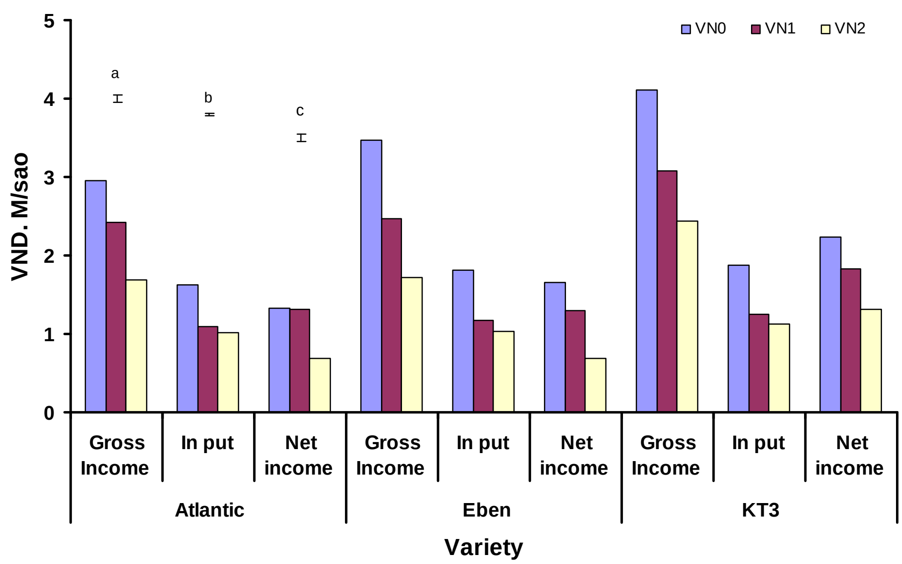


Figure 6.4: Production costs and economic returns of different seed generations for Atlantic, Eben and KT3 with the inclusion of income earnt from seed sales in the RRD. Vertical bars are are l.s.d. values at p=0.05 for gross income (a), total input (b) and net income (c) between seed generations

For these farmers saving seed, the extra cost of storing seed was the same (VND per kg of seed) for all seed sizes, generations and varieties. However, highly significant

[11] Production costs and economic returns of different seed generation for Atlantic, Eben and KT3 with the inclusion of income earnt from seed sales in the RRD are found in Appendix 17.

differences were observed between the production costs for each source. VN0 seed was almost two times more expensive for the farmers to purchase than seed which had been bulked up for just one generation in the RRD. The cost of seed which had been bulked up in the RRD for one generation (VN1) was cheaper than the cost of seed which was retained after bulking up for two generations (VN2), due to seed losses and extra labour cost for seed grading. The marginal difference in the cost between seed generations bulked up in Vietnam was significantly less than the difference in cost between VN0 seed and VN1 for each variety.

Despite the higher costs, VN0 seed provided the highest net incomes compared to VN1 and VN2. The net income, with the inclusion of seed sales, was significantly higher than the corresponding net income achieved from the same crop without saving seed, except for Eben (Figure 6.5).

For Atlantic, the total net income was similar for VN0 and VN1 (VND 1.3 M/sao), but then declined sharply to VND 0.7M/sao for the VN2 crop. For Eben, VN0 seed produced the highest net income of VND 1.7 M/sao which was significantly higher than the gross income achieved from VN1 (VND 1.3 M/sao) and VN2 (VND 0.7 M/sao). A similar result was observed for KT3, where VN0 seed produced the highest net income of VND 2.2 M/sao which was significantly higher than the net income achieved from VN1 (VND 1.8 M/sao) and VN2 (VND 1.3 M/sao).

6.4. Chapter summary

The results from this part of the study have identified the positive socio-economic attributes of WA potato seed in the RRD. This information may be useful for policy makers, researchers and local leaders in supporting smallholder farmers in the RRD. However, the most significant impact to arise from the calculation of production costs and economic returns is to demonstrate to potato farmers in the RRD the financial benefits arising from the use of WA potato seed.

Farmers' attitudes toward high quality seed potatoes were strongly influenced by the perceived benefits. The benefits include the higher yield per unit of land, the improved quality of the tubers (tuber size) and enhanced marketability of the products. Tuber size is of particular importance in the potato processing market in

Vietnam, for there is little opportunity to sell white flesh potatoes in the consumer market.

The lowest level of pest and disease incidence was reported in the first field generation crop (VN0) and the highest level in the third generation seed crop under the agro-ecological conditions in the RRD. Newly imported seed from WA (VN0) produced the highest yield and the tuber quality was significantly better than that which was achieved from seed which had been bulked up in Vietnam for one year (VN1) which in turn, was better than that which had been grown in the RRD for two years (VN2).

Differences in tuber yields and tuber size between the seed treatments impacted significantly on the gross incomes for each variety. VN0 seed of all varieties produced the highest gross income. While high quality seed is more productive, it is also more expensive. As a result, significant differences were observed between the production costs. VN0 seed was almost two times more expensive than the later generation seed (VN1+).

Despite the higher costs, VN0 seed produced the highest net income, irrespective of whether the farmer chose to retain a proportion of the harvest for seed or to sell the entire crop to the ware market. The highest net income was achieved where farmers retained a portion of their crop to sell as seed.

Chapter Seven:

Discussion and Conclusions

7.1. Chapter outline

This chapter provides a general discussion on the agronomic and economic impact on smallholder farmers in the RRD from the use of WA potato seed. The chapter concludes with a discussion of the main limitations of the study and directions for further research.

7.2. Agronomic impact

In this study, the tuber yield declined progressively with the number of times the seed had been grown in Vietnam. The highest yield was recorded for that seed which had been imported directly from WA (VN0) and the lowest yield was recorded for seed grown for two generations in the RRD (VN2). The decline in total yield with the number of field generations was accompanied by a decrease in the marketable yield and an increase in small and reject tubers. This reduction was associated with an increase in the incidence of viral disease with each successive generation.

Virus infection and yield reduction

The incidence of PVX and PVY increased with the number of seed generations in the RRD. This resulted in a significant linear decrease in yield. The decrease in yield with the increasing incidence of virus infection was similar in both locations for both years. However, the level of yield reduction from generation-to-generation, due to virus infection, appeared to vary between varieties.

For Atlantic, although no PVX infection was identified, there was a pronounced reduction in yield with PVY infection. The yield of the first field generation (VN0) declined by 13% after one year and up to 32% after two years in the RRD. The corresponding levels of PVY infection were observed to increase from 0.6% (VN0) to 1.6% (VN1) to 15.8% for VN2. For Eben, the yield produced in the first generation (VN0) decreased by 23% after one generation (VN1) and by 30% after two generations (VN2). The reduction in yield was associated with an increase in virus infection from 0.0% to 12.7% for PVX and from 0.0% to 17.2% for PVY. For KT3, the yield declined by 20% after one generation (VN1) and by 30% after two generations (VN2), while the level of virus infection increased from 0.0% for VN0 to 22.2% (VN2) for PVX and from 5% (VN0) to 23.1% (VN2) for PVY.

The relationship between virus infection and yield showed that there was no significant difference in the relative yield response of Atlantic, Eben and KT3 to PVY infection and all appeared equally susceptible. For example, the yield was reduced by 26% - 29% from VN0 to VN2 as PVY infection increased from 0.0% for the VN0 crop to 23% for the VN2 crop for all three varieties.

In contrast to PVY, there were varietal differences in yield response to PVX infection. For Eben and KT3, the tuber yield declined by similar proportions (26 - 29%) from the first generation (VN0) to the third generation (VN2) as the level of PVX infection increased (22%). However, Atlantic was not infected. These results support previous finding by Pavlista (2003) that Atlantic is tolerant to PVX.

Similar reductions in yield with an increasing percent of PVY infection have been reported for ware potatoes in the Netherlands (van der Zaag 1987) and for two potato varieties, Shepody and Russet Norkotah in Oregon (Hane 1999).

No virus was detected in Eben and Atlantic seed crops from ELISA leaf tests or in KT3 crops from visual inspection prior to shipment of the seed from WA. Virus infection in VN0 crops was therefore most likely the result of current season (primary infection) rather than seed-borne (secondary infection). Virus infection in the crops grown from later seed generations (VN1 and VN2) was assumed to be a combination of seed-borne (secondary) and current season (primary) infection as seed tubers were not tested for virus in those crops and it was not possible to differentiate between the two sources of infections.

It is estimated that the yield of all three varieties would be much lower in later multiplications under the agro-ecological conditions experienced in the RRD. This proposition is support by the findings of Kawakami (1962), Struik and Wiersema (1999) and Fuglie *et al.* (2006), who suggested that the highest yields, were recorded in crops grown from the first field generations of seed.

Absolute differences in tuber yield between varieties showed that KT3 produced a higher yield than Eben and Atlantic in all seed treatments, indicating that KT3 was better adapted to the agro-ecological conditions in the RRD.
There was no evidence of any PLRV or PVA infection of any of the experiments undertaken in the RRD. This contradicts previous reports that PLVR infection of potatoes is widespread in the RRD, especially for Eben (GTZ staff pers.comm).

Other factors contributing to the reduction in tuber yield and tuber quality of potatoes in the RRD

Other factors besides virus could also have contributed to the lower yield in crops grown from later generations of seed compared with earlier ones. For bacterial wilt, results from the farmers' survey showed that the incidence of the disease increased considerably from newly imported seed (VN0) (less than 5%) to 6-10% in the VN2 crop. An increase in the number of bacterial wilt infected plants with the number of seed generations in the RRD is due to the transmissions of the disease from plant-to-plant during the crop and/or from tuber-to-tuber during storage. The disease is likely to be seed-borne, rather than soil-borne as potatoes are grown in rotation with two rice crops and the flooding of the field should prevent the survival of *Ralstonia solanacearum* in the soil (Priou *et al.* 1994). The transmission of bacterial wilt in potatoes in the RRD can be accentuated by: (i) the application of raw manure that includes infected plants and tubers; (ii) inappropriate disposal of infected plants by throwing them into the water source which other farmers use to irrigate their potato crop; (iii) the failure to rogue infected plants properly; and (iv) the failure to select healthy tubers for seed.
The lowest level of late blight was reported in the earliest field crop (VN0) and the highest level was observed in the latest field crop (VN2). However, the incidence of late blight is more likely to be seasonal, for the disease spreads rapidly in the cool moist conditions often experienced in the RRD in late January and February. If the conditions are right, late blight can cause huge losses irrespective of the seed generation.
The level of tubers infected with common scab increased progressively from VN0 (less than 1%) compared to VN1 (1-5%), which in turn was significantly lower than

VN2 (6-10%). Although the disease may not reduce the total yield, the increasing incidence of the disease causes a marked reduction in the marketable yield and quality of the tubers.

Results from the farmer survey showed that the infection of other pests and diseases (Rhizoctonia, leaf miner, thrips etc.) could also contribute to the lower yield and quality of potatoes produced in the RRD. For example, percent of plants infected with leaf miner was observed to increase significantly from the VN0 crop (1-5%) to 6-10% for VN2. The percent infection by other pests and diseases was lower in the first crop (VN0) (1-5%) compared to VN2 (6-10%).

Yield reductions in the RRD may also be caused by the inappropriate storage of the seed and the duration that seed must be stored. Reust (1986), Hartmans and van Loon (1987), Horton (1987), Kumar and Knowles (1996), and Caldiz, Fernandez and Struik (2001) state that the performance of potatoes is closely related to the physiological age of the seed tubers as this influences the rate of plant emergence, crop vigour and growth, the number of stems produced per plant, the time of tuber initiation, dry matter distribution and tuber yield. Seed tubers can only perform at their best when planted at an appropriate physiological age; about 4-6 months after harvest depending on the variety (Kawakami 1962). VN1 and VN2 seed tubers would have been physiologically older due to a longer storage period in the RRD (9 months) compared to VN0 seed that had been stored for less than 6 months.

Reduction in tuber quality

The decline in marketable yields with each successive field multiplication of the seed in the RRD was accompanied with a parallel reduction in the proportion of marketable tubers. If farmers want to sell to the processing market, the tubers need to meet the strict quality requirements of the processors such as tuber size, tuber shape, appearance, flesh colour and dry matter content. In this study, Atlantic and Eben are preferred by the processors, for they have a white skin and pale flesh colour, and produce a large proportion of medium to large tubers. However, small tubers are difficult to sell in the fresh market for Vietnamese customers prefer tubers with a yellow skin and yellow flesh colour.

For Atlantic, VN0 seed produced the highest proportion of large tubers (72%) compared to 61% for VN1 and 50% for VN2. For Eben, VN0 seed produced the highest proportion of large tubers (60%) compared to 47% for VN1 and 42% for VN2. In order to meet the requirements of the processors and secure the best economic returns for a processed potato crop, seed should be renewed every second year under the agro-ecological conditions experienced in the RRD. Even for a fresh market variety such as KT3, a reduction in the proportion of large tubers will influence the price the farmers receive, for large tubers are sold at a higher price compared to smaller tubers. Tuber size therefore will influence both the gross and net income per ha.

The quality of the seed tubers also influenced the proportion of tubers that were retained for seed. A decline in the proportion of tubers retained for seed was associated with the number of seed multiplications for all three varieties. For example, the proportion of medium sized tubers retained for seed from the newly imported crop (VN0) declined by 40% after one multiplication and by 60% after two multiplications in the RRD. For the small tubers, it decreased by 12% in the second multiplication and by 35% in the third crop under the agro-ecological conditions experienced in the RRD. Most of the seed used in the RRD is farmer saved seed (Tung 2000, Batt 2003b), especially among smallholder farmers (Anonymous 2003). By using high quality seed, smallholder farmers are able to supply enough good seed material for their own farm and even provide seed to other farmers.

The loss of seed tubers during cool storage was directly proportional to the number of field multiplications of the seed in the RRD. The proportion of seed losses increased significantly from 7% for the newly imported crop (VN0) to 9% for VN1 and up to 11% for VN2. The increase in seed losses influenced both the quantity and quality of the planting materials available in the following season. This study has identified that using high quality seed can significantly reduce seed losses in storage.

7.3. Socio-economic impact

An economic analysis of the farmer’s net income demonstrated that a decline in economic returns was associated with the number of times imported seed had been multiplied in the RRD. The decrease in economic returns was correlated with the decline in seed quality which adversely impacted on both the productivity per unit area and the marketable yield of all three varieties. Despite the high cost, seed imported directly from WA (VN0) produced the highest economic returns compared to seed which had been multiplied in Vietnam for one or more generations.

High quality seed was not only more productive, but also produced a greater proportion of large tubers which received premium prices in the ware market. In this study, large tubers were sold for a maximum price of VND 2,900 per kg compared to the price of VND 1,700 per kg farmers received from the small tubers. The proportion of large tubers was the highest in the first generation (VN0) and lowest in the third generation (VN2). This means that the higher gross income produced from the VN0 seed, compared to that produced from the later generations (VN1 and VN2), was a function of both the increased yield and the greater tuber size.

The gross income produced from the third generation (VN2) in the RRD was up to 44% lower than that produced from the first generation (VN0). However, this decline was different between varieties due to differences in the total yield and yield components. For Atlantic, the gross income of the VN0 crop declined by 16.7% after one generation and 37.5% after two generations in the RRD. For Eben, the gross income of the VN0 crop declined by 24% after one generation and 44% after two generations in the RRD, while the yield reduction for the first generation crop (VN0) declined by 25% after one generation and 37.7% after two generations for KT3.

The net income from seed directly imported seed from WA (VN0) declined from VND 0.99 M/sao to VND 0.44 M/sao (VN2) for Atlantic; from VND 1.07 M/sao compared to VND 0.41 M/sao for Eben; and from VND 1.68 M/sao to VND 0.96 M/sao for KT3. This supports the findings of Fuglie *et al*. (2006) who reported that imported seed produced the greatest profit after the first planting, with subsequent crops producing lower marginal returns. KT3 produced the highest net income compared to that received from Atlantic and Eben. This indicates the importance of selecting suitable varieties for potato production in the RRD.

For farmers who chose not to retain seed, the net income received was different between varieties. For Atlantic, no difference in the net income was observed for VN0 and VN1 crops, but it declined from VND 1.0 M/sao to VND 0.4 M/sao for VN2. For Eben, the net income decreased from VND 1.1 M/sao for VN0 to VND 0.8

M/sao for VN1 and VND 0.4 M/sao for VN2. For KT3, the net income declined from VND 1.7 M/sao to VND 1.3 M/sao for VN1 and VND 1.0 M/sao for VN2.

For farmers who retained seed, the net income declined from 1.3 M/sao for the VN0 and VN1 crop to VND 0.7 M/sao for VN2 for Atlantic; from 1.7 M/sao to VND 1.3 M/sao to VND 0.7 M/sao for Eben; and from VND 2.2 M/sao to VND 1.8 M/sao to VND 1.3 M/sao for KT3.

Apparently, the farmers who retained seed received a higher net income than those who chose not to retain seed. The net income received was different between varieties. For farmers cultivating KT3, the net income was from VND 0.23 M/sao to VND 0.55 M/sao; from VND 0.16 M/sao to VND 0.60 M/sao for farmers who cultivated Eben; and from VND 0.13 M/sao to VND 0.34 M/sao for farmers who cultivated Atlantic. However, it is estimated that in later seed generations (VN3+), farmers who retained seed will receive a lower net income and benefit even less compared to those farmers who chose not to retain seed due to greater reduction in the proportion of medium-large tubers and greater seed losses in storage.

For those farmers who are unable to access a cool store, they have no choice other than to purchase seed every year, whether newly imported seed or seed retained by other farmers. In fact, the cost of WA seed after one (VN1) or more crops (VN2) in the RRD is almost one half the cost of newly imported seed (VND 6,000 to 6,500 per kg) compared to VND 10,500 to 11,000 per kg. For those farmers who retained seed, the cost of seed was even cheaper. The cost of seed after storage was from VND 3,800 to 4,000 per kg.

Increasing the supply of good quality seed may also have an indirect impact on household income. As most farm families raise some animals, normally pigs, potatoes are used as animal feed when they are plentiful (Batt 2003) or tubers are rejected because of size or physical damage (Yen and Bang pers.comm 2008). In this study, most of the small and reject tubers were used for animal feed. The income earnt from raising pigs can provide an important source of money for the smallholder farmer to buy other pigs, to purchase new seed or to pay for children’s school fees.

The supply of sufficient good quality potato seed may also reduce unemployment in the RRD. Results from the survey suggest that most of the farmers in the RRD are living on farms with a limited land area. There is no other opportunity to make money other than farming, except to rely on young people who work in the city and send some money home. Potato is a cash crop with a short crop duration which is easy to market. The income earnt from potato plays an important role in the household budget. However, in the absence of good quality potato seed, a large potential area (50% of rice planted area) is left uncultivated during winter, especially in Hai Phong and Thai Binh. The living standard of smallholder farmers could be significantly improved if the area planted in potatoes could be extended.

7.4. Seed certification

The introduction of a certified seed system, based on European protocols, has failed in the past, due to its high cost. Vietnam needs to establish its own formal seed production and certification scheme where all of the related stakeholders are involved including researchers, inspectors, policy makers and seed producers (farmers). This certified seed system needs to be suited to the agro-ecological and socio-economic conditions experienced in Vietnam and provide seed at an affordable price.

In order to supply an increasing demand for good quality potato seed in the RRD, the most practical solution is to import good quality seed from abroad and then reduce the cost of that seed to farmers by undertaking one or more subsequent multiplications in-country (Batt 2003). Since seed imported from Europe and North America has been found to be too expensive and is often too immature for planting in Vietnam, seed imported from WA can overcome these problems.

While improved seed quality can have a significant positive impact on the productivity per unit area, significant differences in productivity are also apparent between different varieties. Only those varieties that are well suited to the agro-ecological conditions experienced in the RRD and which fulfil customers' needs should be multiplied.

A formal seed certification system is necessary, for its absence not only impacts on the buyer, but also on those seed growers who endeavour to produce superior quality seed. Most buyers consider seed produced in Vietnam to be of the same quality and price (Hue 2006). If seed producers are to benefit, the introduction of a seed certification system may provide the means by which they can secure a better price for the higher quality seed they have produced.

However, as most farmers in the RRD have only a small farm and lack the necessary funds to purchase desired inputs, individual farmers may not be able to meet the strict requirements of a seed certification scheme (e.g. isolation, storage, plant protection and inspection), especially in meeting the costs of virus testing.

Fortunately, as most potato producers are members of agricultural cooperatives, these cooperatives can organise farmers into groups to ensure that they have enough land and funds to bulk up the newly imported seed in-country. In addition, where the farmer is a member of a registered cooperative, low interest loans are often available to assist with the purchase of new seed (Mr.Yen pers.comm. 2008). This enables them to make the prerequisite investments in cool storage capacity and other infrastructure such as irrigation systems.

From the experiences of potatoes farmers in the RRD, using whole small round seed (21-40 tubers/kg) enables them to avoid the risk of crop loss due to pests and diseases through seed cutting. Therefore, seed potato producers have to manage the seed tuber size to meet farmers' demand.

Results from the survey indicated that most farmers in the RRD prefer to purchase seed from research institutions and cooperatives. This implies that the reputation of the seed supplier has a strong influence on the farmers' decision to purchase seed because farmers consider that the seed quality will be better compared to alternative seed sources.

Importance of disease management

Appropriate strategies for the management of aphids will be important in reducing the spread of virus in the RRD for both seed and ware potato production in Vietnam. As isolation is impossible in the RRD, the application of effective insecticides can reduce aphid populations (Zitter and Gallenberg 1984; Burrows and Zitter 2005). The application of mineral oils to interfere with the aphid's feeding process may provide the most effective and practical solution to control aphid populations in potatoes. These practices can minimize the spread of PVY.

According to Zitter & Gallenberg (1984); Beukema and Zaag (1990), and Burrows and Zitter (2005), PVX is only transmitted by contact, even through wounds caused when an infected leaf rubs against a healthy leaf, via humans, animals and machines moving through the crop; by biting insects such as grasshoppers and beetles; and through contamination during seed cutting. PVX can be controlled by using certified seed, sanitising all tools, limiting within-field movement (Burrows and Zitter 2005) and controlling the population of grasshoppers and beetles in the potato field.

As the seed quality declined through an increase in virus infection and the increasing incidence of other pests and diseases with each successive generation under the growing conditions in the RRD, higher rates of chemical application may be necessary to control the increasing incidence of pests and diseases. However, in this study, no difference in chemical application rates between seed sources was observed for any variety or location. Improving farmer' knowledge and skills in pests and disease identification and chemical application through training farmers may be able to ameliorate the impact of poor seed quality on the potato crop.

7.5. Limitation of the research

The duration of the project (two years) was too short to fully evaluate the crop performance of the three potato varieties in the RRD.

Many factors influence the yield, quality and the productivity of the potato crop (Beukema and van der Zaag 1990; Struik and Wiersema 1999). Since only virus testing and farmer's observations of other pests and diseases were performed, the influence of other factors such as fertilizers, chemical application and storage need to be examined to explore how these variables influence the performance of WA potato seed under the agro-ecological conditions experienced in the RRD.

All the experiments in Thai Binh were undertaken in the farmers' fields with their assistance. Although there should not be any difference in the quantity of fertilizer and chemical applied as all practices were supervised by technical assistants from FCRI, farmers may give more attention to the trials rather than their own crops. The yield therefore may be higher than that which would be obtained from the same seed source in the farmers' field. In this study, means of the total yields recorded in the experiments were higher than those which were reported by farmers. For example, the mean of total tuber yields recorded from experiments were 27.7 t/ha for VN0; 23.3 t/ha for VN1 and 19.9 t/ha for VN2 while the figures provided by the farmers were 23.7 t/ha for VN0, 20.7 t/ha for VN1 and 17.4 t/ha respectively for VN2.

The results of this study cannot be extrapolated to the population of potato farmers in the RRD, for by necessity, a non probability sample was drawn. Only those farmers who had some experience with WA potato seed were selected. Invariably, these were better farmers, who through previous contact with the FCRI had participated in one or more collaborative and international projects. Therefore, these farmers were atypical of those found in the RRD.

In previous studies, Batt (2002) and Embry (2003), reported significant differences in the farm gate price between potato farmers in Thai Binh and Hai Duong. However, of greater significance was the difference in the price paid for potatoes as the season progressed. Significant price premiums were paid for early or late potatoes, but as the quantity of tubers increased, the price correspondingly decreased. Towards the end of the season, as the supply of fresh potatoes dwindled, the prices began to increase again, but were constrained, in part, by the increasing availability of Chinese potatoes.

In this study, no such difference in price was observed, presumably because farmers reported the average price that they received from traders. As there was no marketed increase or decrease in the average prices between the two seasons, it can be assumed that these were typical or normal harvests uninterrupted by torrential rain, disease or some other climatic variable which may otherwise limit the quantity of potatoes available.

Struik and Wiersema (1999) state that seed of the highest quality will produce maximum yields and good quality tubers. Furthermore, tubers produced from healthy seed and from a long growing crop will contain more dry matter than tubers produced from low quality seed in a short growing season. In this study, the respondents reported that the first generation crop (VN0) remained green longer, suggesting that it had the potential to grow a longer period. Beukema and van der Zaag (1990) observed that longer crop cycles produced a higher yield and greater dry matter content. For the varieties used in processing such as Atlantic and Eben, high dry matter content is one of the major factors determining the market position. This influences positively not only on the price of the potatoes, but also on the economic returns per unit area. However, the study did not test the differences in the growing season between seed sources or variety. Further research needs to be undertaken to explore the association between seed quality and growth duration, and seed quality and the dry matter content of the tuber for different generations of WA potato seed under the agro-ecological conditions in the RRD.

Thai Binh has been considered a suitable location for seed production in the RRD because it has a lower population of aphids than Hai Duong (Tuyen *et al.* 2003). However, in this study there was no significant difference found in the level of virus infection between locations. This would suggest that the work of Tuyen *et al.* no longer applies, perhaps because of global warming, aphid population are more widespread, or because aphids were appropriately controlled at FCRI.

In terms of exploring the relationship between virus infection and yield, Hane (1999) concluded that the yield reductions in larger plan populations in larger plots of farmer fields infected with PVY may be less depending on the compensatory growth of uninfected plants. The degree of compensatory growth in healthy plants next to a virus infected plant was found to be negligible in the case of PVY in single plant studies but needs to be confirmed with larger plant populations. In this study, no information on the proportion of plants in each plot infected with both PVY and PVX or with a single virus and their relative effects on yield were recorded.

In this study, it was assumed that the use of WA seed will help to reduce the risk of importing new pests and diseases into the RRD. Beukema and van der Zaag (1990) report that good quality seed not only impacts upon the productivity and profitability of the current potato crop, but may also influence the productivity and profitability of any other potato crops grown from the same seed or grown in the same soil. While this study explored the impact of selected virus on seed quality and productivity, an additional study is necessary to examine the impact of seed quality on the incidence of soil-borne disease in a typical farming system in the RRD.

7.6. Conclusion

This study has provided empirical findings on the positive agronomic and economic impact arising from the use of certified WA potato seed in the RRD.

The study has identified that newly imported WA seed (VN0) had the lowest level of pest and disease infection compared to later seed generations in the RRD. In addition, the findings of this study provide new information on the relative importance of viruses in potato production, where PVY and PVX are more important and PLRV and PVA less important in the RRD. This information is necessary for the implementation of a successful certified seed potato scheme in Vietnam.

The newly imported seed (VN0) produced the highest yield and tuber quality compared to the later seed generations (VN1+) under the agro-ecological conditions experienced in the RRD.

Results from this study have shown that, despite the higher purchase price, the use of limited field generation seed (VN0) has helped farmers to receive a better price and higher gross income. This significantly improved the net income of potato farmers compared to that obtained from the use of later seed generations (VN1+).

However, despite the enhanced profitability, the majority of potato farmers in the RRD are reluctant to purchase newly imported seed due to the high cost of the seed compared to other seed sources. They preferred to spend less money to purchase inferior quality seed because most households did not have access to sufficient capital. In addition, with the greater capital outlay for more expensive seed, most small potato farmers are very cognisant of the increased risk. Natural disasters in the RRD (e.g. flooding, hail, storms, and disease out-breaks) have potential to either wipe out the crop completely or to severely reduce the productivity per unit area.

Later seed generations (VN1+) are not only more affordable for the smallholder farmers in the RRD, but also less risky than the newly imported seed. However, the introduction of a seed certification system for Vietnam is necessary to manage the quality of later seed generations (VN1+) and to secure a better price for the higher quality seed farmers have produced.

7.7. Taking advantage of the opportunities

The large size of newly imported WA potato seed is a constraint for the majority of potato farmers in the RRD who prefer small round seed. Furthermore, most of the Vietnamese (producers and consumers) prefer to use potato varieties which have a yellow skin and yellow flesh. In order to capture a greater market share, the WA seed potato industry needs to: (i) produce small round seed tuber to meet the Vietnamese farmers' demand; (ii) continue to liaise with the FCRI (VAAS) to identify superior varieties that are suited to the agro-ecological conditions in the RRD and where possible, to bulk up those Dutch or German potato varieties which have been accepted by Vietnamese farmers; and (iii) in cooperation with FCRI, to train Vietnamese potato farmers to improve their crop managements and seed selection.

Increasing the supply of good seed may encourage farmers to plant more potatoes in the RRD. However, if the productivity per unit area increases, the price of potatoes in the ware market may decline, especially in the peak season as farmers don't have access to cool stores for ware potatoes. In addition, most potatoes in the RRD are sold to small collector agents or the open markets where potatoes will rot easily. To solve this problem, the Vietnamese potato industry needs to explore alternative markets for potatoes by developing a sustainable network between farmers and traders, processing companies, import and export companies and supermarkets. This will enable potato farmers to secure better prices.

In the last five years, a number of potato processing companies have established themselves in Vietnam (Chung 2006; Tuyen 2008). In order to secure a sufficient quantity of raw potatoes in the low season, these companies will need to establish a sustainable relationship with ware potato suppliers and farmers, where the companies will need to provide seed inputs and technical advice. To what extent smallholder farmers will be willing to enter into such long term relationships requires further investigations.

References:

Allen, C., Kelman, A. and French, E.R. (2001). Brown rot. In: Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 11-13.

Alvin, R.M. and Richard, W.C. (1993). Selecting cultivars and obtaining health seed lots. In: Rowe, R.C. (ed.), Potato Health Management. The American Phytopathological Society, Ohio, Wooster: 19-26.

Anonymous (1983). Potato Production in Vietnam." Typescript.

Anonymous (2001). Western Australian certified seed potato scheme incorporating national standard.

Anonymous (2003). Final Report AusAID Project. Increasing the capacity of the Food Crops Research Institute to enhance the production and management of potatoes in the Red River Delta. Department of Agriculture Western Australia, Perth. 157p.

Anonymous (2005). The inspection of Dutch seed potatoes; the important approval NIVAP and NAK, Holland.

Anonymous (2006a). Potato Production and Consumption in Vietnam. Vietnamese - German Potato Promotion Project (GTZ): 50p.

Anonymous (2006b). Vietnam, About the Potato Atlas Archives. http://research.cip.cgiar.org/confluence/display/wpa/Vietnam.

Anonymous (2006c). Seed potato nuclear stock production and classification in Scotland. Scottish Agricultural Science Agency (SASA): 6p. http://edis.ifas.ufl.edu/pdffiles/NF/NFREC2200.pdf.

Arpiwi, N.L. (2003). The application of novel methods for increasing the yield of small round seed potatoes (Solanum tuberosum L.) varieties Atlantic and Granola. University of Western Australia, 2004., Perth. 160 p.

Australian Bureau of Statistics (ABS) and Department of Agriculture and Food Western Australia (DAFWA) 2008.

Balaoing, V.G. and Lazo, F.D. (1967). Irish Potato Production in the Philippines: Problems and Prospects. Philippine Journal of Plant Industry 32 (3-4): 195-216.

Bantarri, E.E., Ellis, P.J. and Khurana, S.M.P. (1993). Management of diseases cause by viruses and viruslike pathogens. In: Rowe, R.C. (ed.), Potato Health Management. The American Phytopathological Society, Minnesota: 127-134.

Batt, P. J. (2002). Final report for Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) on the market for seed potatoes, fresh potatoes and processed potato products in Vietnam. Hanoi.

Batt, P.J. (2003a). A Review of the Export Market for Western Australian Seed Potatoes in South East Asia. Curtin University. 58p.

Batt, P. J. (2003b). Examining the performance of the supply chain for potatoes in the Red River Delta using a pluralistic approach, Supply Chain Management: an International Journal, Vol 8 (5): 442-454.

Batt, P. J.(2003c). Promoting Australian exports to Asia through building close and long lasting relationships with focal customers: An empirical study of Australian seed potato exports. Perth, Curtin University of Technology. PhD.

Beenster, A.B.R. and de Bokx, A.J. (1987). Survey of properties and symptoms. In: de Bokx, A.J. and van der Want, J.P.H. (eds.), Viruses of Potatoes and Seed - potato Production Pudoc Wageningen Wageningen: 84-113.

Beukema, H.P. and van der Zaag, D.E. (1990). Introduction to potato production. Pudoc, International Agricultural Centre.,Wageningen. 208 p.

Bleasdale, J.K.A. (1965). Relationship between set characters and yield in main crop potatoes. The Journal of Agricultural Science 64: 361-366.

Blount, A.R, Quesenberry, K.H, Chambliss, C.G and Stadsklev, T. (2005). Seed Certification. http://edis.ifas.ufl.edu/pdffiles/NF/NFREC2200.pdf.

Bohl, W.H., Nolte, P. and Thornton, M.K. (1992). Potato Seed Management: Seed certification and selection. http://info.ag.uidaho.edu/Resources/PDFs/CIS0974.pdf.

Bohl, W.H., Nolte, P., Kleinkopf, G.E. and Thornton, M.K. (1995). Potato seed management seed size and seed age. http://info.ag.uidaho.edu/Resources/PDFs/CIS1031.pdf (2/16/05).

Brinkman, H. and Mulder, A. (2005). Columbia Root - Knot nematodes. In: Mulder, A. and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 124-126.

Brown, P.H, Beattie, B and Laurence, R. (2003). Intergenerational effects on seed potato physiological ageing. In Yada, R.Y. (ed). Acta Horticulturae. 619: 241-249. http://www.actahort.org/books/619/619_27.htm.

Burrows, M.E. and Zitter, T.A. (2005). Virus Problems of Potatoes. Cornell University, USDA-ARS and Department of Plant Pathology. 6p.

Burton, W.G. (1966). The potato: a survey of its history and of factors influencing its yield, nutritive value, quality and storage. H. Veenman, Wageningen. 382 p.

Bus, C.B. and Wustman, R. (2007). The canon of potato science. Potato Research 50: 319-322.

Bus, C.B., van Loon, C.D. and Veerman, A. (1996). Teelt van pootaardappelen. PAGV (In Dutch)', Lelystad, the Netherlands.

Caldiz, D.O., Fernandez, L.V. and Struik, P.C. (2001). Physiological age index: a new, simple and reliable index to access the physiological age of seed potato tubers based on haulm killing date of incubation period. Field Crop Research 69: 69 – 79.

Caldiz, D.O., Brocchi, G., Alaniz, J.R. and Marchan, L. (1996). Effects of the physiological age of seed potatoes on tuber initiation and starch and dry matter accumulation. Pesq. Agrop Brasileira 31: 853-858.

Chien, D. H., Ho, T.V., Tung, P.X., My, T.V. and Dam, N.D. (2000). Results on research and development of potato production from HYB TPS in Vietnam, 1993-2000. Paper presented at CIP-ADB Symposium on Testing Hybrid TPS in the Lowland Tropics of Asia, September 13-14, Bogor, Indonesia.

Chung, D.K. (2001). Research on Socio-economic assessment of potato production target groups in the Northern Vietnam. Hanoi, June 2001.

Chung, D.K. (2003). Potato market in Vietnam, submitted to the project. Promotion of Potato Production in Vietnam on behalf of Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ).

Chung, D.K. (2006). Potato Markets in Vietnam. Information and Cultural Publishing House, Hanoi.

Cuperus, C. and de Bokx, A.J. (2005a). Potato Leaf Roll Virus / PLRV. In: Mulder, A. and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 93-95.

Cuperus, C. and de Bokx, A.J. (2005b). Potato virus A (PVA). In: Mulder, A. and Turkensteen, L.J. (Eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 98-99.

Cuperus, C. and de Bokx, A.J. (2005c) Virus diseases. In: Mulder, A., Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 89-91.

Cuperus, C. and van de Haar, H. (2005). Potato virus Y (PVY). In: Mulder, A. and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 106-110.

Das, G. P. (1995). Plants used in controlling the potato tuber moth, Phthorimaea operculella (Zeller). Crop Protection 14(8): 631-636.

David, M. (2001). Australian Potato Export Opportunities - Bonanza or Myth. Australian Natural Resource and Environment. 88 p.

Davidson, M.M., Butler, R.C., Wratten, S.D. and Conner, A.J. (2006). Field evaluation of potato plants transgenic for a cry1Ac gene conferring resistance to potato tuber moth, Phthorimaea operculella (Zeller) (Lepidoptera: Gelechiidae). Crop Protection 25: 216-224.

Dawson, P. (2000). Overview of potato research activities in Western Australia. Improving the Efficiency of Potatoes Production and Marketing in Indonesia, the Philippines. In Batt, P.J. (ed). Vietnam and Nepal, Adelaide, South Australia. ACIAR: 71-80.

Dawson, P., McPharlin, I.R. and Howes, M. (2003). Table and seed potatoes from Western Australia: at a glance. Bulletin 4586. Agriculture Western Australia, South Perth. 2p.

de Bokx, J.A. (1981). Potato virus Y. In: Hooker, W.J. (ed.). Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 70-71.

de Bokx, A.J. (2005). Potato virus X / PVX. In Mulder, A. and Turkensteen, L.J.(eds). Potato diseases, Aardappel wereld magazine, NIVAP Holland, Wageningen: 104-106.

Dean, B. (1994). Managing the potato production system. Food Products Press, New York. 183 p.

Dehaan, T.L. (1994). Seed potato certification and diagnostic testing. Canadian Journal of Plant Pathology 16: 156-157.

Dowling, B. (1995). Developing advanced seed potato technology: the case of Technico Pty. Ltd Australian Agribusiness Review 3: 16-23.

Embry, J. (2003). Investigation of household economics of potato growers in the Red River Delta 2000-2001. In: Final Report of AusAID Project: Increasing the capacity of the Food Crops Research Institute to enhance the production and management of potatoes in the Red River Delta. Department of Agriculture and Food Western Australia Perth. 157p.

Ernest, E.B., Peter, J.E. and PaulnKhurana, S.M. (1993). Management of diseases caused by viruses and viruslike pathogens. In Rowe, R.C. (ed.). Potato Health Management. The American Psychopathological Society, Minnesota: 127 - 134.

Fernie, A.R. and Willmitzer, L. (2001). Molecular and biochemical triggers of potato tuber development. Plant Physiology. 127: 1459-1465.

Flier, W.G. and Turkensteen, L.J. (2005). Late blight. In Mulder, A and Turkensteen, L.J. (eds). Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 28-33.

Floyd, R. (1989). Bacterial soft rot of potato. Farmnote 88/1989. Department of Agriculture and Food, Perth.

Food and Agriculture Organization of the United Nations. Commodities Division (1995). Potatoes in the 1990s: situation and prospects of the world potato economy. FAO, Rome. 39 p.

Fuglie, K.O., Adiyoga, W., Asmunati, R., Mahalaya, S. and Suherman, R. (2006). Farm demand for quality potato seed in Indonesia. Agricultural economics. 35: 257-266.

Fuglie, K.O., Nga, D.T.B., Chien, D.H. and Hoa, N.T. (2001). The Economic Impact of True Potato Seed in Vietnam. http://www.eseap.cipotato.org/MF-ESEAP/Fl-Library/EcoImpTPSVietnam-Keith.pdf, 23pp.

Fulton, D. and Fulton, A. (2000). Seed Potato Quality: What is it and what can be done to improve it? In William, C.M. and Walters, L.J. (eds). Potatoes 2000. Linking research to practice. Australian Potato research, development and Technology Transfer conference. Adelaide, South Australia**:** 155-160.

German, T.L. (2001). Potato virus Y. In Hooker, W.J. (ed.). Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 67-71.

GSO, (General Statistic Office). (2006). Statistical Yearbook of Vietnam. Statistic publishing house. Hanoi. 738 p.

Hair, J.F.J., Anderson, R.E., Tatham, R.L. and Black, W.C. (1998). Multivariate data analysis Prentice Hall Inc, New Jersey.

Hartmans, K.J. and van Loon, C.D. (1987). Effect of physiological age on growth vigour of seed potatoes of two cultivars 1. Influence of storage period and temperature on sprouting characteristics. Potato Research 30: 397- 409.

Ho, T.V. (1987). Results of potato storage experiments in Vietnam during 1983. In Potato Research and Development in Vietnam: A Collaborative Experience from 1982 - 1987. Ministry of Agric. and Food Industry, Hanoi, Vietnam.

Ho, T.V., Tuyet, L.T., Tung, P.X. and Zaag, P.V. (1983). Potato Research and Development in Vietnam in Recent Years. Circular. International Potato Center 15, No. 3: 1- 5.

Hoa, N.T., Hue, T.T., Ho, T.V., Hung, N.T., Baarveld, H. and Brands, J. (1995). Research on seed potato storage using a cold store. In Root Crop Research 1991-1995. Vietnam Agricultural Science Institute (VASI), Vietnam 1995 (in Vietnamese).

Holland, M. and Spencer, D. (2007). Western Australian certified seed potato scheme production rules. AGWEST. Plant Laboratories. Perth.

Hooker, W.J. (1981). Compendium of potato diseases, American Phytopathological Society, St. Paul, Minnesota. 125p.

Hooker, W.J. (2001). Compendium of potato diseases, American Phytopathological Society, St. Paul, Minnesota. 125p.

Horton, D.E. (1987). Potatoes: production, marketing, and programs for developing countries. Westview Press, Boulder. 243p.

Horton, D.E. and Anderson, J.L. (1992). Potato production in the context of the world and farm economy. In: Harris, P. (ed.), The potato crop- the scientific basic for improvement. Chapman and Hall, London: 794-815.

Hue, D.T. (2006). Potato Seed Production in Vietnam. In Country Report, Wageningen, the Netherlands, June 2006.

Hue, D.T., Batt, P.J., McPharlin, I.R. and Dawson, P. (2008a). Performance of Western Potato Seed in Vietnam. Fifth biennial workshop of Horticulture Program. Department of Agriculture and Food, Mandurah Quay Resort, Western Australia, 8-9 May 2008: 52-53.

Hue, D.T., Batt P.J., McPharlin, I.R. and Dawson, P. (2008b). The Economic Impact on Smallholder Potato Farmers in the Red River Delta, Vietnam, from the Use of Superior Quality Seed. In Batt, P.J. (ed) Proceeding of an International symposium on the Socio-Economic Impact of Morden Vegetable Production technology in Tropical Asia. Acta Horticulturae. Chiang Mai, Thailand 3-6 February 2008. (in press).

Ingham, R., Dick, R. and Sattell, R. (1999). Columbia root-knot nematode control in potato using crop rotations and cover crops. Oregon cover crops. Oregon State University. 8p.

Jones, B.R., Kumar, S. and Mackie, A. (2003). Potato virus Y. Fact sheet, Department of Agriculture. 2p. http://www.agric.wa.gov.au/content/PW/PH/DIS/FS00203.PDF.

Jones, E.D., Munro, J. and Darling, H.M. (1981). Seed potato certification. In Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 103-106.

Kawakami, K. (1962). The physiological degeneration of potato seed tubers and its control, Potato Research 5: 40-49.

Kawakami, K. (1980). Age of potato tubers. Potato Research 23: 256.

Kelman, A. (1981). Brown rot. In Hooker, W.J. (ed.). Compendium of potato diseases. American Phytopathological Society, St. Paul, Minn: 29-31.

Knowles, N.R. and Botar, G.I. (1991) Modeling the effects of potato seed-tuber age on plant establishment. Canadian Journal of Plant Science 71: 1219-1232.

Knowles, N. R. and Botar, G. I. (1992). Effect of altering the physiological age of the potato seed tubers in the fall on subsequent production in a short season environment. Canadian Journal of Plant Science 72: 275-287.

Knoxfield, G.B. (2006a). Root knot nematode on potatoes. Agriculture Notes. 2p.

Knoxfield, G.B. (2006b). Potato Cyst Nematode Agriculture Notes. 3p.

Kris, C.H. and McCashion, L. (2005). Dietary Guideline Revisions Uncover Nutrients of Concern. http://www.healthypotato.com/downloads/DietaryGuidelinesReleaseforKit.pdf.

Kumar, G.N.M. and Knowles, N.R. (1993). Involvement of auxin in the loss of apical dominance and plant growth potential accompanying aging of potato seed tubers. Canadian Journal of Botany 71: 541-550.

Kumar, G.N.M. and Knowles, N.R. (1996). Nature of enhanced respiration during sprouting of aged potato seed – tubers. Physiologia Plantarum 97: 228-236.

Kustiati, T. (2005). Production of Seed Potatoes (Solanum tuberosum L.) in the Tropics, Natural and Agricultural Sciences, University of Western Australia, Perth: 167p.

Leedy, P.D. and Ormrod, J.E. (2001). Practical Research, Planing and Design. 7th edn. Maeerill Prentice Hall, Inc., New Jersey.

Love, A.L., Baker, T.P., Ojala, J.C., Pavek, J.J. and Corsini, D.L. (1993). Characteristics of potato varieties in the Pacific Northwest. A Pacific Northwest Extension Publication, University of Idaho. 24p.

MacGillivray, E.M. (1981). Aphids. In Hooker, W.J. (ed.). Compendium of potato diseases. American Phytopathological Society, St. Paul, Minn: 101-103.

MacGuidwin, A.E. (1993). Management of Nematodes. In Rowe. R.C.(ed.). Potato Health Management, the American Phytopathological Society, Ohio, Wooster: 159-166.

McKinna, D. (2001). Potato export market development. Horticulture Research and Development Cooperation (HRDC).

Molhotra, N., Hall, J., Shaw, M. and Oppenheim, P. (2002). Marketing Research, An Applied Orientation Prentice, Australia.

Monares, A. (1981). The Potato Seed System in the Andean Region: The Case of Peru. PhD thesis. Cornell University.

Mulder, A. and Turkensteen, L.J. (2005a). Potato tuber moth. In: Mulder, A., Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 176-177.

Mulder, A. and Turkensteen, L.J. (2005b). Potato diseases. In: Mulder, A., Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen. 280p.

Mulder, A. and Stolte, A. (2005). Aphids. In Mulder, A. and Turkensteen, L.J. (eds.). Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 149-153.

Mulder, A. and Brinkman, H. (2005a). Nematodes. In Mulder, A. and Turkensteen, L.J. (eds.). Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 121-123.

Mulder, A. and Brinkman, H. (2005b). Potato Cyst Nematodes. In: Mulder, A., Turkensteen, L.J. (eds.). Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 131-135.

Munro, J. (1981). Potato virus X. In Hooker, W.J. (ed.). Compendium of Potato Diseases American Phytopathological Society, St. Paul, Minnesota. 125p.

Oosterveld, P. (1987). Inspection and grading. In: de Bokx, A.J. and Van der Want, J.P.H. (eds.), Viruses of Potatoes and Seed -potato Production Pudoc Wageningen Wageningen: 204 -214.

Panda, J.M. and Mohanty, C.R. (1981). Utilisation of individual tuber sprouts in potato production Scientia Horticulturae 14 (3): 215-218.

Pavlista, A.D. (2003). Atlantic: Characteristics University of Nebraska, Nebraska http:/www.panhandle.unl.edu/potato/html/atlantic.htm [9/92004].

Perez, J.C. (2001). Revisiting lowland potato production. In Upward Field note 10: 27-29.

Peters, D. and Jones, R.A.C. (1981). Potato leafroll virus. In Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 68-70.

Potato Marketing Corpotation of Western Australia (2004). Annual Report 2004. (PMCWA Perth)

Powelson, M.L. and Ranc, G.D. (2001). Blackleg, Aerial stem rot, and tuber soft rot. In Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 10-11.

Priou, S., Aley, P., Chujoy, E., Lemage, B. and French, E.R. (1994). Integrated control of bacterial wilt of potato. 30 p.

Radcliffe, E.B., Ragsdale, D.W. and Flanders, K.L. (1993). Management aphids and leafhoppers. In: Rowe, R.C. (ed.). Potato Health Management. The American Phytopathological Society, Minnesota: 117-127.

Ragsdale, D.W., Radcliffe, E.B., DiFonzo, C.D. and Connelly, M.S. (1994). Action thresholds for an aphid vector of potato leafroll virus. In: Zehnder, G.W., Powelson, M.L., Jansson, R.K., Raman, K.V. (eds.), Advances in Potato Pest Biology and Management. American Phytopathological Society, Minnesota: 99-111.

Reust, W. (1986). EAPR Working group Physiological age of potato. Potato Research 29: 268-271. http://info.ag.uidaho.edu/Resources/PDFs/CIS1031.pdf (2/16/05)

Rex, B.L. (1990). Effect of seed piece population on the yield and the processing quality of Russet Burbank potatoes. American Potato Journal 67: 473-489.

Rich, A.E. (1983). Disease caused by viruses, viroids, and mycoplasmas. In: Rich, A.E. (ed.), Potato diseases. Academic press, New York, London: 92-135.

Rotem, J. (1981). Fungal disease of potato and tomato in Negev. Plant Disease 65: 315-318.

Rowe, R.C. (1993). Potato health management: A holistic approach. In: Rowe, R.C. (ed.), Potato Health Management. The American Phytopathological Society, Minnesota:3-10.

Salazar, L. F. (1996). Potato viruses and their control. Lima, Peru, International Potato Center.

Schmiediche, P. (1995). The production of seed potatoes in South East Asia, in Batt, P.J. (ed) Proceedings of an industry workshop, an emerging opportunity the export of tropical seed potatoes to Asia. Curtin University.

Shepard, J.F. and Claflin, L.E. (1975). Critical Analyses of the Principles of Seed Potato Certification. Annual review of phytopathology 13: 271-293.

Slack, S.A. (2001a). Diseases caused by phytoplasmas In Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 56-57.

Slack, S.A. (2001b). Potato leafroll virus. In: Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 63-64.

Steven, A.S. (1993). Seed certification and seed improvement programs. In: Rowe, R.C. (ed.), Potato Health Management. The American Phytopathological Society, Minnesota: 61-66.

Struik, P.C. and Wiersema, S.G. (1999). Seed potato technology. Wageningen Pers, Wageningen. The Netherlands. 383 p.

Sully, R. (2000). National Seed Potato Certification Standards. In: William, C.M., Walter, L.J. (eds.), Potatoes 2000. Linking research to practice. Australian potato research, development and technology transfer. SARDI, Adelaide, South Australia: 253-254.

Thackray, D.J, Jones R.A.C, Bwye, A.M. and Coutts B.A. (2000). Further studies on the selects of insecticides on aphid vector numbers and spread of cucumber mosaic virus in narrow-leafed lupins (Lupinus angustifolius). Crop Protection 19: 121- 139.

Thurston, H.D. and Schultz, O. (1981). Late Blight. In: Hooker, W.J. (ed.), Compendium of potato diseases. American Phytopathological Society, St. Paul, Minnesota: 40-42.

Tung, P.X. (2000). Potato Produc`tion in Vietnam, 11p. http://www.eseap.cipotato.org/MF-ESEAP/Fl-Library/Pot-Vietnam.pdf

Tung, P.X. (2001). The late blight disease of potato in Vietnam. Agricultural University of Henei, 7p.

Turkensteen, L.J. (2005a). Phytoplasmas and viroids. In: Mulder, A. and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 117-120.

Turkensteen, L.J. (2005b). Bacteria diseases. In: Mulder, A. and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 71-87.

Turkensteen, L.J. (2005c). Early blight. In: Mulder, A.and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 19-20.

Turkensteen, L.J. (2005d). Bacterial wilt and brown rot. In: Mulder, A. and Turkensteen, L.J. (eds.). Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 78-80.

Turkensteen, L.J. (2005e). Fungi diseases. In: Mulder, A. and Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 11.

Turkensteen, L.J. and Flier, W.G. (2005). Late blight. In: Mulder, A., Turkensteen, L.J. (eds.), Potato diseases. Aardappel wereld magazine, NIVAP Holland, Wageningen: 28-33.

Tuyen, T.C. (2001). Relationship between Growing Conditions and Agronomic Practices on Yield and Quality of Potatoes in Red River Delta in 2000/2001. FCRI, Ministry of Agriculture and Rural Development, Hai Duong (in Vietnamese).

Tuyen, T.C. (2008). An overview of potato production in Vietnam (in Vietnamese). Food Crop Research Institute Hai Duong, Vietnam.

Tuyen, T.C., Chuc, N.C. and Mentz, D.C. (2003). Aphids population on potatoes in the north, Vietnam. Report for Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), Hanoi. 42p (in Vietnamese).

Tuyen, T.C., Hue, D.T. and Thoai, N.D. (2003). Results from Evaluation of Potato Varieties for Processing with Western Australian Seed Source. Annual Report (in Vietnamese). Food Crop Research Institute, Hai Duong, Vietnam (in Vietnamese).

Ulmer, A. and Stuber, L. (1997). Producing Certified Seed. NDSU; http://www.ag.ndsu.edu/pubs/plantsci/crops/a1125w.htm.

van Baarlen, P., de Bokx, A.J., Brinkman, H., Cuperus, C., Flier, W.G., van de Haar, H., Meijers, C.P., Mulder, A., Scholte, K., Stolte, A., Turkensteen, L.J. and van der Zaag, D.E. (2005). Potato diseases. Aardappel wereld magazine, NIVAP, Wageningen. 280 p.

van der Zaag, D.E. (1987). Yield reduction in relation to virus infection. Viruses of Potatoes and Seed Potato Production. In: de Bokx, A. J. and van der Want, J. P. H. (eds). Wageningen, Pudoc Wageningen: 146-149.

van der Zaag, D.E. (1990). Research and developments in seed potato production systems and its implications in Bangladesh. In: Rashid, M.M.; Siddique, M.A. and Hussain, M.M. (eds). Seed Potato in Bangladesh, Bangladesh-Netherlands Seed multiplication Project: 90 -99.

van der Zaag, D.E. and van Loon, C.D. (1987). Effect of physiological age on growth vigour of seed potatoes of two cultivars. 5. Review of literature and integration of some experimental results. Potato Research 30: 451- 472.

van Ittersum, M.K. (1993). Advancing growth vigour of seed potatoes by storage temperature regimes. Netherlands journal of Agricultural Science 41: 23-36.

Webb, R.E., Wilson, D.R., Shumaker, J.R., Graves, B., Henninger, M.R., Watts, J., Frank, J.A. and Murphy, H.J. (1978). Atlantic: A new potato variety with high solids, good processing quality, and resistance to pests. American Potato Journal 55: 141- 145.

Western Australia facts, viewed 5 October 2008 (2008). http://www.about-australia.com/facts/western-australia

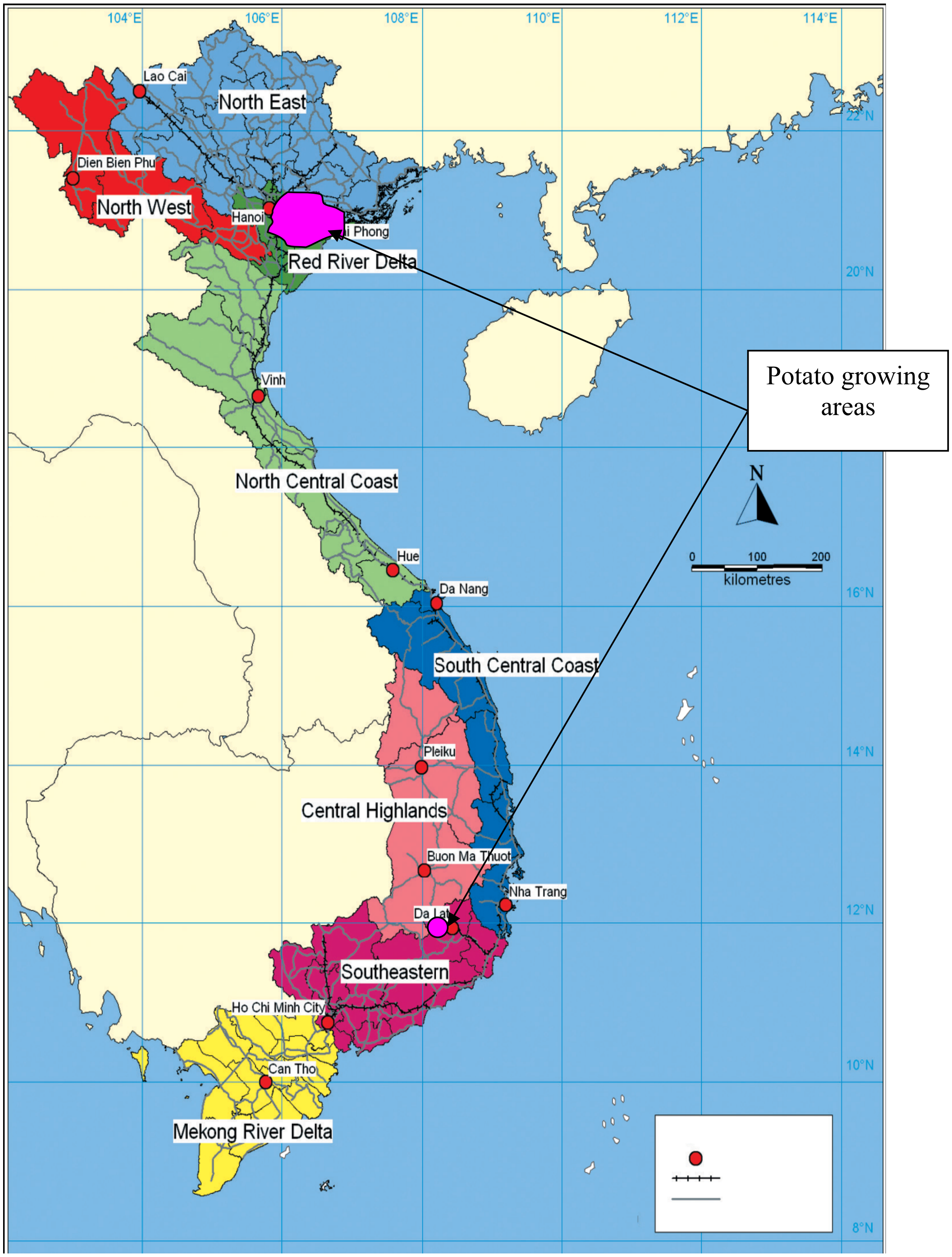
Western Potatoes (2004). Potato Growing in Western Australia viewed 3 November 2008. http://www.westernpotatoes.com.au/go/consumers/education/potato-growing-in-western-australia. .

Wicks, T. (2004). Bacterial wilt of potatoes. SARDI.

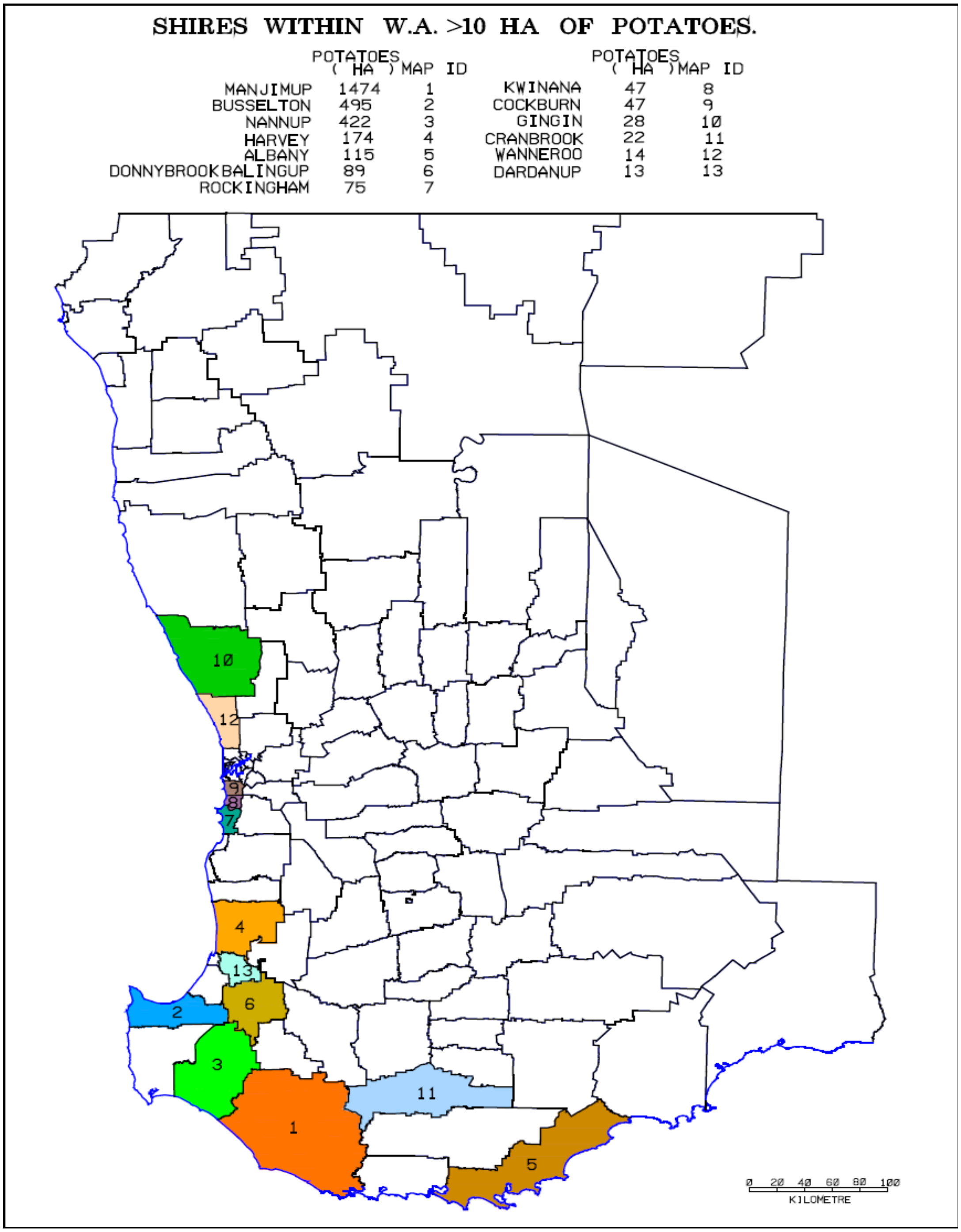
Wurr, D.C.E. (1979). The effect of variation in the storage temperature of seed potatoes on sprout growth and subsequent yield. J. Agric. Sci., Camb 93: 619–622.

Zitter, T.A. and Gallenberg, D.J. (1984). Virus and Viroid Diseases of Potato.

Appendix 1: Potato growing regions in Vietnam



Appendix 2: Potato growing area in Western Australia



Source: Department of Agriculture and Food, Western Australia 2004.

Appendix 3: List of pests and diseases that have not been found in Western Australia

(Source: Holland and Spencer 2007)

No.	**Common name**	**Scientific name**
1	Potato cyst nematode	*Globodera rostochiensis*
2	Potato cyst nematode	*Globodera pallida*
3	Late blight A2 mating strain	*Phytophthora infestans*
4	Phoma leaf spot	*Phoma andia*
5	Bacterial wilt	*Pseudomonas solanacearum*
6	Potato wart	*Synchytrium endobioticum*
7	Ring rot	*Corynebacterium sepedonicum*
8	Ring Rot	*Clavibacter michiganensis*
9	Rubbery rot	*Geotrichum candidum*
10	PSTVd	Potato spindle tuber viroid
11	Mop-head or mop-top	Potato mop-top virus
12	PVY	Potato virus Y
13	Andean potato mottle virus	Andean potato mottle virus
14	Colorado beetle	*Leptinotarsa decemlineata*
15	Andean potato weevil	*Premnotrypes spp.*
16	Potato tuber eelworm	*Ditylenchus destructor*
17	Serpentine leaf miner	*Liriomyza huidobrensis*

Appendix 4: Tuber yield and quality for three different WA seed generations of Eben and KT3 in Hai Duong and Thai Binh during the winter season 2006/07.

Location	Variety	Gen.	Total yield (t/ha)	Marketable tubers (%)		% small and rejected tubers (%)	
				> 50g	30-50g	< 30g	Reject
H.Duong	Eben	VN0	26.3	57.5	31.0	10.1	1.4
		VN1	20.3	45.4	33.0	17.2	4.4
	KT3	VN0	32.9	68.1	22.4	8.7	0.8
		VN1	25.5	52.8	29.3	14.5	3.4
		VN2	22.1	42.4	32.2	18.4	7.0
T.Binh	Eben	VN0	27.5	58.0	26.7	14.3	1.0
		VN1	20.3	43.5	32.4	20.7	3.4
	KT3	VN0	33.1	69.4	20.3	9.5	0.8
		VN1	27.5	53.3	28.5	15.2	3.1
		VN2	24.5	46.7	32.5	16.0	4.9
LSD.			*0.76*	*2.11*	*2.08*	*1.55*	*1.08*

Appendix 5: Tuber yield and quality for three different WA seed generations of Atlantic, Eben and KT3 in Hai Duong and Thai Binh during the winter season 2007/08

Location	Variety	Gen.	Total yield (t/ha)	Marketable tubers (%)		% small and rejected tubers (%)	
				> 50g	30-50g	< 30g	Reject
	Atlantic	VN0	24.4	70.5	19.5	7.2	2.3
H.Duong		VN1	21.4	60.8	25.9	8.3	4.1
		VN2	16.6	47.9	29.5	13.4	7.4
	Eben	VN0	26.2	62.3	25.7	10.4	1.3
		VN1	21.7	53.3	31.8	10.9	3.2
		VN2	16.5	44.4	32.3	14.9	6.7
	KT3	VN1	26.3	57.8	25.3	13.8	2.5
		VN2	22.5	45.1	31.7	17.8	4.3
T.Binh	Atlantic	VN0	24.9	73.9	16.8	7.0	1.8
		VN1	21.6	61.5	25.7	8.3	3.6
		VN2	16.7	52.6	27.3	11.7	6.8
	Eben	VN0	26.0	60.9	25.8	12.1	1.0
		VN1	21.3	45.4	32.8	18.1	3.0
		VN2	16.9	41.1	33.2	16.3	7.5
	KT3	VN1	26.9	56.6	26.2	14.2	2.4
		VN2	23.6	46.7	32.2	16.1	4.0
LSD.			*0.904*	*2.90*	*2.54*	*1.73*	*0.80*

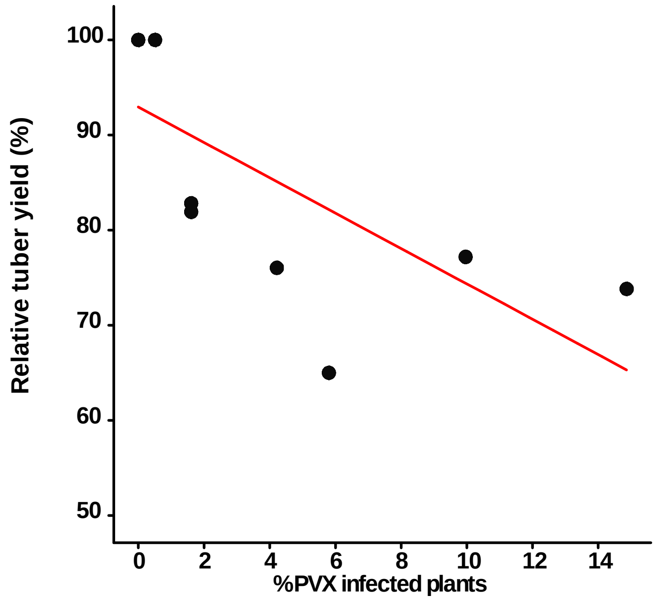
Appendix 6: Virus infection for three different WA seed generations of Eben and KT3 in Hai Duong and Thai Binh during the winter season 2006/07

Location	Variety	Generation	PVX (%)	PVY (%)
Hai Duong	Eben	VN0	0.0	3.6
		VN1	10.5	15.4
	KT3	VN0	0.0	5.0
		VN1	5.0	12.1
		VN2	11.7	19.4
Lsd.			*4.4*	*10.6*
Thai Binh	Eben	VN0	0.1	4.2
		VN1	12.7	17.2
	KT3	VN0	0.0	6.1
		VN1	6.9	7.4
		VN2	22.2	23.1
LSD.			*10.8*	*13.1*

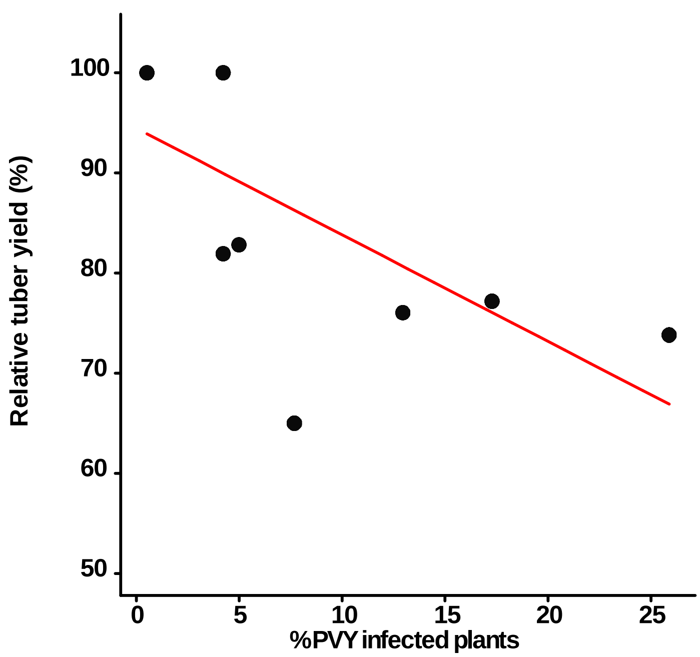
Appendix 7: Virus infection for three different WA seed generations of Eben and KT3 in the Trong Quan during the winter season 2007/08

Location	Variety	Generation	PVX (%)	PVY (%)
Hai Duong	Atlantic	VN0	0.0	0.6
		VN1	0.0	0.9
		VN2	0.0	9.0
	Eben	VN0	0.0	0.1
		VN1	0.9	5.0
		VN2	3.5	13.2
	KT3	VN1	4.4	0.6
		VN2	10.3	9.9
LSD.			*7.4*	*7.1*
Thai Binh	Atlantic	VN0	0.0	2.8
		VN1	0.0	2.8
		VN2	0.0	15.8
	Eben	VN0	0.1	0.1
		VN1	0.9	4.2
		VN2	5.2	4.2
	KT3	VN1	1.7	1.3
		VN2	6.1	6.1
LSD.			*7.0*	*8.1*

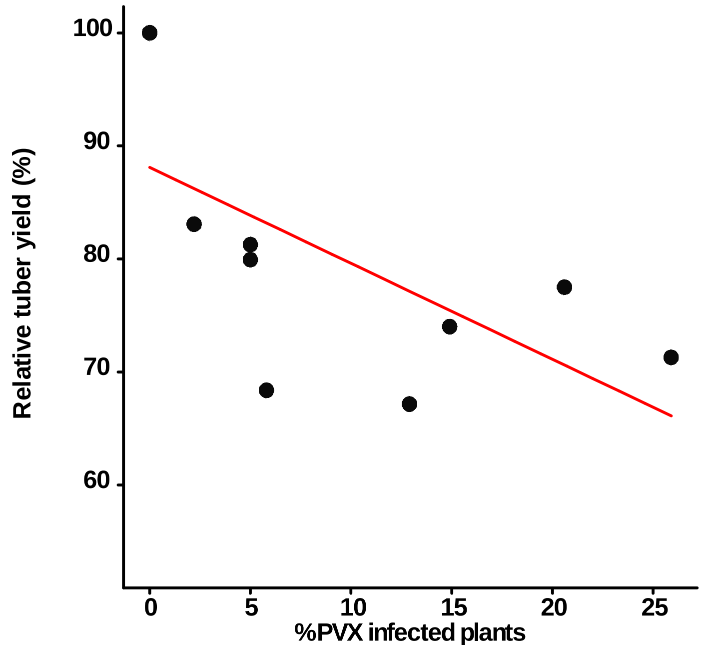
Appendix 8: Relationship between relative tuber yield (%) and PVX infected plants (%) of three different WA seed generations for Eben in two locations during two potato crops from 2006 to 2008 in the RRD.
The equation for the regression is: $Y = 92.95 - 1.86x$ ($p < 0.024$; $r^2 = 0.43$)



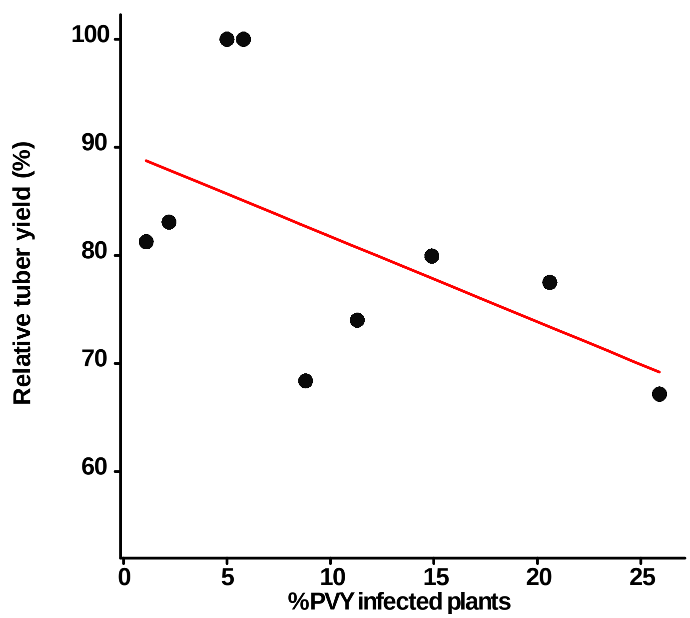
Appendix 9: Relationship between relative tuber yield (%) and PVY infected plants (%) of three different WA seed generations for Eben in two locations during two potato crops from 2006 to 2008 in the RRD.
The equation for the regression is: $Y = 94.45 - 1.1x$ ($p < 0.041$; $r^2 = 0.36$)



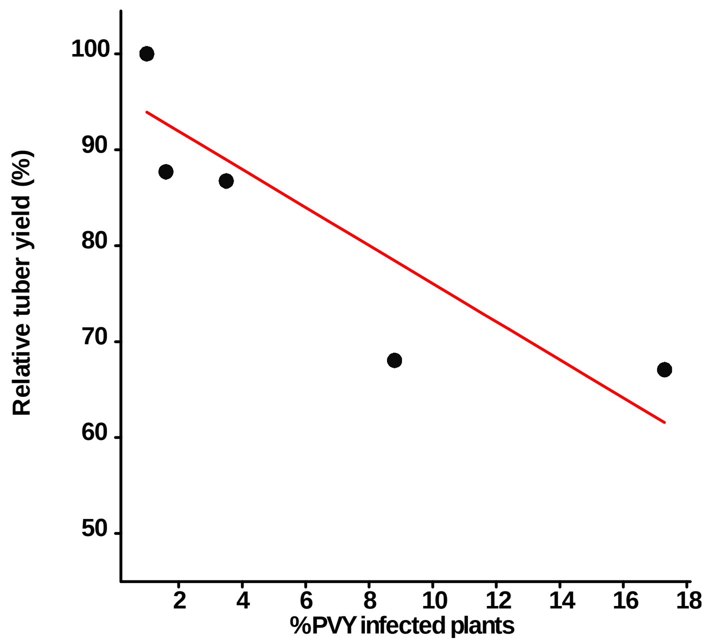
Appendix 10: Relationship between relative tuber yield (%) and PVX infected plants (%) of three different WA seed generations for KT3 in two locations during two potato crops from 2006 to 2008 in the RRD.
The equation for the regression is: $Y= 88.09 - 0.8x$ ($p<0.042$; $r^2= 0.35$)



Appendix 11: Relationship between relative tuber yield (%) and PVY infected plants (%) of three different WA seed generations for KT3 in two locations during two potato crops from 2006 to 2008 in the RRD.
The equation for the regression is: $Y= 89.64 - 0.8x$ ($p< 0.118$; $r^2= 0.2$)



Appendix 12: Relationship between relative tuber yield (%) and PVY infected plants (%) of three different WA seed generations for Atlantic in two locations during two potato crops from 2006 to 2008 in the RRD.
The equation for the regression is: $Y= 95.91 – 2.0\ x$ ($p< 0.021$; $r^2= 0.72$)



Appendix 13: Questionnaires for WA potato grower survey in 2006/07

Date: ……………………Location: ……………………….. ID:…………………..
Interviewer: ………………………………………………………………………

Hello, my name is ………………I am conducting a survey on the performance and economic impacts of WA grown potato seed in the RRD. Your answers will be confidential and only used for research purposes. Would you like to spend one hour of your time to assist me with this survey?

Q1. Have you ever used WA potato seed?

Yes No

If the farmer says "no" discontinue the survey and thank farmer for his/her time then move to other farmers.

Section A: General information

Q1. How big is your farm? ……………sao/ ……….m^2

Q2. What area of your farm is planted in potatoes? ……………sao/ ……….m^2

Q3. How many potato crops did you plant annually? …………………………..

3.1. During which months do you normally plant potatoes?

First crop ……………………
Second crop …………………
Third crop ……………………

3.2. For which purpose did you plant potato? (Circle the applicable answer)

1. for ware
2. for seed
3. for both ware and seed

Section B: Seed origin (seed history)

Q4. For how many years have you been growing potatoes from WA seed?.................

Q5. For your last potato crop, what proportion of the WA seed used did you purchase?...

What proportion of the seed used was your own seed? Your answer should equal 100%

Own seed………………	…………………………..
Purchased seed…………	………………….………
Total	100%

Q6. For how many crops have you retained this seed?(Circle the applicable answer)

1. Only one
2. Two crops
3. Three crops
4. More than 3

6.1 How often do you seek to renew or to replace the seed that you use? (Circle the applicable answer)

1. After one crop
2. After 2 crops
3. After 3 crops
4. After more than 4 crops

6.2 What stops or prevents you from replacing the seed after every crop?

…………………………………………………………………………………

6.3 Why do you want to renew the seed?

…………………………………………………………………………………………

Q7. Where did you store the seed that you retained? (Circle the applicable answer)

1. Cool store
2. Diffuse light store
3. other

7.1 What proportion of the seed was lost during storage for each generation

(% of the seed losses or kg/ bag)

Cool store

Seed source	Seed losses (%)	Seed losses (kg/bag)
VN0 seed		
VN1		
VN2		

Diffuse light store

Seed source	Seed losses (%)	Seed losses (kg/bag)
VN0 seed		
VN1		
VN2		

7.2 What were the main reasons for the losses of seed during storage?

……………………..………………………………………………………..

7.3 How much did you pay for seed storage (for 1 kg or 1 bag) VND /kg or per seed load?

1. By cool store……………………….…..
2. By diffuse light store………………..
3. other…………………………………

Q8. From where did you purchase the WA seed that you planted? (Circle the applicable answer)

1. Research Institute
2. Trader
3. Open market
4. Seed company
5. Cooperative
6. Agricultural Extension
7. Neighbour
8. Other

Q9. For how many times (generations) had this seed been multiplied in Vietnam? (Circle the applicable answer)

1. None. Newly imported	4. three generations
2. one generation	5. 4 + generations
3. two generations	6. Unknown

Section C: Seed selection and preparation for the crop (before planting)

Q10. What quantity of seed did you use to plant your last potato crop? (Circle the applicable answer)

1. <20 kg/ sao	6. 41-45 kg/sao
2. 21 -25 kg/sao	7. 46-50 kg/sao
3. 26-30 kg /sao	8. 51-55 kg/sao
4. 31-35 kg/sao	9. 56-60kg/sao
5. 36-40 kg/sao	10. 61+ kg/sao

Q11. What type of seed did you use? (Circle the applicable answer)

1. Cut seed [ ]
2. Round seed [ ] (Go to question 14)
3. Both cut and round seed [ ]

11.1 If you used cut seed, did you treat it before planting? (Circle the applicable answer)

1. Yes [ ]
2. No [ ]

11.2 If yes, which treatment did you use prior to planting?

1. Cement [ ]
2. Mancozeb [ ]
3. Other (please indicate) ……………………………………..

11.3 How many man-days did you spend to cut and treat the seed?………….

11.4 How much did it cost to cut and treat the seed per kg? …………VND/kg of seed

Q12. Which seed size do you prefer to plant? (Circle the applicable answer)

1. 10 – 20 tubers/ kg
2. 21 – 30 tubers/kg
3. 31 – 40 tubers/kg
4. 41- 50 tubers/kg
5. 51- 60 tubers/kg
6. 61 - 70 tubers/kg
7. 71-80 tubers/kg
8. 81- 90 tubers/kg
9. 91 - 100 tubers/kg
10. more than 100 tubers/kg

Why do you prefer do you seed of this size?

………………………………………………………………………………………

Q13. What seed size did you actually plant? (Circle the applicable answer)

1. 10 – 20 tubers/ kg
2. 21 – 30 tubers/kg
3. 31 – 40 tubers/kg
4. 41- 50 tubers/kg
5. 51- 60 tubers/kg
6. 61 - 70 tubers/kg
7. 71-80 tubers/kg
8. 81- 90 tubers/kg
9. 91 - 100 tubers/kg
10. more than 100 tubers/kg

Why do you plant seed of this size?

………………………………………………………………………………………

Section D: On farm practice (soil preparation, manure and fertilizer application and crop protection) – During the crop

Q14. How did you prepare the soil prior to planting? (Circle the applicable answer)

1. Cattle [ ]
2. Machine [ ]
3. Hand hoe [ ]

How much did it cost to prepare the land? …………………VND/ sao

Q15. Do you apply any manure prior to planting? (Circle the applicable answer)

1. Yes [ ]
2. No [ ] (please go to question 18)

15.1 If yes, what kind of manure did you use?

1. Composted manure [ ]
2. Fresh manure [ ]

15.2 From where did you obtain this manure?

1. Own manure
2. Buy from neighbour
3. Buy from cooperative/ open market
4. Other ………………..

15.3 How much manure did you apply per sao? ………………..Kg/sao

15.4 If purchased, how much did it cost? ……………………VND/sao

Q16. Which pests and diseases did you seek to control in your potato crop?

(Circle the applicable answer)

1. Bacterial wilt
2. Late blight
3. Early blight
4. Fusarium
5. Caterpillar
6. Aphid/ thrips
7. Rhizoctonia
8. Leaf miner
9. Other?

How did you identify these pests and diseases?

1. Own experience
2. Plant protection workers
3. Extension workers
4. Chemical seller
5. Neighbour
6. Others :………………….

Q17. What chemicals did you use to control these diseases for each seed source?

Do you remember the name of the chemicals that you used?

1. Yes
2. No (go to question 21)

If yes, please complete the table below:

17.1 VN0 seed

Name of the chemicals	Pests/ disease to be controlled?	How many times was the chemical applied?	Was the pest/disease controlled?	How much does it cost? VND

17.2 VN1 seed

Name of the chemicals	Pests/ disease to be controlled?	How many times was the chemical applied?	Was the pest/disease controlled?	How much does it cost? VND

17.3 VN2 seed

Name of the chemicals	Pests/ disease to be controlled?	How many times was the chemical applied?	Was the pest/disease controlled?	How much does it cost? VND

Q18. How would you describe the pest and disease status of the potato crop you cultivated? (Circle the applicable answer)

18.1 VN0 (WA newly imported seed)

18.1.1 Late blight

6. Not found
7. Very low rate (1-5% infected plant)
8. Low rate (6-10% infected plant)
9. High rate (11-20% infected plant)
10. Serious (21%+ infected plant)

18.1.2 Bacterial wilt

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.1.3 Virus

1. Not found
2. Very low rate (1-10% infected plant)
3. Low rate (11-20% infected plant)
4. High rate (21-30% infected plant)
5. Serious (31%+ infected plant)

18.1.4 Leaf miner

1. Not found
2. Very low rate (1-10% infected plant)
3. Low rate (11-20% infected plant)
4. High rate (21-30% infected plant)
5. Serious (31%+ infected)

18.1.5 Scab

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.1.6 Other pests and diseases

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2 VN1 (WA seed after one year bulked up in VN)

18.2.1Late blight

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.2 Bacterial wilt

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.3 Virus

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.4 Leaf miner

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.5 Scab

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.6 Other pests and diseases

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3 VN2 (WA seed after two year bulked up in VN)

18.3.1Late blight

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.2 Bacterial wilt

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.3Virus

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.4 Leaf miner

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.5 Scab

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.6 Other pests and diseases

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

Q19. Did you rogue or remove plants from the field that were wilted or dying?

(Circle the applicable answer)

1. Yes [ ]
2. No [ ]

19.1 Why did you remove diseased or dying plants?

…………………………………..………………………………………………….

19.2 How many times was the crop rogue?

……………………………………………………………………..…………………..

19.3 How did you dispose of the plants you removed?

1. Bury/ burn
2. Bring home and feed the pig/animal
3. Leave in the field
4. Throw into the water source

19.4 What proportion of the plants did you remove?

19.4.1 VN0 seed:

1. None
2. 1-5 %
3. 6-10%
4. 11-15 %
5. > 16%

19.4.2 VN1 seed:

1. None
2. 1-5 %
3. 6-10%
4. 11-15 %
5. 16%

19.4.3 VN2 seed:

1. None
2. 1-5 %
3. 6-10%
4. 11-15 %
5. > 16%

19.5 How much did it cost for roguing? ………………………………… VND/ sao

Section E: Seed supply

Q20. From where do you most prefer to buy seed? (Circle the applicable answer)

1. Research Institute
2. Trader
3. Retail market
4. Seed company
5. Cooperative
6. Agricultural Extension
7. Neighbour

Why do you prefer to buy seed from this source?

………………………………………………………………………..……………….

Q.21 From which country do you most prefer to buy seed? (Circle the applicable answer)

1. Holland
2. Germany
3. Australia
4. China
5. Vietnam
6. other

Why do you prefer to buy seed from this country?

1. good quality/proper physiological age
2. cheap price/reasonable price
3. high yield
4. all of them

Q22. What things do you most like about sourcing seed from WA?

………………………………………………………………………………………

Q23. What things do you most dislike about sourcing seed from WA?

……………………………………………………………………………………

Q24. Which varieties did you plant?

1. Diamant
2. KT3
3. P3
4. Marriella
5. Solara
6. Eben
7. TPS
8. Atlantic
9. Others: ……………………………

Q25. Which varieties do you most prefer?

1. Diamant
2. KT3
3. P3
4. Marriella
5. Solara
6. Eben
7. TPS
8. Atlantic
9. Others: ……………………………

Why do you prefer these varieties?

……………………………………….……………………………………………

Section F: Harvest and post harvest practice

Q26. In which month was your potato crop harvested? (Circle the applicable answer)

1. January
2. February
3. March
4. April
5. other

Why did you harvest at this time?

……………………………………………………………………………………

Q27. What was the average yield from each seed source?

VN0 ……..………… kg per sao
VN1…………………kg per sao
VN2…………………kg per sao

Q28. What quantity (kg) and proportion (%) of the harvest was in different size grades from each seed source?

28.1 From VN0 seed?

	Kg	%
Large tuber (>50g)		
Medium tubers (30-50g)		
Small and rejected tubers (< 30 g and wastage)		
Total		

28.2 From VN1 seed?

	Kg	%
Large tuber (>50g)		
Medium tubers (30-50g)		
Small and rejected tubers (< 30 g and wastage)		
Total		

28.3 From VN2 seed?

	Kg	%
Large tuber (>50g)		
Medium tubers (30-50g)		
Small and rejected tubers (< 30 g and wastage)		
Total		

Q29. What proportion (%) of the harvest was sent to different markets from each seed source?

29.1 From VN0 seed?

	Large	Medium	Small	Reject
Sold				
retained for your own consumption				
retained for stock food				
retained for seed				
given away to other farmers/family				
Total:	100%	100%	100%	100%

29.2 From VN1 seed?

	Large	Medium	Small	Reject
Sold				
retained for your own consumption				
retained for stock food				
retained for seed				
given away to other farmers/family				
Total:	100%	100%	100%	100%

29.3 From VN2 seed?

	Large	Medium	Small	Reject
Sold				
retained for your own consumption				
retained for stock food				
retained for seed				
given away to other farmers/family				
Total:	100%	100%	100%	100%

Section G. Marketing

Q30. What were the average prices per kg received for potatoes sold to the market from each seed source?

Tuber sizes	VN0 seed	VN1	VN2	Other
XLarge (> 150 g)				
Large (50 – 150 g)				
Medium (30 -50 g)				
Small (<30 g)				
Reject				

Q31. When were the potatoes sold?

1. Immediately after harvest
2. 1 – 2 week after harvest
3. 3- 4 weeks after harvest
4. more than 4 weeks after harvest

Why were the potatoes sold then? ………………………………………………

Q.32 where did you sell your potatoes?

………………………………………………………………………………………

………………………………………………………………………………………

Q33. The following question is about the cost and return per sao for potatoes harvested in early 2007. The question will be used for each seed source in order to find out the net income.

33.1 VN0 seed (Newly imported seed)

	Unit	Quantity	Price (VND)	Total value (VND)
Inputs				
Seed	kg			
Manure	kg			
Urea	kg			
Potassium	kg			
Phosphorus	kg			
Other chemical fertilizer	kg			
Pesticides and fungicides	VND			
Labour (total)	VND			
Harvesting	VND			
Grading	VND			

33.2 VN1 (WA seed after one generation in Vietnam)

	Unit	Quantity	Price (VND)	Total value (VND)
Inputs				
Seed	kg			
Manure	kg			
Urea	kg			
Potassium	kg			
Phosphorus	kg			
Other chemical fertilizer	kg			
Pesticides and fungicides	VND			
Labour (total)	VND			
Harvesting	VND			
Grading	VND			

33.3 VN2 (WA seed after two generations in Vietnam)

	Unit	Quantity	Price (VND)	Total value (VND)
Inputs				
Seed	kg			
Manure	kg			
Urea	kg			
Potassium	kg			
Phosphorus	kg			
Other chemical fertilizer	kg			
Pesticides and fungicides	VND			
Labour (total)	VND			
Harvesting	VND			
Grading	VND			

Section H: farmer's information

Q34. Gender

1. Male
2. female

Q35. Can you please indicate your age category?

1. 18-25
2. 26-35
3. 36-45
4. 46-55
5. over 56

Q36 How many people live in your household?...

Appendix 14: Questionnaires for WA potato grower survey in 2007/08.

Date: ……………………Location: ……………………….. ID:…………………..
Interviewer: ………………………………………………………………………

Hello, my name is ………………I am conducting a survey on the performance and economic impacts of WA grown potato seed in the RRD. Your answers will be confidential and only used for research purposes. Would you like to spend one hour of your time to assist me with this survey?

Q1. Have you ever used WA potato seed?

Yes No

If the farmer says "no" discontinue the survey and thank farmer for his/her time then move to other farmers.

Section A: General information

Q1. How big is your farm? ……………sao/ ……….m^2

Q2. What area of your farm is planted in potatoes? ……………sao/ ……….m^2

Q3. How many potato crops did you plant annually? …………………………..

3.1. During which months do you normally plant potatoes?

First crop ……………………
Second crop …………………
Third crop ……………………

3.2. For which purpose did you plant potato? (Circle the applicable answer)

1. for ware
2. for seed
3. for both ware and seed

Section B: Seed origin (seed history)

Q4. For how many years have you been growing potatoes from WA seed?.................

Q5. For your last potato crop, what proportion of the WA seed used did you purchase?...

What proportion of the seed used was your own seed? Your answer should equal 100%

Own seed………………	…………………………..
Purchased seed…………	………………….………
Total	100%

Q6. For how many crops have you retained this seed?(Circle the applicable answer)

1. Only one
2. Two crops
3. Three crops
4. More than 3

6.1 How often do you seek to renew or to replace the seed that you use? (Circle the applicable answer)

1. After one crop
2. After 2 crops
3. After 3 crops
4. After more than 4 crops

6.2 What stops or prevents you from replacing the seed after every crop?

………………………………………………………………………………………

6.3 Why do you want to renew the seed?

…………………………………………………………………………………………

Q7. Where did you store the seed that you retained? (Circle the applicable answer)

1. Cool store
2. Diffuse light store
3. other

7.2 What proportion of the seed was lost during storage for each generation

(% of the seed losses or kg/ bag)

Cool store

Seed source	Seed losses (%)	Seed losses (kg/bag)
VN0 seed		
VN1		
VN2		

Diffuse light store

Seed source	Seed losses (%)	Seed losses (kg/bag)
WA seed		
VN1		
VN2		

7.2 What were the main reasons for the losses of seed during storage?

……………………..………………………………………………………..

7.3 How much did you pay for seed storage (for 1 kg or 1 bag) VND /kg or per seed load?

1. By cool store……………………..…..
2. By diffuse light store………………..
3. other…………………………………

Q8. From where did you purchase the WA seed that you planted? (Circle the applicable answer)

1. Research Institute
2. Trader
3. Open market
4. Seed company
5. Cooperative
6. Agricultural Extension
7. Neighbour
8. Other

Q9. For how many times (generations) had this seed been multiplied in Vietnam? (Circle the applicable answer)

1. None. Newly imported	4. three generations
2. one generation	5. 4 + generations
3. two generations	6. Unknown

Section C: Seed selection and preparation for the crop (before planting)

Q10. What quantity of seed did you use to plant your last potato crop? (Circle the applicable answer)

1. <20 kg/ sao	6. 41-45 kg/sao
2. 21 -25 kg/sao	7. 46-50 kg/sao
3. 26-30 kg /sao	8. 51-55 kg/sao
4. 31-35 kg/sao	9. 56-60kg/sao
5. 36-40 kg/sao	10. 61+ kg/sao

Q11. What type of seed did you use? (Circle the applicable answer)

1. Cut seed [ ]
2. Round seed [ ] (Go to question 14)
3. Both cut and round seed [ ]

11.1 If you used cut seed, did you treat it before planting? (Circle the applicable answer)

1. Yes [ ]
2. No [ ]

11.2 If yes, which treatment did you use prior to planting?

1. Cement [ ]
2. Mancozeb [ ]
3. Other (please indicate) ……………………………………..

11.3 How many man-days did you spend to cut and treat the seed?………….

11.4 How much did it cost to cut and treat the seed per kg? …………VND/kg of seed

Q12. Which seed size do you prefer to plant? (Circle the applicable answer)

1. 10 – 20 tubers/ kg
2. 21 – 30 tubers/kg
3. 31 – 40 tubers/kg
4. 41- 50 tubers/kg
5. 51- 60 tubers/kg
6. 61 - 70 tubers/kg
7. 71-80 tubers/kg
8. 81- 90 tubers/kg
9. 91 - 100 tubers/kg
10. more than 100 tubers/kg

Why do you prefer do you seed of this size?

…………………………………………………………………………………

Q13. What seed size did you actually plant? (Circle the applicable answer)

1. 10 – 20 tubers/ kg
2. 21 – 30 tubers/kg
3. 31 – 40 tubers/kg
4. 41- 50 tubers/kg
5. 51- 60 tubers/kg
6. 61 - 70 tubers/kg
7. 71-80 tubers/kg
8. 81- 90 tubers/kg
9. 91 - 100 tubers/kg
10. more than 100 tubers/kg

Why do you plant seed of this size?

…………………………………………………………………………………

Section D: On farm practice (soil preparation, manure and fertilizer application and crop protection) – During the crop

Q14. How did you prepare the soil prior to planting? (Circle the applicable answer)

1. Cattle [ ]
2. Machine [ ]
3. Hand hoe [ ]

How much did it cost to prepare the land? …………………VND/ sao

Q15. Do you apply any manure prior to planting? (Circle the applicable answer)

1. Yes [ ]
2. No [ ] (please go to question 18)

15.1 If yes, what kind of manure did you use?

1. Composted manure [ ]
2. Fresh manure [ ]

15.2 From where did you obtain this manure?

1. Own manure
2. Buy from neighbour
3. Buy from cooperative/ open market
4. Other ………………..

15.3 How much manure did you apply per sao? ………………..Kg/sao

15.4 If purchased, how much did it cost? …………………….VND/sao

Q16. Which pests and diseases did you seek to control in your potato crop?

(Circle the applicable answer)

1. Bacterial Wilt
2. Late blight
3. Early blight
4. Fusarium
5. Caterpillar
6. Aphid/ thrips
7. Rhizoctonia
8. Leaf miner
9. Other?

How did you identify these pests and diseases?

1. Own experience
2. Plant protection workers
3. Extension workers
4. Chemical seller
5. Neighbour
6. Others :………………….

Q17. What chemicals did you use to control these diseases for each seed source?

Do you remember the name of the chemicals that you used?

1. Yes
2. No (go to question 21)

If yes, please complete the table below:

17.1 VN0 (WA newly imported seed)

Name of the chemicals	Pests/ disease to be controlled?	How many times was the chemical applied?	Was the pest/disease controlled?	How much does it cost? VND

17.2 VN1 seed (WA seed after one generation in Vietnam)

Name of the chemicals	Pests/ disease to be controlled?	How many times was the chemical applied?	Was the pest/disease controlled?	How much does it cost? VND

17.3 VN2 (WA seed after two generations in Vietnam)

Name of the chemicals	Pests/ disease to be controlled?	How many times was the chemical applied?	Was the pest/disease controlled?	How much does it cost? VND

Q18. How would you describe the pest and disease status of the potato crop you cultivated? (Circle the applicable answer)

18.1 VN0 (WA newly imported seed)

18.1.1 Late blight

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.1.2 Bacterial wilt

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.1.3 Virus

1. Not found
2. Very low rate (1-10% infected plant)
3. Low rate (11-20% infected plant)
4. High rate (21-30% infected plant)
5. Serious (31%+ infected plant)

18.1.4 Leaf miner

1. Not found
2. Very low rate (1-10% infected plant)
3. Low rate (11-20% infected plant)
4. High rate (21-30% infected plant)
5. Serious (31%+ infected)

18.1.5 Scab

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.1.6 Other pests and diseases

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2 VN1 (WA seed after one generation in Vietnam)

18.2.1Late blight

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.2 Bacterial wilt

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.3 Virus

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.4 Leaf miner

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.5 Scab

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.2.6 Other pests and diseases

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3 VN2 (WA seed after two generations in Vietnam)

18.3.1Late blight

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.2 Bacterial wilt

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.3Virus

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.4 Leaf miner

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.5 Scab

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

18.3.6 Other pests and diseases

1. Not found
2. Very low rate (1-5% infected plant)
3. Low rate (6-10% infected plant)
4. High rate (11-20% infected plant)
5. Serious (21%+ infected plant)

Q19. Did you rogue or remove plants from the field that were wilted or dying?

(Circle the applicable answer)

1. Yes [ ]
2. No [ ]

19.1 Why did you remove diseased or dying plants?

…………………………………..…………………………………………………

19.2 How many times was the crop rogue?

…………………………………………………………………..…………………..

19.3 How did you dispose of the plants you removed?

1. Bury/ burn
2. Bring home and feed the pig/animal
3. Leave in the field
4. Throw into the water source

19.4 What proportion of the plants did you remove?

19.4.1 VN0 seed:

1. None
2. 1-5 %
3. 6-10%
4. 11-15 %
5. > 16%

19.4.2 VN1 seed:

1. None
2. 1-5 %
3. 6-10%
4. 11-15 %
5. 16%

19.4.3 VN2 seed:

1. None
2. 1-5 %
3. 6-10%
4. 11-15 %
5. > 16%

19.5 How much did it cost for roguing? ………………………………… VND/ sao

Section E: Seed supply

Q20. From where do you most prefer to buy seed? (Circle the applicable answer)

1. Research Institute
2. Trader
3. Retail market
4. Seed company
5. Cooperative
6. Agricultural Extension
7. Neighbour

Why do you prefer to buy seed from this source?

……………………………………………………………………..………………

Q.21 From which country do you most prefer to buy seed? (Circle the applicable answer)

1. Holland
2. Germany
3. Australia
4. China
5. Vietnam
6. other

Why do you prefer to buy seed from this country?

1. good quality/proper physiological age
2. cheap price/reasonable price
3. high yield
4. all of them

Q22. Thinking about your most preferred seed supplier, on a scale of 1 to 4 where 1 is "not at all well" and 4 is "very well", how well did your most preferred source of seed meet EACH of the following criteria. (Circle the applicable answer)

Not at all very well

Seed was available from my preferred seed supplier at the time of planting	1	2	3	4
There is a substantial difference in the productivity of the seed that I purchase from my preferred seed supplier and that seed which I retain of my own	1	2	3	4
Seed from my preferred seed supplier is pathogen tested	1	2	3	4
Seed from my preferred seed supplier is expensive relative to the alternatives	1	2	3	4
Seed from my preferred seed supplier is of the desired physiological age	1	2	3	4
Seed from my preferred seed supplier degenerates at a slower rate than seed sourced from alternative suppliers	1	2	3	4
I obtain a high market price for the potatoes grown from seed I have obtained from my preferred seed supplier	1	2	3	4
There is less variability in production from year to year using seed from my preferred seed supplier	1	2	3	4
Seed from my most preferred seed supplier has a good reputation among the other potato farmers	1	2	3	4
I have had many favourable prior experiences using seed obtained from my preferred seed supplier	1	2	3	4
Seed is available from my preferred seed supplier in the sizes I require for planting	1	2	3	4
Seed of the variety I require for planting is available from my preferred seed supplier	1	2	3	4
Seed from my preferred seed supplier does not contain a mix of varieties	1	2	3	4
Seed from my preferred seed supplier is free from the major pests and diseases	1	2	3	4

Q23. What things do you most like about sourcing seed from WA?

………………………………………………………………………………

Q24. What things do you most dislike about sourcing seed from WA?

………………………………………………………………………………

Q25. Which varieties did you plant?

1. Diamant
2. KT3
3. P3
4. Marriella
5. Solara
6. Eben
7. TPS
8. Atlantic
9. Others: ……………………………

Q26. Which varieties do you most prefer?

1. Diamant
2. KT3
3. P3
4. Marriella
5. Solara
6. Eben
7. TPS
8. Atlantic
9. Others: ………………………

Why do you prefer these varieties?

…………………………………………………………………………………………

Q27. In selecting a variety to grow, how important were each of the following variables. Please circle the appropriate response where 1 is "not important" and 4 is "very important"

	Not important			very important
availability of seed at planting time	1	2	3	4
price of potatoes in the ware market	1	2	3	4
productivity per hectare	1	2	3	4
variety traditionally grown	1	2	3	4
tuber shape	1	2	3	4
tuber size	1	2	3	4
flesh colour	1	2	3	4
skin colour	1	2	3	4
storage characteristics	1	2	3	4
fast maturing	1	2	3	4
resistance to disease	1	2	3	4
eating characteristics	1	2	3	4
processing qualities	1	2	3	4
suitability to growing environment	1	2	3	4
vigorous growth	1	2	3	4
drought tolerance	1	2	3	4
heat tolerance	1	2	3	4
new variety	1	2	3	4

Section F: Harvest and post harvest practice

Q28. In which month was your potato crop harvested? (Circle the applicable answer)

1. January
2. February
3. March
4. April
5. other

Why did you harvest at this time?

…………………………………………………………………………………………

Q29. What was the average yield from each seed source?

VN0 ……..………… kg per sao
VN1…………………kg per sao
VN2…………………kg per sao

Q30. What quantity (kg) and proportion (%) of the harvest was in different size grades from each seed source?

30.1 From VN0 seed?

	Kg	%
Large tuber (>50g)		
Medium tubers (30-50g)		
Small and rejected tubers (< 30 g and wastage)		
Total		

30.2 From VN1 seed?

	Kg	%
Large tuber (>50g)		
Medium tubers (30-50g)		
Small and rejected tubers (< 30 g and wastage)		
Total		

30.3 From VN2 seed?

	Kg	%
Large tuber (>50g)		
Medium tubers (30-50g)		
Small and rejected tubers (< 30 g and wastage)		
Total		

Q31. What proportion (%) of the harvest was sent to different markets from each seed source?

31.1 From VN0 seed?

	Large	Medium	Small	Reject
Sold				
retained for your own consumption				
retained for stock food				
retained for seed				
given away to other farmers/family				
Total:	100%	100%	100%	100%

31.2 From VN1 seed?

	Large	Medium	Small	Reject
Sold				
retained for your own consumption				
retained for stock food				
retained for seed				
given away to other farmers/family				
Total:	100%	100%	100%	100%

31.3 From VN2 seed?

	Large	Medium	Small	Reject
Sold				
retained for your own consumption				
retained for stock food				
retained for seed				
given away to other farmers/family				
Total:	100%	100%	100%	100%

Section G. Marketing

Q32. What were the average prices per kg received for potatoes sold to the market from each seed source?

Tuber sizes	VN0 seed	VN1	VN2	Other
XLarge (> 150 g)				
Large (50 – 150 g)				
Medium (30 -50 g)				
Small (<30 g)				
Reject				

Q33. When were the potatoes sold?

1. Immediately after harvest
2. 1 – 2 week after harvest
3. 3- 4 weeks after harvest
4. more than 4 weeks after harvest

Why were the potatoes sold then? ………………………………………………

Q.34 where did you sell your potatoes?

……………………………………………………………………………………………

Q35. The following question is about the cost and return per sao for potatoes harvested in early 2007. The question will be used for each seed source in order to find out the net income.

35.1 Newly imported seed from WA (VN0)

	Unit	Quantity	Price (VND)	Total value (VND)
Inputs				
Seed	kg			
Manure	kg			
Urea	kg			
Potassium	kg			
Phosphorus	kg			
Other chemical fertilizer	kg			
Pesticides and fungicides	VND			
Labour (total)	VND			
Harvesting	VND			
Grading	VND			

35.2 VN1 (WA seed after one yield bulked up in VN)

	Unit	Quantity	Price (VND)	Total value (VND)
Inputs				
Seed	kg			
Manure	kg			
Urea	kg			
Potassium	kg			
Phosphorus	kg			
Other chemical fertilizer	kg			
Pesticides and fungicides	VND			
Labour (total)	VND			
Harvesting	VND			
Grading	VND			

35.3 VN2 (WA seed after two yield bulked up in VN)

	Unit	Quantity	Price (VND)	Total value (VND)
Inputs				
Seed	kg			
Manure	kg			
Urea	kg			
Potassium	kg			
Phosphorus	kg			
Other chemical fertilizer	kg			
Pesticides and fungicides	VND			
Labour (total)	VND			
Harvesting	VND			
Grading	VND			

Section H: farmer's information

Q36. Gender

1. Male
2. female

Q37. Can you please indicate your age category?

1. 18 – 25
2. 26-35
3. 36-45
4. 46-55
5. over 56

Q38. How many people live in your household?..

Appendix 15: Total yields and tuber quality produced by three different WA seed generation during two years 2006/08 in the RRD. VN0, VN1 and VN2 refer to crops grown directly from imported WA seed or after one or two generations in Vietnam respectively.

Variables	VN0	VN1	VN2
Total tuber yield			
Yield (kg/sao)	853.4±23.0[a]	745.7±20.7[b]	627.4±17.4[c]
Yield (t/ha)	23.7±0.6[a]	20.7±0.3[b]	17.4±0.9[c]
Proportion of each tuber size per total yield (%)			
Large tubers (%)	70.4±1.0[a]	61.4±0.6[b]	51.0±0.5[c]
Medium tubers (%)	20.7±0.9[c]	26.2±0.5[b]	32.4±0.5[a]
Small and rejected tubers (%)	8.9±0.5[c]	12.4±0.3[b]	16.6±0.3[a]

Those items with the same superscript are not significantly different at p= 0.05

Appendix 16: Production costs and economic returns for different seed generations for Atlantic, Eben and KT3 in the RRD. VN0, VN1 and VN2 refer to crops grown directly from imported WA seed or after one or two generations in Vietnam respectively.

Variety	Generation	Total yield (kg/sao)	Gross income (VND.M/sao)	Total input (VND.M/sao)	Net income (VND.M/sao)
Atlantic	VN0	954.1	2.39	1.44	0.99
	VN1	751.5	2.01	1.08	0.94
	VN2	601.9	1.46	1.02	0.44
Eben	VN0	887.6	2.51	1.41	1.07
	VN1	775.1	1.87	1.07	0.80
	VN2	599.1	1.44	1.02	0.41
KT3	VN0	1,188.6	3.21	1.53	1.68
	VN1	956.1	2.45	1.16	1.29
	VN2	833.8	2.05	1.09	0.96
LSD		*29.1*	*0.082*	*0.024*	*0.079*

Appendix 17: Production costs and economic returns of different seed generations for Atlantic, Eben and KT3 with the inclusion of income earnt from seed sales in the RRD. VN0, VN1 and VN2 refer to crops grown directly from imported WA seed or after one or two generations in Vietnam respectively.

Variety	Generation	Total yield (kg/sao)	Gross income (VND.M/sao)	Total input (VND.M/sao)	Net income (VND.M/sao)
Atlantic	VN0	954.1	2.96	1.63	1.33
	VN1	751.5	2.42	1.10	1.33
	VN2	601.9	1.70	1.01	0.69
Eben	VN0	887.6	3.47	1.81	1.66
	VN1	775.1	2.47	1.17	1.30
	VN2	599.1	1.72	1.03	0.69
KT3	VN0	1,188.6	4.11	1.87	2.23
	VN1	956.1	3.09	1.25	1.83
	VN2	833.8	2.44	1.13	1.31
LSD		*29.10*	*0.10*	*0.03*	*0.09*