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SEED POTATO PRODUCTION AND CERTIFICATION GUIDELINES

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North Rift Potatoes: Trans Nzoia, 2012

Potato field, Timau, 2014

potatoes growing in Sogoo, Narok, 2014

Potato tubers harvested, Suera farm, Nyahururu, 2014

Potato tubers harvested, Suera farm, Nyahururu, 2014

Sprouted Seed potato, ADC Molo, 2012

Kingdom of the Netherlands

KENYA PLANT HEALTH INSPECTORATE SERVICE • KEPHIS •

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Disclaimer

Where specific commercial names are mentioned in the text, these are generally given as examples and should not be regarded as excluding others or giving preference of such names.

This **Seed Potato Production and Certification Guidelines** will enrich the already existing information on seed potato production but does not intend to replace any such document(s).

Cover pages
Front: Pictures depicting some stages of potato seed production and handling
Back: Picture of potato crop in net shade and in the open field

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Preface

Potato (*Solanum tuberosum* L) being the second most important staple food crop has emerged as one of the promising enterprises that is playing a great role towards realization of Kenya Vision 2030. Potato is currently grown on 161,000 hectares with a production of about 1.5 million tonnes worth about KShs. 40 to 50 billion annually; it directly and indirectly employs approximately 800,000 growers and about 2.5 million people as market agents, transporters, processors, vendors, retailers and exporters. In spite of the efforts by the farmers, researchers and other stakeholders in the sub-sector, the yields average about 10 tonnes against a potential average of 40 tonnes per hectare. This is due to limited use of high-quality seed, other inputs and poor agronomic practices. The current national certified seed potato production is about 2 % of the requirement; the rest comes from informal systems which are often of low quality.

In the last fifty years, only 15 varieties from KALRO have been in commercial production. However, collaboration between governments of Kenya and The Netherlands has resulted in 33 new Dutch varieties being released in the last four years. In addition, one Scottish and two varieties from KALRO have been released for commercial production within the same period. Importation of Dutch seed was necessary to boost seed volumes and availability of varieties for different purposes. The importation of Dutch seed together with the available 2% certified seed is a step in the right direction towards achieving the estimated demand of 70,000 metric tonnes annually of certified seed. Since 98 % of seed source is informal, there is need for concerted effort towards raising the level of knowledge on production and use of certified seed amongst Kenyan potato growers. This book is envisaged to empower the grower on better ways of improving seed productivity and use. In addition, students of agriculture, agricultural extension agents and other interested parties may also find it useful as a quick reference in their day to day work.

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Contributors

These Guidelines are compilation of inputs from specialists in various institutions working in the potato sub-sector in Kenya. The initial format and table of contents was developed by Dr. Simeon Komen (KEPHIS) and Dr. Siert Wiersema (Wageningen CDI) with input from Joseph Kigamwa, Simeon Kibet, Simon Maina and Pamela Kipyab (all from KEPHIS).

The selection of contributors reflects the seed potato value chain actors ranging from potato research and early seed generation (KALRO), public sector in seed potato multiplication (KALRO, ADC), private sector seed potato multiplication and distribution (Kisima Farm Ltd), seed regulation (KEPHIS), crop protection (Bayer E.A. Ltd) and the overarching role of policy formulation and facilitation ((MoALF).

Dr. Maina Machangi (MoALF) compiled chapter one on introduction and purpose of the guidelines. Chapter two on seed sources and seed quality was a joint contribution from Dr. Moses Nyongesa and Judith Oyoo (KALRO), Dr. Maina Machangi and Dr. Simeon Komen. Information on seed production and agronomic practices for chapter three was produced by Judith Oggema (ADC), Judith Oyoo and John Kibet (Kisima Farm Ltd). Chapter four on pests and diseases was a joint effort of Florence Munguti and George Ngundo (KEPHIS), Dr. Moses Nyongesa, and Diana Gitonga (Bayer E.A. Ltd), Judith Oyoo and Dr. Simeon Komen. Finally, chapter five on seed certification was a contribution of Dr. Simeon Komen and Caroline Mutete (KEPHIS). Editing and formatting was done by Dr. Moses Nyongesa and Joseph Kigamwa. All the contributors and others who supported this work are highly acknowledged. It is the hope of the contributors and editors of these Guidelines that it will be a helpful tool to the seed potato growers in Kenya.

Purpose and use of the Booklet

This booklet is a collection and synthesis of available information into an easy-to-read and apply document in seed potato production that can be used by anyone in the seed potato value chain; this includes students in Agriculture and related disciplines as well as the general public interested in seed potato production. This book is organized into chapters.

Chapter one introduces the potato and its significance to the Kenyan economy, the challenges faced and legal provisions supporting its growth, research, seed multiplication and marketing.

Chapters two and three considers different seed systems, sources of seed and seed degeneration. Currently about 2% of seed used is certified seed from the formal system while the rest is from the informal system. In the formal system, emphasis is given on how to produce quality seed.

Chapter four is on seed potato production while chapter five focuses on the description of diseases and pests, their causes and management options. The diseases are classified into fungal, bacterial and those caused by viruses. Major pests of potatoes are also discussed.

Chapter six is on seed certification, regulations, rules and procedures.

List of Acronyms and abbreviations

ADC	Agricultural Development Corporation
AFFA	Agriculture, Fisheries and Food Authority
ASDS	Agricultural Sector Development Strategy
ASL	Above Sea Level
CDI	Wageningen Centre for Development Innovation
CGIAR	Consultative Group on International Agricultural Research
CIP	International Potato Research Centre
DAP	Di Ammonium Phosphate
EA	East Africa
ELISA	Enzyme-Linked ImmunoSorbent Assay
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GTIL	Genetics Technologies International Limited
IF	Immuno-Fluorescence
KALRO	Kenya Agricultural & Livestock Research Organization
KEPHIS	Kenya Plant Health Inspectorate Service
KFA	Kenya Farmers Association
MoALF	Ministry of Agriculture, Livestock and Fisheries
NAK	Acronym for Dutch General Inspection Service for seed of agricultural crops
NPCK	National Potato Council of Kenya
NPTs	National Performance Trials
NSS	Negative Selected Seed
OECD	Organization of Economic Cooperation and Development
PBR	Plant Breeder's rights
PCN	Potato cyst nematode
PCR	Polymerase Chain Reaction
PhD	Doctor of Philosophy
PLRV	Potato leaf roll virus
PSS	Positive Selected Seed
PTM	Potato Tuber Moth
PVA	Potato virus A
PVS	Potato Virus S
PVX	Potato Virus X
PVY	Potato virus Y

1 INTRODUCTION

1.1 Overview of potato sector in Kenya

Agriculture directly contributes 25% to GDP and 65% of export earnings. Growth and development in the agricultural sector is crucial for Kenya's overall economic and social development. To highlight the importance of this sector to national economy, the government has outlined strategies for the sector and key roles in various policy documents including Kenya Vision 2030 and the Agricultural Sector Development Strategy (ASDS) 2009-2020. Both policies aim at improving the standard of living of Kenyans by substantially reducing the number of people affected by hunger, famine and starvation (Machangi et al. 2016).

In Kenya, root and tuber crops are important food crops that have gained increased importance in the recent past due to their role in food security, short maturity period that allows it to escape drought as well as their potential for commercial processing. Among the tuber crops, in deed, the potato is emerging as one of the promising enterprises that will play a great role towards realization of the objectives of Kenya Vision 2030 under the economic pillar because of its substantial contribution to food availability. Potato, therefore, requires attention both in terms of resources and long term planning as outlined in the draft National Root and Tuber crops Policy.
However, there are numerous challenges facing the potato sub-sector such as inadequate research and development, inadequate quality seed and planting materials, low productivity, weak research-extension-farmer linkages, low level of value addition and poor market infrastructure. Others

are inadequate financing and credit services and as well as poor enforcement of produce and product standards. These shortcomings have resulted in poor performance of the root and tuber crops industry (Ministry of Agriculture Livestock and Fisheries, 2015).

1.1.1 Potato Production in Kenya

In Kenya Irish potato has a high potential for addressing food insecurity, unemployment and low farm incomes due to its high productivity per unit area and its versatility in utilization. Potato is the second most important food crop in Kenya after maize. About 1.5 million tonnes of potatoes worth KShs. 40 to 50 billion is produced each year, generating source of livelihood for millions of Kenyans. This compares well with annual maize production of 40 million bags worth KShs. 120 billion.

Potato is cultivated mainly in the high altitude areas between 1,500 and 3,000 meters above sea level, found mostly in Central, Rift Valley, Western, Nyanza, Eastern and Coast Regions. Its importance is attributed to its high nutritive value, good productivity and good processing qualities for starch, flour, bread, soap, alcohol, weaning foods and animal feed. Potato production has been variable but with a general increase in area from 2,400 hectares producing 16,000 metric tonnes in 1939 to 108,000 hectares producing roughly 1 million tonnes in 2009.

In the year 2014, about 161,035 hectares of potato were grown and over 1.5 million metric tonnes produced; annual production of the crop is worth about KSh.50 billion at farm gate prices. The industry directly and indirectly employs about 3.3 million people as producers, market agents, transporters, processors, vendors, retailers and exporters. There were approximately 800,000 growers in the country by 2015. It is grown twice annually i.e. during the long and short rains. Potato yields are generally low with an average yield of approximately 10 tonnes per hectare due to limited use of high quality seed and other inputs. Other challenges include lack of proper on-farm storage facilities and at the marketing centres leading to huge losses during marketing; instability of supply and prices; lack of technical know-how by farmers to store potatoes; need for immediate cash could result in premature harvests; poor quality produce due to pests, diseases or mechanical damage.

1.1.2 Potato research

The National Potato Research Programme in Kenya is largely undertaken by the public sector at KALRO-Tigoni Research Centre in collaboration with the International Potato Research Centre (CIP) a CGIAR Centre and local universities. The KALRO Tigoni Centre carries out testing and evaluation of the breeding material, submits potential varieties to KEPHIS for evaluation and release. They also do cleaning and maintenance of varieties; avail breeders' seed potato to ADC and other private seed multipliers. To date KALRO-Tigoni research centre has released over 16 improved varieties with special attributes such as pest and disease tolerance and high yields. The breeding program in particular has been the most challenging to sustain due to difficulties of retaining qualified and experienced breeders at the facility. Variety development activities have typically been via selection of advanced breeding lines from the CIP. The recent financial support from the State Department of Agriculture, MoALF towards the Seed Potato Action Plan has contributed to the revival of breeding work at the centre, leading to five entries in the NPT during the 2016 long rains season.

As a result, other players have recently moved in to introduce new varieties in compliance with the mandatory National Performance Trials (NPTs) conducted by the Kenya Plant Health Inspectorate Service (KEPHIS). Introduction of Dutch potato varieties into Kenya followed a bilateral agreement that provided the guidelines to be followed in order to prevent possible introduction of quarantine pests and diseases. Through this arrangement, 33 new varieties have been released in Kenya in the last four years from the Netherlands. A Scottish variety has also been released in the same period. Seed companies from other countries have also expressed interest in local seed potato production. The urgent need for more processing varieties by the local potato processing sector seems to have been met by the recent introductions.

1.1.3 Seed multiplication and distribution

For a long time, the Agricultural Development Corporation (ADC) had the mandate for multiplication of breeder seed (or basic seed) obtained from KARI (now KALRO) and bulking certified seed potatoes for farmers. It achieved this role through use of its farms and also use of the out grower model to facilitate multiplication. However, due to financial constraints, ADC retained few out growers and their capacity to produce seed potato was hampered by lack of adequate land. Recently however, the government purchased more land (750 acres) for ADC to boost its capacity. Even with this increased capacity, production of seed potato does not meet the national demand. Perhaps the entry of private seed potato multipliers (such as Kisima Farm Ltd, Agrico East Africa, Syngenta East Africa and Suera Flowers) will continue to narrow the gap between seed demand and supply in Kenya in the near future. Other seed companies affiliated to Dutch companies apply the model of direct importation of seed potato for further multiplication locally and sale to ware growers. This model has the potential to rapidly increase supplies of certified seed in Kenya due to the wide availability of basic seed as starting material for production of certified seed.

Public sector seed cold storage stores exist in KALRO Tigoni with a capacity of 40 tons and at ADC Molo with a capacity of 2,000 tons. The government has rehabilitated the potato cold stores to enable ADC fulfil her seed potato mandate, and in addition strengthen its capacity to produce pre-basic seeds through establishment of a tissue culture laboratory and green houses for minituber production. In an effort to make certified seed from

ADC accessible to famers, the government has further funded ADC to start satellite centres in six major potato growing counties. Additional capacity for cold stores has been developed by the private sector such as Kisima Farm Ltd with 1,000 tons cold store and Suera Flowers with 200 tons); while firms such as Agrico E.A. are putting up a 2,000 tons cold store at Nakuru.

1.1.4 Grading and Packaging

Ware potato grading and packaging standards had been established specifying 110 kg bag as the standard in the Legal Notice No. 44 of May 2005. Enforcement however has been weak despite the provision of the legal notice No.113 of 2008 empowering Local governments to enforce Legal Notice No. 44 of 2005. With coming into effect of the Crops Act, 2013 and AFFA Act, 2013 in January 2014 and August 2014 respectively, the legal notices ceased since the Crop Production and Livestock Act (Cap. 321) where they were anchored was repealed by the Crops Act, 2013. The effective packaging weight is now 50 kg bag (AFFA ACT, 2013 PART VII, 42) for all scheduled crops which includes potato. However, implementation of this is facing challenges e.g. in most areas, ware potatoes are still packaged in extended bags weighing between 130-180 Kg containing ungraded poor quality produce. Seed potato is however sold in 50kg bags or less without any challenges.

1.1.5 Marketing and transportation

There is no organised Marketing of ware potatoes. Major handicaps include: lack of market infrastructure such as cold storage facilities and poor state of roads leading to high transportation costs; existence of exploitative middlemen leading to lower farm gate prices and absence of strong producer organizations. Transmission of Market information has however improved due to mobile phone services and radio broadcasts.

1.1.6 Consumption and Processing

Irish Potatoes are commonly consumed in the fresh forms but change of eating habits especially in the urban centres has led to increased consumption of processed products. It is estimated that there are over 40 local processors of crisps. Nairobi alone has over 800 restaurants selling chips. Varieties with high dry matter content are preferred for processing into chips and crisps. Industrial level processing of potatoes is mainly in the production of starch and snack foods such as crisps, chevda (a mixture of potato crisps, corn), frozen potato chips and dried potato cubes.

2 SEED SYSTEMS AND SOURCES

2.1 Introduction

There are two main seed production systems in Kenya:

(a) Formal or legally recognized – that undergoes seed certification by KEPHIS; it follows laid down legal procedures and involves public and private organizations such as KALRO, ADC, Kisima Farm, Agrico East Africa Ltd, other certified seed growers and KEPHIS.

(b) Informal or not legally recognized – Seed potato produced outside the formal seed certification system. This includes positive selected seed; farm saved seed and so called "clean seed". Clean seed usually starts with planting certified or basic seed potato; it produces seed whose quality is much better than farm saved seed from unknown sources but the quality is usually lower than that of certified seed produced in the formal system. Farm saved seed is produced by farmers with no input from other seed industry players. Farm saved seed is of poor or unknown quality; also some farmers purchase their seed from open air market/ road sides.

The two seed production systems (formal and informal) result in three different types of seed potatoes:

1) Certified seed – these are used by less than 2 % of potato farmers; the quality is assured according to the law (Cap 326) by an independent organization (KEPHIS).
2) So called "Clean seed" – used by about 4 % of potato farmers; it is produced using Good Agricultural Practices (GAPs) and quality is

assured by area extension officers (MoALF).

3) Farm saved seed – used by around 95% of potato farmers; it has no quality standards and is generally of poor quality; the seed is blamed for endemic spread of diseases especially late blight, bacterial wilt and viruses.

2.2 Informal Seed Potato Production

2.2.1 Definition of informal seed system

This includes all not legally recognized seed supply systems, including farm saved and exchange, open air market or road side purchases. The quality of such seed is not guaranteed and generally can be very poor. However, informal seed can be improved through use of clean seed and applying positive or negative selection practices.

2.2.2 Positive selected seed

Under Positive Selected Seed (PSS) farmers plant their potatoes and during active growth, they stick pegs next to healthy looking plants which will be harvested separately and retained for the next crop planting. This may reduce the disease load in the subsequent crop.

2.2.3 Negative selected seed

In Negative Selected Seed (NSS), the farmer establishes a crop from certified seed. As the crop is growing, the farmer goes through the field and removes any plant that does not look healthy, leaving only healthy plants which will be harvested and used as seed in the next cropping cycle.

2.3 Formal Seed System

2.3.1 Definition of a formal seed system

This includes all legally recognized seed supply systems carried out by public and private bodies. It includes research, breeding, seed certification, multiplication, distribution and marketing. The public bodies involved include KALRO, Universities, KEPHIS, Agricultural Development Corporation (ADC) and MoALF (O'Connor and Wamache, 2012); while private entities include Agrico East Africa Ltd, Kisima Farm Ltd, Syngenta East Africa Ltd and Suera Flowers Farm.

There are several types of formal seed systems which are:

(a) **Public formal seed system** – the public sector undertakes all activities involved in seed development to marketing. For example KALRO carries out breeding of new varieties and also the seed production, multiplication under the supervision of KEPHIS and distribution.

(b) **Public-private formal seed system** – participation of the public and private sector from variety development to marketing. In such a scenario KALRO does the research/breeding while private sector multiplies the seed under the supervision of KEPHIS and distributes the seed to farmers.

(c) **Closed value chains or fully private formal seed system**– Systems that are entirely controlled by the private sector from breeding and variety development to seed multiplication and distribution. There is minimal government involvement except in seed quality control and certification (KEPHIS). This system is applied by private companies including Agrico E.A. Ltd, Kisima Farm Ltd, Syngenta E.A. Ltd and Suera Flowers in close cooperation with their partners in the Netherlands.

Legal aspects of using formal seed system

The Seed industry is governed and regulated by the Seeds and Plant Varieties Act (Cap 326) of 2012 which recognizes breeders, pre-basic, basic and certified seed classes.

2.3.2 Plant breeder's rights and their implications

Definition

Plant Breeder's rights are propriety rights granted to a breeder who has successfully filed an application for protection of the variety the breeder has developed and officially released.

Implications of breeders' right

Breeder's rights commonly referred to as 'Plant Breeder's rights (PBR)' is an incentive to promote research, breeding and development of new varieties and also recover this investment. PBR only applies to formal seed systems. The breeder is anybody who has developed a registered variety and includes companies, organizations, farmers, university graduates or professors. Anyone who wants to use such a variety to grow for commercial purposes must seek consent from the breeder. The rights are granted for 20 years and once such period elapses, the variety becomes available for anyone to use without seeking prior consent from the breeder. The variety may also become free if the breeder fails to meet obligatory requirements or withdraws.

2.3.3 Formal Sources of seed Potato

The formal sources of seed are public institutions (KALRO and ADC) and private seed companies (Kisima Farm Ltd, Agrico E.A. Ltd, Syngenta E.A. Ltd and Suera Flowers) and registered individual seed growers. Such seed must have undergone certification by KEPHIS.

2.3.4 Sources of basic seed Potato

The official source of basic seed class for Kenyan varieties is KALRO Tigoni Centre and ADC. The official source of basic seed for other varieties is the owner of that variety; in all cases that is a private seed company. Before producing basic seed, the breeder materials are checked for all major diseases and pests. The basic seed production begins at tissue culture where meristem tissues are multiplied in controlled environment to produce *in vitro* plantlets. These plantlets are transferred to the glass house for hardening. Afterwards, they are then planted in pots, aeroponics or hydroponics to produce minitubers.

Picture 1. Depicting minituber production in aeroponics system (courtesy of KALRO Tigoni)

Picture 2. Depiciting minituber production in a hydroponics system (Courtesy of ADC Sirikwa farm)

Picture 3. Depicting minitubers of variety Asante in an aeroponics system (Courtesy of KALRO Tigoni)

The minitubers are planted and certified to produce pre- basic seed and multiplied to basic seed. The basic seed is sold to authorized seed multipliers for production of further classes of certified seed.

2.3.5 Sources of certified seed

Sources of certified seed are the authorized multipliers that plant the basic seed to produce certified first generation class. They obtain basic seed of the Kenyan varieties from KALRO Tigoni, ADC Molo and Kisima Farm Ltd. to produce certified seed. Provided the seed meets the quality standards the certified seed can be further multiplied maximum two times before being sold to ware growers. Other sources of certified seed are Agrico E.A. Ltd, Syngenta E.A. Ltd, and Suera Farm. They obtain their basic seed from international breeding companies for further multiplication in Kenya into certified seed. All seed potato multipliers must be registered by KEPHIS.

2.4 Seed classes of Formal Seed Potato

Once a variety has been officially released, the breeder is allowed to multiply the seed several cycles (usually 5) to reach substantial quantities a farmer can use to grow ware potato. The starting material for this multiplication is either minitubers or healthy mother plants. From this material pre-basic seed is produced followed by basic seed and certified seed in the subsequent multiplications. In the formal seed system these multiplications are classified as classes. Each seed class has specific quality standards and tolerances for diseases and pests (see chapter 6 Seed certification). Schematically the classification system in Kenya is shown in table 1.

Table 1. Classification system of seed potatoes produced in Kenya

Type of material	Seed class	Generation (maximum)
- Healthy mother plants (clonal selection) - in-vitro plants, minitubers	Breeders seed	G0
Tubers	Pre-basic	G1
Tubers	Basic	G2
Tubers	Certified 1	G3
Tubers	Certified 2	G4
Tubers	Certified 3	G5

Source *CAP 326 i.e. Seed and Plant Varieties Act of 2012*

Note:

- Pre-basic and basic seed is produced by KALRO, ADC Molo, Kisima Farm
- Certified seed is produced by seed multipliers
- Every season seed crops are automatically downgraded one class. Depending on inspection results further downgrading or rejection may occur, so the generations indicated in the table 1 apply to the maximum number of generations possible in each seed class.

2.4.1 Breeder Seed

From breeding work, the seed derived is called breeder seed. This seed is of the highest status but of very limited quantity. In order to multiply to large quantities, the breeder often hands over to institution or specialized farms.

2.4.2 Pre-basic and basic seed class

The breeder's seed is then passed on to specialized farmers or farms to grow and register for certification with KEPHIS. The first generation from the breeder's seed after fulfilling the certification standards is labeled as Pre-basic seed potato. Further multiplication is done following similar procedures to produce basic seed potato.

2.4.3 Certified seed class

Basic seed potato is further multiplied to produce certified first generation seed class (C1). This can be done two more times (C2 and C3) to raise sufficient quantities to be sold to ware growers. During all these stages the seed is checked against set standards and only those meeting the standards are advanced to the next multiplication cycle. It is important to note that the higher the classes of seed the higher are the standards. Those that fail to meet the standards of the specific class are downgraded to a lower class if it meets that class standard. Those which fail to meet any class standards are rejected and may be disposed of as ware potato. In case the rejection is on quarantine diseases, such seed should be safely disposed under supervision by KEPHIS.

2.5 Supply systems of Certified Seed

There are currently two supply systems of certified seed produced in the formal system in Kenya. These supply systems are:

1) Production of certified seed starting from minitubers or healthy mother plants produced in Kenya as outlined in table 1, and
2) Production of certified seed through multiplication of imported seed (e.g. from the Netherlands) as shown in table 2.

In the second system pre-basic and basic seed is produced in the Netherlands by specialized seed growers guided by strict national seed certification rules and regulations. Basic seed (usually class E or SE) is then exported to Kenya by private seed companies based on an import permit issued by KEPHIS. The basic seed is further multiplied in Kenya into certified seed classes following KEPHIS regulations and certification standards.

The two supply systems complement each other since the varieties available differ per system. Basic seed of a wide range of varieties is widely available in the Netherlands so the second system based on seed imports has the potential to rapidly boost volumes of certified seed in Kenya.

Table 2. Classification system of seed potatoes imported from the Netherlands and multiplied in Kenya

Type of material	Seed class	Generation (maximum)	Location of production
- Healthy mother plants (clonal selection) - in-vitro plants, mini tubers		G0	Netherlands
Tubers	Pre-basic 1	G1	Netherlands
Tubers	Pre-basic 2	G2	Netherlands
Tubers	Pre-basic 3	G3	Netherlands
Tubers	Pre-basic 4	G4	Netherlands
Tubers	S (basic 1)	G5	Netherlands
Tubers	SE (basic 2)	G6	Netherlands
Tubers	E (basic 3)	G7	Netherlands
Tubers	Certified 1	G8	Kenya
Tubers	Certified 2	G9	Kenya
Tubers	Certified 3	G10	Kenya

***Source**: NAK & KEPHIS, 2016**

***NAK and KEPHIS agreed on this table.** NAK is the Dutch General Inspection Service for seed of agricultural crops. The statutory duty is fulfilled under the authority and supervision of the Minister of Economic Affairs (EZ) of the Netherlands.

Note: Every season seed crops are automatically downgraded one class. Depending on inspection results further downgrading or rejection may occur, so the generations indicated in the table 2 apply to the maximum number of generations possible in each seed class.

3 SEED DEGENERATION

3.1 Definition of seed degeneration

The health of seed potatoes decreases after each multiplication, a process that is called degeneration. The definition of seed degeneration is the gradual loss in productivity of a potato crop during successive multiplication cycles as a result of buildup of seed borne diseases. Important seed borne diseases are virus diseases and bacterial diseases such as bacterial wilt. Seed degeneration is significant when seed potatoes are used for several subsequent seasons without special measures to control seed borne diseases (e.g. in ware potato production). To control seed degeneration ware potato growers need to replace their seed stocks with healthy seed regularly; only that way they can achieve high potato yields. In seed potato production seed degeneration is kept to a minimum due to strict control of seed borne diseases and selection of suitable areas for seed production (low aphid populations and absence of bacterial wilt).

3.1.1 Decrease in plant productivity during multiplication

In the following section the mechanism of seed degeneration is explained in more detail, as well as the consequences for ware and seed potato production. When a crop is established using virus infected seed, the yields will be reduced in terms of tuber yield and quality. The yield reduction will depend on the type of virus, incidence of virus infected plants, and prevailing environmental conditions. Crops affected by serious viruses like potato leaf roll virus (PLRV) or potato virus Y (PVY) show more yield reduction compared to those infected by potato virus A (PVA). Equally those diseased plants growing under stress conditions will produce lower tuber yields compared to similar ones grown in ideal conditions. In cases where no management measure is instituted, tubers from these plants when used as seed to grow the next crops will produce again lower yields. Thus, repeated use of seed from infected crops will result in a gradual decline in yields to the extent that potato growing becomes uneconomical. This is worse where farmers select small tubers as seed for the next crop since they are the ones with highest level of virus infection. The reason is that infected plants produce small tubers so selection for small (seed size) tubers means automatic selection for infected tubers. This observed decrease in crop yield produced by an increasing number of infected plants in successive multiplication cycles is referred to as degeneration.

The degeneration rate depends on a number of factors; i) susceptibility of the variety to seed borne diseases, ii) presence of aphid transmitting viruses and sources of infection, iii) presence of bacterial diseases in the soil, and iv) prevailing warmer conditions. Cooler environments do not favor rapid buildup of aphid populations and therefore such areas (high altitudes) are good for seed potato production.

Seed degeneration rate is an important factor which determines the areas suitable for seed potato production. In areas with high degeneration rates it is nearly impossible to produce certified seed that meets the quality standards of the official certification system (formal system).

3.2 Reducing/ameliorating degeneration rates

In order to slow the degeneration rate several measures can be taken. These measures are different for ware potato growers and seed growers.

Ware potato growers are advised to start with healthy planting materials and replace their seed stocks with certified seed regularly. They can also apply positive selection to reduce degeneration rate of farm saved seed (see section 2.2.2).

Seed potato growers need to apply strict crop management and post-harvest handling measures aimed at controlling seed borne diseases. They are advised to use seed from official sources (formally certified seed), register with KEPHIS to multiply seed, and respect all seed multiplication rules and regulations. They should select seed fields in cooler areas (above 2,100 meters ASL) with low aphid populations and soils free of bacterial wilt. Seed fields should have adequate isolation distance from ware potato crops (at least 50 m for production of certified seed classes) to reduce virus infection by aphids. Seed growers should also plant timely to escape increasing aphid populations and control diseases and pest during crop growth, with special attention to seed borne diseases. Regular rogueing is required to remove plants with visible virus symptoms, together with their newly developed tubers. Early haulm killing (dehaulming) is recommended to avoid late season virus infection. These measures should help to reduce degeneration rates of seed and produce high quality seed during several multiplication cycles.

4 SEED POTATO PRODUCTION

Seed production is more demanding than producing ware potatoes. Seed potato production is a highly professional job which requires adequate knowledge, skills and attention to details to achieve high yields of good quality. The cost involved to produce certified seed is significantly higher than that of producing ware potatoes. As a result prices of certified seed potatoes are higher than those of ware potatoes.

4.1 Factors affecting crop yield and quality

4.1.1 Prerequisites to achieving high yields

Factors to consider include:

Altitude

A seed grower has to bear in mind the most suitable altitude for seed growing. Potato grows well at altitudes between 1,500 to 3,000 meters ASL. Knowledge of altitude enables the grower to know which challenges exist in these regions. At altitudes lower than 2,000 meters ASL the grower will face the challenge of high disease pressure such as potato virus diseases due to high aphid populations and incidence of bacterial wilt. The recommended altitude range for seed potato production in Kenya is above 2,100 meters ASL.

Choice of variety

Careful selection of suitable variety for a particular area is important in obtaining high yields. A formal seed grower should aim to produce seed that will be marketable through understanding the customer preference. Varieties to be selected should be high yielding, disease resistant/tolerant, good keeping and processing qualities. An overview of current varieties available in Kenya and their characteristics is given in the NPCK potato variety catalogue (NPCK, 2015).

Correct physiological age of the seed

Physiological age of seed influences the subsequent performance of the crop and ultimately affects the yield. A grower should aim to use seed potato tubers that have broken dormancy with 4 to 6 sprouts per tuber which are healthy, strong, and of good colour development.

Early planting

For rain fed seed production, the grower should aim to prepare the field at least one to two months prior to the onset of rains to give the crop residue time to decompose. This will give the grower adequate time to plant just before the rains start for quick emergence, crop establishment and may allow the crop to escape major incidences of late or early blight. A crop that receives all the season's rainfall also has high growth vigour and is able to produce high yields.

Crop management

During crop growth, early and timely good agricultural practices enable the crop to grow faster:

- **Weed control** - After crop emergence, first weeding is important and should be done early because they compete with the crop for nutrients, water, light and they also harbor pests and diseases. They should be removed early enough to give the potato plant time to recover.
- **Soil moisture** - Essential during emergence, tuber initiation and tuber expansion stages. Usually potato crop relies on rainfall and where it is irregular it can be supplemented with irrigation. Irrigate

up to a stage where when the soil is squeezed and released it does not leave mud in the hand. Ensure the quality of irrigation water is tested for suitability.

- **Crop protection** - Timely spraying and correct choice of crop protection solutions saves costs and prevents disease spread giving the plant sufficient time to grow and give high yields. Regular scouting for pests and diseases to determine when to control is recommended.
- **Hilling** - Hilling or earthing up should be done twice, the first at 75 % emergence and the second 2-3 weeks later. Adequate ridge volume is essential to give ample room for tuber expansion, to prevent potato tuber moth from tunneling the tubers, and to prevent that tubers are exposed to light and turn green.
- **Rogueing** - A seed grower has to keep on removing (rogueing) off-types and diseased plants from the seed crop to ensure purity and health of the seed. Rogueing should start early (as soon as disease symptoms are visible) and done continuously till crop maturity.

4.1.2 Seed tuber Quality

Formal seed potato growers are advised to purchase basic or certified seed potato from KALRO (a research body in Kenya mandated to produce basic potato seed) or from another formal seed grower such as ADC, Agrico E.A. Ltd, Syngenta E.A. Ltd, Kisima Farm Ltd, or Suera Flowers. The bag containing the seed should be well sealed with a label from KEPHIS as a proof of certification.

Variety - The grower should ensure that the variety indicated on the label is the variety delivered. This can be done through confirming that the description given on the label matches the product in the bag.

Seed tuber health - Upon receiving the seed, the grower should randomly open the bag(s) and visually check that the seed does not have any diseases or rots.

Seed size - The correct seed size is usually indicated on the label and therefore the grower should confirm the size of the seed tuber with the size indicated. Recommended tuber size is from 28mm to 60mm.

Seed physical aspects - The tubers should have good skin, free of rots, bruises or cuts and should have broken dormancy. The 'eyes' should be 'open' showing signs of growth and the tubers should be free of any pest infestation or disease. The bag containing the seed should not be torn or open before reaching the end-user.

4.1.3 Physiological developments

Potato tubers undergo dormancy from tuber initiation to when new growth is observed. Dormancy is a period during the potato life cycle that growth will not occur even when conditions that favor growth (ambient temperatures of 15-20ºC and high humidity) are available. End of dormancy period is indicated when sprouts growing from the 'eyes' are 3mm long. The grower should check the status of the seed before planting. The number of sprouts should be 4 to 6 per tuber and about 15 mm long. Such seed tubers are at a good physiological age and suitable for planting.

4.2 Seed Preparation

The seed grower should take into consideration the following aspects:

4.2.1 Seed dormancy

Definition: Dormancy is a condition where seeds will not sprout even when the environmental conditions are favourable for sprouting. Usually there are two types of dormancies: innate and enforced. Innate, also called true or absolute dormancy is caused by factors genetically controlled while enforced dormancy is caused by external factors like temperature, light, humidity and age of the tuber.

Breaking dormancy

The potato tuber undergoes several physiological stages as soon as they are formed on the parent plant. Innate dormancy can be broken naturally by storing tubers in diffused light stores until sprouts are observed or by use of dormancy breaking products like phytochemicals.

Picture 4. Depicting diffused light store loaded with seed potatoes for sprouting before planting (courtesy of Molly Flowers)

Table 3. Showing dormancy periods of different varieties

Variety®	**Days to full maturity**	**Dormancy period (days)**
Asante	90-120	30
Tigoni	>120	30
Dutch Robjin	>120	90
Kenya Mpya	90-120	30
Kenya Mavuno	>120	90
KenyaBaraka	90-120	30
Kenya Karibu	>120	90
Purple Gold	90-120	90
Sherekea	>120	90
Shangi	90-120	20
Jelly	>120	90
Markies	90-120	90
Connect	90-120	30-60
Kerr's pink	90-120	90

***Source**: NPCK, 2015*

In case you need more information on potato varieties, you can refer to the Potato Variety Catalogue (NPCK, 2015).

Dormancy ends with visible new growth and when the sprouts have reached 3mm. Young tubers which have a single sprout, or maybe two, at the rose end of the tuber will exhibit apical dominance. If the tuber is planted, it will give rise to only one stem and low yields. This top sprout should be removed to encourage development of multiple sprouts (4 to 6 sprouts). Such tubers when planted in ideal soil conditions, will give rise to more stems and higher tuber yields per plant.

4.2.2 Pre-sprouting

Pre-sprouting refers to the condition where potato tubers with one or two sprouts are de-sprouted and placed in controlled environment (indirect light or shade and temperatures of 15-20ºC) to promote development of multiple sprouts. Multiple sprouts are important to increase the number of stems produced from each seed tuber. More stems increase the productivity and yield of the plant developing from each seed tuber. Another way of pre-sprouting is chitting where the tubers which have broken dormancy are exposed to controlled conditions such as higher temperatures and more light to produce strong, well attached sprouts. Chitting seed potatoes will hasten overall development of sprouts to achieve strong, hardy sprouts that will not break off easily, leading to rapid and uniform emergence.

Procedure for pre-sprouting

The tubers with 1 or 2 sprouts are de-sprouted and placed in indirect light (shade) at ambient temperature until multiple sprouts of at least 3 mm are observed. During pre-sprouting good ventilation and sufficient light is important to produce strong and hardy sprouts. Direct sun light on seed tubers should be avoided; instead indirect light or shade is applied for pre-sprouting. Also tubers in diffused light stores may need to be de-sprouted in case they exhibit only 1 or 2 sprouts per tuber. After de-sprouting the tubers are placed back in the diffused light store for multiple sprouting.

4.3 Requirements of seed production

4.3.1 Site selection

Select land that has not been planted with potatoes before or any plants from the *Solanaceae* family (potato) like tomato, brinjals, nightshades and tamarillo (tree tomato). Preferably the land should have good drainage, free of diseases such bacterial wilt, and free of pests like potato cyst nematode (PCN). During site selection, it is important to consider what neighbouring crops will be planted. Provide adequate isolation distance from other potato crops in order to reduce chances of spread of diseases to the seed crop. For production of certified seed classes an isolation distance of at least 50 m from ware potato crops is required.

Crop rotation

Potato should be rotated with non solanaceous crops like maize, wheat, or horticultural crops such as carrots, onions and legumes. At least three years (six seasons) rotation is recommended provided the previous potato crop was free from diseases like bacterial wilt. In case bacterial wilt infection is detected, a longer rotation cycle of up to 7 years is recommended with cereal crops and removal of any volunteer potato plants.


Picture 5. Depicting commercial maize crop (left) and wheat Seed crop (right) in a rotational program (Courtesy of ADC)

4.3.2 Soil characteristics

Seed potatoes require well-drained, light, deep, loose soils that are high in organic matter content. Potatoes are shallow rooted plants and therefore deep loose soils high in organic matter content would encourage good root formation and provide room for tuber expansion. However, potatoes have been grown on a range of soils varying from sandy to clay loam soils, all with different water holding capacities. An ideal soil type for potato should be well structured, with good drainage to allow proper aeration to promote root development and tuber growth with minimal disease infestation.

4.3.3 Soil temperature

Soil temperature is an important aspect in potato growth and tuber formation. The cooler the soil temperature, the more rapid the initiation of tubers and the greater the number of tubers formed. Optimum soil temperature for tuber formation is 15-20ºC. Higher temperatures reduce tuber formation. One way of avoiding high soil temperatures is timely ridging and adequate ridge volumes.

4.3.4 Soil pH

Seed potatoes require soils with a pH of 5.5 to 7.0. However, in practice potatoes are grown in soil pH ranging from 4.5 to 8.5 and this has a significant impact on the availability of certain nutrients. Extreme soil pH should be adjusted by liming or use of acidic fertilizer(s) based on the soil analysis recommendations. When liming is advised to increase the pH, it is advisable to apply lime in the previous crop before planting potato to reduce the risk of infection by common scab.

4.3.5 Agronomic practices

Land preparation is very important in seed potato production since it directly affects conditions for emergence and plant establishment, and therefore affects the quantity and quality of tubers. Land preparation begins with ploughing using tractor drawn disk or mould board plough. It should be carried out during the dry season, few months to planting. The type of land determines the number of ploughings to be done. Virgin land requires 2 ploughings while land already cultivated needs only 1 ploughing. After 2 to 4 weeks, harrowing is done to cut the plough share into loose soil. Usually the plough depth should be 20–30cm while harrowing depth is 20cm in order to incorporate the crop debris which breaks down into humus.

4.3.6 Seed bed preparation

Once land preparation is complete, the land is made into either beds or furrows. The furrows are generally spaced at 75cm apart and 25cm deep. Tuber to tuber spacing depends on the tuber size and variety. For example a seed tuber of size 28-45mm is spaced at 21-25 cm whereas that of 45-60 mm is spaced at 28-30cm.

Picture 6. Depicting manual planting of seed potato (Courtesy of ADC Londiani satellite centre)

4.3.7 Crop nutrition

Potato crop has high nutritional requirements. Soil sampling and analysis should be done in the field where seed potato will be grown. This will show the fertility status of the soil and form the basis for recommending the type and rate of fertilizer to apply. Nitrogen has a strong effect on foliage development and length of the growing period of the plant to maturity. Too much Nitrogen in a seed crop will result in abundant foliage growth and late maturing crops. This is not desirable since seed crops need to be dehaulmed and harvested early to reduce virus infection by aphids. In addition, skin setting of tubers before harvesting is more difficult in crops with too much Nitrogen. For these reasons Nitrogen rates in seed crops need to be moderate. Nitrogen rates in seed crops are significantly lower compared to that in ware potato crops which have a longer growing period.

The fertilizers currently used by growers in planting of potatoes are NPK and DAP. However, potato, being a crop that requires high nutrient levels demands key elements such as phosphorus, potassium, nitrogen, calcium, amongst others, depending on soil analysis. The fertilizer is applied by spreading along the furrows and incorporating into the soil before planting. In areas with organic manures, it is recommended to spread on the land after first ploughing and incorporated in the soil especially in sandy soils. This will improve soil moisture retention and slow release of plant nutrients enhancing crop growth. When manure is used, it is important to ensure that the manure is disease-free and well decomposed by taking it for laboratory analysis. An application rate of 10 tonnes per hectare is recommended. Top dressing fertilizers can be applied later during crop growth depending on the results of leaf analysis.

4.3.8 Plant population, spacing and seed rates for seed and ware potatoes

Plant population is expressed as number of plants per ha or number of stems per ha (see section 4.3.9). The optimum plant population depends on the purpose of the crop and the target market. This is because plant population has a strong effect on the size of tubers at harvest. Higher plant population results in more stems per unit area, higher tuber number per unit area and smaller average tuber size at harvest.

The plant population in seed production is higher compared to that in ware potato production. This is because in seed production small and medium size seed potatoes are required at harvest while the aim of ware potato production is to produce large tubers for the ware market. So with the same size of seed tubers planted, the plant to plant spacing within the row in seed production is closer compared to that in ware potato production. The inter row spacing (spacing between rows) is usually 75-90 cm in both seed production and ware potato production.

Plant to plant spacing also depends on the size of seed tubers planted. Larger tubers produce more sprouts per tubers and more stems will arise in the plant from a larger seed tuber. Therefore, larger seed tubers should be planted at wider spacing compared to smaller seed tubers.

Since in seed production higher plant populations are required, seed rates (tons of seed planted per ha) are higher compared to that in ware potato production. Seed growers plant up to 4 tons/ha while ware potato growers use 1.5 – 2 tons/ha of the same tuber size.

4.3.9 Stem density

Plant population is expressed as number of plants per unit area or number of stems per unit area (stem density). Each seed tuber planted gives rise to a plant with one or more stems capable of producing tubers. Each stem produces stolons and tubers and can be considered as an independent plant. Therefore, the more stems that a plant produces the higher the productivity and yield from that plant. For this reason the number of stems per unit area is a more accurate way of indicating plant population than the number of plants per unit area. Because of this, many farmers prefer using stem density (stems/ha) instead of plants/ha or number of seed tubers planted per ha. The seed grower targets 200,000 – 300,000 stems/ha while a ware potato grower aims at 100,000 – 150,000 stems/ha depending on variety and growing conditions.

Normally the grower counts the number of sprouts per seed tuber before planting. Based on the average number of sprouts per tuber and the target number of stems per ha, the exact plant to plant spacing can be calculated.

4.3.10 Planting

For high yields, only well sprouted seed potatoes are planted. The soil should be moist at planting to ensure rapid and uniform plant emergence and establishment. During planting, well sprouted tubers are placed in the furrows and covered by soil. Tubers should be covered as soon as possible after placing on the soil to avoid water loss and drying out of the seed bed. Quite often, the soil is raised to form ridges. Depending on the seed sizes, variety and required stem density, average seed rate in seed production ranges from 2.5 to 4 tons per hectare.

4.3.11 Irrigation

Water is an important factor in potato production and is needed to support plant growth after planting, during tuber initiation and tuber expansion. Immediately after planting, water should be supplied through irrigation in case of rainfall failure. This will ensure good crop emergence and establishment. Avoid too much irrigation just after planting since this will cause lack of oxygen in the soil and rotting of seed tubers. Irrigation should be in accordance with crop growth and crop development. When the crop is in full production during tuber bulking considerably more water is required than in the early stages of plant development just after emergence.
At the stage of tuber initiation in the plant, soil moisture is particularly critical since it affects the number of tubers and infection by common scab. Adequate moisture in the soil at tuber initiation increases the number of tubers produced and reduces incidences of common scab. Avoid water logging at all stages of crop development as this encourages powdery scab and bacterial diseases such as black leg and brown rot (Teagasc Irrigation Fact sheet, 2016).

4.3.12 Weeding

As soon as the crop emerges, weed control is important to avoid weeds competing with the young potato plants. Usually it is done 30-45 days after planting, although it is dependent on the season. During the wet seasons, weed intensity is higher as compared to the dry season. However, the grower should monitor the weeds to know when is appropriate to control.

There are several weed control measures which the grower can use depending on the scale of production. In small scale units, manual weed control is practiced by use of simple hand tools and removal of weeds at the base of potato plant. However, in large scale potato growing mechanical and chemical weed control is employed. In such situations, herbicides are applied as well as tractor drawn weed cultivators. The latter are also used to do the ridging (earthing up).

4.3.13 Ridging or earthing up

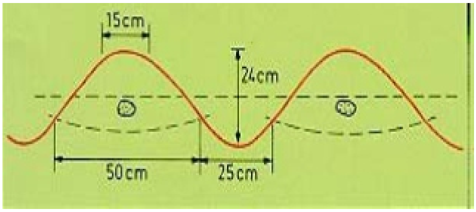


Fig. 1. Depicting seed tuber placement in the ridge

A potato plant produces tubers after crop establishment and this process is triggered by cool and dark conditions. As tubers enlarge, they require complete dark conditions to avoid greening. High loose soil volume is necessary to allow tuber expansion without hindrance. Therefore loose soil should be raised by earthing up as the plant grows. Earthing up improves the tuber positions on the plant and improves the quality of tubers produced besides protecting the crop from getting infested with Potato Tuber Moth (PTM).

Good earthing up ensures sufficient environment for root development and promotes uptake of water and nutrients required for plant growth and tuber production. It also keeps the tubers cool and minimizes tuber deformities.

Poor ridging leads to a high proportion of green tubers as well as to exposure of stolon tips which instead of forming tubers give rise to secondary, non-productive stems.

4.3.14 Rogueing and crop hygiene

Undesirable plants in a seed crop need to be removed to ensure high quality standard of the harvested tubers. Undesirable plants include plants infected by seed borne diseases (viruses or bacterial diseases) and off-types or volunteers. Volunteers are plants in the seed crop which don't conform to the variety being grown. Volunteers are plants grown from tubers left in the soil from a previous potato crop in that field. Volunteers are often infected with diseases like those caused by viruses that can infect the new seed crop. They may also be from another variety than the variety that is being grown.

Picture 7. Depicting a seed crop of variety Kenya Karibu (Courtesy of ADC Sirikwa farm)

Removal of undesirable plants during growth in the field is called rogueing. During rogueing undesirable plants are removed together with any newly formed tubers, placed in a polythene bag, taken away from the field and disposed safely either by burying in a deep pit or burning. Rogueing is done throughout the growing season to ensure purity of the desired variety as well as high health standard of the seed crop. In cases where there are weeds which may serve as sources of diseases, they too have to be removed.

Equally important are hygienic measures to prevent spread of diseases. Tools and protective gear used in seed crops should be disinfected and only used at the seed crop in a particular field and not in other crops.

4.3.15 Sampling for seed size determination

Once the potato plant has established it produces more foliage and closes the rows. During flowering, tuber production starts from initiation and tuber formation stage. This stage is followed by tuber bulking stage and finally tuber maturity stage. Seed crops are monitored for the tuber sizes to avoid them becoming too big for seed. In the course of crop growth when tubers are bulking, the grower is advised to up root few plants at random and determine the number of tubers falling within the seed size grade (28-60 mm in diameter). Usually KEPHIS advices on when to cut off the tops but the farmer should do so when about 60-70% of the newly formed tubers are in seed grade or when the foliage begins to turn yellow as a sign of the crop attaining physiological maturity.

4.3.16 Dehaulming

When 60-70 per cent of the number of tubers is in seed size grade, dehaulming can be done by use of hand tools or uprooting the entire stems at the ground by pressing around the plant and pulling the stems with the other hand. Alternatively, the foliage is cut at soil level and removed out of the field. At times dehaulming is done earlier in the event of likely build-up of vectors like aphids which transmit virus diseases. After dehaulming the tubers are left in the ground for 2 weeks to harden the skin before harvesting. When the field is large spraying with suitable non-selective herbicides is done to kill the foliage and the tubers are left in the soil for 2 - 3 weeks for the skin to harden.

Picture 8. Depicting dehaulmed field crop of seed potatoes (Courtesy of Kisima Farm Ltd)

4.3.17 Harvesting and postharvest handling

It is advisable for the grower to visit the seed potato field, uproot some plants at random and take tubers and rub the rose ends to see if they still peel easily. If they are not peeling, then the seed is ready for harvesting. Potato harvesting is done by lifting up to expose the tubers out of the ground. Several turnings and picking of tubers ensures successful recovery of tubers. It is ideal to harvest tubers when the temperatures are warm and the soil is moist but not wet. Suitable times to harvest potatoes are early morning or late afternoon so as to minimize scorching of tubers caused by bright sunlight. In

Picture 9. Depicting mechanized harvesting of seed potato crop (Courtesy of Kisima Farm Ltd)

large scale potato harvesting, mechanical harvesters are used. The tubers may be left in the field to surface dry before collection and packing into bags for ease of transportation. Care should be done to ensure that the bags are filled to half and transported on smooth trailers to the store.

4.3.18 Seed curing, grading and packaging

When tubers arrive at the store they have to be left to cure for up to two weeks at room temperature with good ventilation. Warm and aerated conditions and high humidity (above 90 % relative humidity) promote healing of wounds of the tubers resulting from harvesting, handling and transport. Once the tubers have healed enough and surfaces are dry, sorting is done by removal of bruised, misshapen, diseased or rotting tubers and any plant residues. With the use of seed gauge, the tubers are graded into the various seed sizes. Tubers measuring 28-45mm in diameter are regarded as size one while size two measures 45-60mm. Those tubers below 28mm are called chatts and may be used to feed farm animals like pigs, while those of size beyond 60mm are graded as ware and may be sold for food or used at the farm for consumption. Seed is then weighed into units of 25 or 50 Kg and packed in jute or sisal bags and stored. In large scale production, tubers may be packed in wooden crates or 1 ton boxes and stored in stores where temperature and humidity are controlled or in diffused light stores at ambient temperature. Packed tubers should not be piled as this can cause bruising and result in accelerated rotting. Packed potatoes may be placed on pallets in the store. If bags are used to pack potatoes, it is advisable to have the bags in upright position. Care should be taken to ensure seed potatoes are handled gently at all the stages.

Picture 10. Depicting packaging seed Potato in 50 kg bags (Courtesy of Kisima Farm Ltd)

4.3.19 Storage requirements

For proper seed potato storage, temperature and humidity are two critical environmental factors to be considered. The temperature in the store depends on initial temperature of the tubers at the time they are placed in store and duration of storage. Before storage tubers have to be cured at ambient temperature. Air movement (ventilation) is necessary during storage to remove the heat generated by the potatoes. If a long storage period (longer than 5 months) is anticipated, then the tubers must be stored at temperatures of 4-8 degrees Celsius whereas, if such conditions are not available, the tubers may be stored in diffused light conditions at ambient temperature until they start sprouting.

Picture 11. Depicting modern seed potato store with adjacent seed box store (Courtesy of Kisima Farm Ltd)

Up to 80 % of potato tuber content is water and this need to be maintained to avoid loss of weight and vigor. Thus in order to achieve this, maintain a 95 per cent relative humidity at all times. High humidity is also essential for optimum wound healing and curing.

So depending on the scale of storage, duration of storage, there are several storage types which include heaping and covering in the field, in sacks and in slatted stores made of timber or sophisticated ones under controlled environment. For small scale storage, use of diffused light stores at ambient temperature is ideal while for large scale storage and for long periods, cold storage is a requirement. After cold storage, seed tubers need to be pre-sprouted in indirect light (shade) at ambient temperature before planting.

4.3.20 Storage and distribution

Where more than one variety or seed sizes are stored, it is important to mark individual bags or crates for ease of tracking. Details of storage need also to be recorded in the office on when the seed entered the store, variety, seed size, unit of weight, number of bags and any remarks.

Such information is important when seed is moving out of store to the purchasers as well as for other purposes like computation of profitability.

5 DISEASES AND PESTS

In Kenya a healthy potato crop is able to produce 25 – 35 tons of fresh potatoes. Unfortunately most of the farmers are not able to achieve this high yield due to poor control of pest and diseases. Viruses and the poor control of late blight may result in yield losses of between 80 to 90%. Late blight is a disease caused by the fungus *(Phytophthora infestans)*. There are effective fungicides which have been registered to control it.

5.1 Scouting and monitoring

Daily farm visits is necessary to help access insect levels and know the most critical period for intervention. For diseases, scouting for symptoms is not advisable as this may be too late especially for fungal foliar diseases e.g. late blight. Therefore ensure that your crop is always protected throughout the growing period with a fungicide.

5.2 Fungal diseases

5.2.1 Late blight

Potato late blight is a fungal disease common in potato growing regions and it's the foremost disease that threatens potato production. It can infect plants from crop emergence until harvest and often causes crop failure. Severe attacks occur during high rainfall, high humidity (>95%) such as morning dew, fog, and low temperatures (<15°C). Farmers rely solely on the intensive use of fungicides for controlling this disease. Some of these fungicides are metalaxyl containing fungicides. Metalaxyl containing fungicides should be avoided since they cause the late blight fungus to become resistant to such fungicides. The fungicides recommended in this publication should not contain metalaxyl and the fungus has not shown resistance to these fungicides.

Picture 12. Depicting a blight infected potato crop (Courtesy of KALRO Tigoni)

Picture 13. Depicting a typical foliar symptoms (Courtesy of KALRO Tigoni)

Late blight symptoms

The symptoms begin as white to grey spots on the lower tips or edges of young leaves and spread quickly to cover the infected leaves if conditions remain favourable. In severe cases, the disease damages stems and tubers. If it is not controlled, infected plants will die within two or three days. The tubers get infected when spores are washed to the ground by rain or irrigation water and seep into the soil area coming in contact with the tubers. Affected tubers display dry brown-colored spots on their skins and flesh.

Source and spread

Sources of late blight infective spores include cull piles (potato tubers which have been discarded), infected seed tubers, remnants of infected plants, and volunteer plants (plants grown from tubers that remained in the soil from a previous potato crop) and infections on other members of the *Solanaceae* family (example tomato). Spores can also survive in the soil and infect the newly developing plants. Spores are spread by wind and by splashing raindrops.

Management of late blight

Late blight management practices are focused to reduce the optimum conditions for the disease to develop. The activities focus to reduce the amount of spores (= reduction of primary inoculum), reduce the leaf wetness of the crop, and reduce the ability of the spores to germinate and infect the leaves, stems or tubers.

Key practices in late blight management are:

- The use of tolerant varieties (if available)
- Routine observations (scouting for early signs), and
- Developing management techniques based on these observations.

Varieties with moderate to good resistance to this disease are available to Kenyan farmers. Management techniques also emphasize the appropriate use of fungicides. The main aim of routine observations and early scouting when dealing with late blight are:

- Limiting initial inoculum of the disease at the early plant growth stages.
- Implementing a proper fungicide strategy.
- Implementing an effective resistance management strategy for the fungicides.
- Avoiding serious contamination of the environment.
- Reducing potato production costs.

Management options to control Late blight are:

- Using healthy, certified seed.
- Removing sources of infection by destroying remnants of plants from the previous crop by collecting all plant remains and disposing them in a deep pit, cover and burn them or burying them in a pit.
- Destroying or covering heaps of discarded tubers (cull piles) with

black plastic.

- Rogueing volunteer plants as soon as possible after emergence.
- Crop rotation with non-solanaceous crop such as Maize, beans, cabbages and napier grass in a 1 to 5 year rotation program.
- Maintaining field and store sanitation.
- Early planting to enable the crop to mature earlier and escape the disease infection period. This also helps the farmer not to get infections from neighbouring potato crops which is the case during late planting.
- Correct spacing that is recommended should be observed during planting. Too close spacing will create humid conditions under the foliage which is suitable for disease development.
- Use of fungicides - fungicides reduce infection, limit the formation of spores and thus limit the spread of the infection. For effective control, fungicide applications have to be repeated with a 7 – 10 days interval till maturity of the crop. It is advisable to ensure that your crop is protected as soon as it emerges and continue doing so till maturity.

Protectant fungicides (contact fungicides) such as Antracol, Mancozeb can be applied under conditions with dry weather or slow crop growth.

Systemic fungicides (curative fungicides) such as Milraz, Consento or Infinito need to be applied either during the rapid growth of the crop or under conditions of high relative humidity i.e. prolonged periods of fog or rain. In case of extreme wet weather conditions repeat the fungicide application with systemic fungicides within 4-7 days. Continue with the foliar fungicide applications till the maturity stage of yellow leaves has been reached. These techniques are extremely important and provide a high likelihood of success if farmers plant potatoes in fields that aren't infected with late blight. However, they can be less effective if surrounding potato or tomato crops are infected with late blight and when these fields are not managed using the same techniques. The spores of late blight are more likely to spread from these fields by wind.

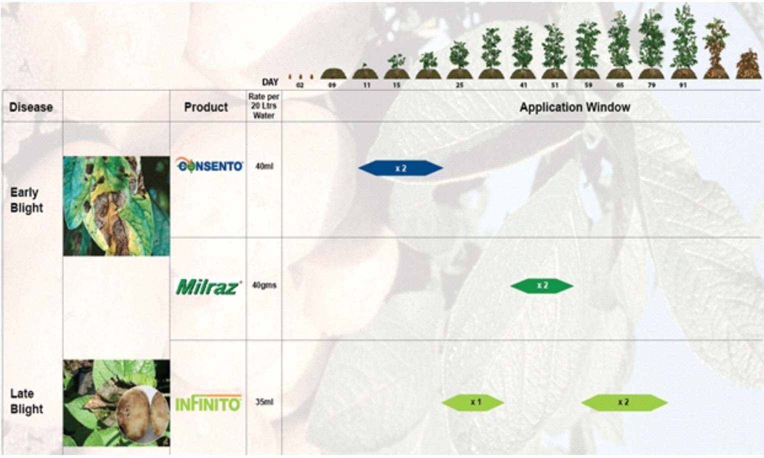


Fig. 2. Depicting late blight control protocol
(Courtesy of Bayer East Africa Ltd)

5.2.2 Early blight

Picture 14. Depicting symptoms of Early blight caused by *Alternaria solani* (Courtesy of KALRO Tigoni)

Early blight is caused by the fungus *Alternaria solani* and is found in all potato producing regions. It is not as important as late blight, because it rarely causes severe damage or crop failure. Early blight is favoured by warm (>20°C) temperatures during early growth stages coupled with dry periods alternating with wet periods. Early blight affects mainly old leaves. The fungus survives in soil as mycelium on leaf debris and as spores.

Source and spread

Sources of infection are contaminated seed and plant remnants, tools and machinery. Spores may be spread by wind or by water droplets.

Symptoms of early blight

Symptoms include dry brown spots, usually bound by the leaves' ribs. The spots enlarge and join together to form big concentric/circular rings. This disease first becomes apparent during the tuber bulking stage and develops leading up to harvest.

Management of early blight

Management should be carried out when this disease is discovered in the vegetative growth or tuber initiation stages. Infection at the late stage of the tuber bulking phase does not affect harvest quality or yield; therefore, it is not economical to manage the disease during this late stage. Management techniques to control this disease should be targeted at early growth stage and includes:

- Use of resistant/tolerant varieties.
- Removing sources of infection by using healthy seed, destroying contaminated plants and strict crop rotation helps to eliminate inoculum in the soil.
- Using good irrigation systems such as drip irrigation to reduce drought stress and to support the uptake of nutrients.
- Balanced use of fertilizer (especially increased level of potassium) to produce healthy plants more resistant to infection from this disease. The recommended rates should be used during planting to give the crop a good start.
- Use of fungicides (example Antracol, Consento, Mancozeb) to prevent early foliar disease development
- Reduce mechanical damage during harvesting, transportation, sorting and grading.

5.2.3 Black scurf/ stem canker

The black scurf/stem canker (*Rhizoctonia* spp) disease is common in all potato growing regions worldwide. The disease is spread through infected seed and contaminated soil. *Rhizoctonia* does not damage the tubers but attacks the sprouts, stolons and roots. High soil moisture coupled with low/cool temperatures in highly fertile soils with pH below 7 are predisposing conditions for development of stem canker. Wet soils contribute to more damage because they warm up more slowly than dry soils while delaying the emergence of the potato crop.

Source and spread of black scurf

The disease is spread by contaminated soil and infected seed.

Symptoms of black scurf

Black scurf forms spots which are dry and sunken on the stem which become big and join together forming dead tissue areas. A whitish mold forms on stems just above the soil line affecting movement of nutrients and water from the leaves to the roots. The affected part of the stem may have the top skin peel off (girdling) affecting the functions of the stem. Damage is most severe at low temperatures when emergence and growth of stems and stolons from the tuber are retarded. The disease results in a low stem density due to the fungal attack of sprouts leading to reduced or no emergence and weak stems. The plant may have reduced stolon system that leads to the reduced number and size of tubers. Tubers may have irregular black to brown hard masses on the surface of the tubers which reduce the visual quality

Management of black scurf

a) Use certified seed which has sprouted well
b) Do not plant in soils that are cold (< 7ºC) or wet. Soils for potato growing should have proper drainage to prevent water logging
c) Crop rotation program of 1 to 5 seasons
d) After dehaulming, wait for two to three weeks for tuber skin to harden; harvest the tubers immediately after two weeks to keep off tuber infection

5.2.4 *Fusarium* Dry rot

This is a common disease of the potato caused by *Fusarium* spp. This disease can stay in the soil for very long and enters the potato plant through wounds. Mature tubers which are infected may not show signs until few weeks of storage when they start to rot.

Source and spread

The *Fusarium* fungus lives in the soil and in infected tubers. The disease is spread during planting, weeding, harvesting, transportation and grading.

Symptoms of *Fusarium* rot

In storage, the spots/lesions develop on the skin as small brown areas which are dry and spongy. These lesions develop into dead areas on the tuber surface which run deep into the flesh. As the spots expand to cover the entire tuber, the skin on the lesions shrivels due to water loss. When infected tubers are cut, dry internal browning or black coloration of the dead tissues is seen. The heart of the tubers may also be infected where mycelia grows (white cotton like) and hardens to form dry necrotic areas.

Management of *Fusarium* rot

- Use healthy, certified seed for planting.
- Crop rotation of 1 to 7 seasons to eliminate the disease from the soil.
- Dehaulm the crop to ensure good skin development and ensure minimal bruising to the tubers when harvesting or grading.
- Promote wound healing after harvesting and transport to store by providing adequate ventilation and maintaining temperatures of 15 to 20ºC with relative humidity of 90 to 95 % for 14 to 21 days.
- Field and store sanitation: clean and disinfect all tools and equipment for handling potato tubers.

5.3 Bacterial diseases

5.3.1 Bacterial wilt

Bacterial wilt is a disease caused by the bacterium *Ralstonia solanacearum*. In addition to infecting potatoes, it also damages other plants in the *Solanaceae* family such as chili, tomato, tobacco and eggplant, as well as several species of weeds. This disease is extremely dangerous, especially in regions where potatoes are cultivated intensively and is the biggest cause of reduced production in some areas. The disease spreads rapidly in areas with warmer temperatures, and will cause tubers to rot. Infected seed can also be a source of the disease in the field.

Symptoms of bacterial wilt

Bacterial wilt expresses best under conditions of warm temperatures and high soil moisture. Plants begin to wilt, starting from the tips of the leaves or where the stems branch out, and spreads to all parts of the plant even when soil moisture is sufficient. Leaves become yellow at their bases, then the whole plant wilts and dies. When stems are cut a brown colored ring will be visible. Mildly infected tubers will not show any outward signs of disease as symptoms will be hidden from view. When a tuber is cut in half, black or brown rings will, however, be visible. If left for a while or squeezed, these rings will exude a thick white fluid. A further symptom is fluid coming out of tuber eyes. This can be signified by soil sticking to tuber eyes when crops are harvested. Serious infection causes tubers to rot starting with the vascular rings.

Picture 15. Depicting plants in the foreground showing symptoms of Bacterial wilt (Courtesy of KALRO Tigoni)

Picture 16. Depicting soil sticking to bacterial exudates especially near the eyes (Courtesy of KALRO Tigoni)

Picture 17. Depicting bacterial ooze from infected stem (Courtesy of KALRO Tigoni)

Picture 18. Depicting bacterial ooze from vascular ring of infected tuber (Courtesy of KALRO Tigoni)

Source and spread of bacterial wilt

On potato crops, bacterial wilt originates from:

- Soil - bacterial wilt can survive in soil without a host for several years.
- Water, especially run off water
- Infected seed tubers
- Infected potato plant remnants and crop residues

The disease can spread from field to field or from plant to plant by:

- Infected seed
- Water
- Soil
- Farming tools
- Livestock and people

Observation in the field

Field observations for bacterial wilt should commence at 30 days after planting by looking at symptoms on affected plants. It should be noted that *Ralstonia solanacearum* is a regulated non-quarantine organism in Kenya and as such there is a zero tolerance in seed crops. Identifying bacterial wilt infection in the field can be done by using the following methods:

- ***Testing plants with vascular flow test*** –This will determine whether plants with symptoms of wilting are infected by bacterial (and not fungal) wilt. Cut 2-3 cm lengths of stems at the base of plants showing signs of infection. Suspend these pieces vertically in clear water and leave for a while. If the plant is infected with bacterial wilt, milky threads of bacterial ooze will flow from the stem pieces into the water.
- ***Testing tubers*** – Cut a sample tuber near its base, leave it for a few minutes, or squeeze it. If it is infected with bacterial wilt, it will exude a thick white fluid.
- ***Testing soil with bioassay test*** – Three-week old tomato seedlings grown on Bacterial Wilt free substrate and several soil samples

suspected of infection are used for testing. Put the soil samples in pots and water them with clean water. Plant five tomato seedlings in each pot, and tend them for one or two months. Make observations by looking at symptoms that appear on each of the plants in the pots. When wilting appears, test the plants with vascular flow tests. Wilting plants that exude a milky flow in the vascular flow test are proof that their pots contain infected soil. You can also do this test to determine if manure contains bacterial wilt.

- *Laboratory test methods* – There are a variety of methods utilized for bacterial wilt testing including Enzyme Linked Immunoassays (ELISA), Polymerase Chain Reaction (PCR), Immuno-Florescence (IF) Microscopy and Biochemical assays. These are available in several laboratories in Kenya including at KEPHIS Muguga.

Management of bacterial wilt

Bacterial wilt cannot be controlled with fungicides, and bactericides are seldom available to farmers and generally very expensive. Management principles for control of bacterial wilt include removing sources of disease from the field by:

- Selecting land that is free of bacterial wilt for potato production and planting potatoes in soils free from bacterial wilt.
- Using healthy or certified seed that is not infected with bacterial wilt.
- Rotating potato crops with other non-solanaceous crops. Good practice is to rotate potatoes with corn or sweet potato or leaving the land fallow. In fields with serious infections, it is best to plant non-host plants for more than 2 years, as agents of bacterial wilt can survive in the ground without host for that amount of time.
- Rogueing of all diseased plants with mother tuber and any newly-formed tubers. Also remove the soil of the hill of the infected plant.
- Removing infected plant debris and tubers and burying them in a deep pit. Clearing weeds away before planting, timely weeding during plant growth and at harvesting time.

- Using composted organic fertilizer not infected with bacterial wilt. Always take manure samples for testing before application.

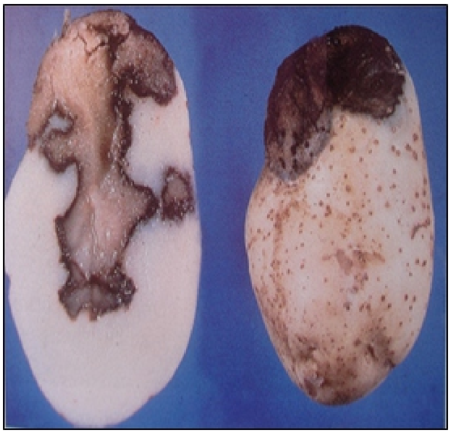
5.3.2 Blackleg or soft rot

In Kenya blackleg or soft rot is a widespread seed borne disease caused by a bacterium *Erwinia* spp., which affects stems and tubers through breakdown of plant cell walls. It causes losses both in the field and in storage particularly in warm and humid regions. The bacteria invade the plant from the mother seed tuber but disease development is dependent on the time the mother tuber rots. Planting rotting tubers or tubers rotting before emergence leads to poor plant population but rotting during crop growth leads to development of symptoms.

Source and spread of soft rot

Blackleg or soft rot is spread through seed tubers, other infected plants, soil and water. It can spread from plant to plant via water, soil, and seed, and on farming tools & machinery or people.

Picture 19. Depicting blackleg in the field (Courtesy of KALRO Tigoni)



Picture 20. Depicting soft rot on tubers (Courtesy of KALRO Tigoni)

Blackleg or soft rot can affect potatoes at various stages in their growth. Plants begin to turn yellow while other plants are healthy. Black spots which are soft and slimy develop on the stem in the field. When the stem with spots is cut, the vascular tissues and the pith are brown or black in colour. Stem bases become black, rot and exude slime. Severe infection can cause plants to wilt and die. Tubers may become infected either in storage or in the field. Tuber infection occurs through the stolons where the bacteria pass from the stem. The point where the tuber is attached to the stolon develops black spots which spread to the entire tubers causing rotting of the tubers. Tubers do not exude the white slime you will find with bacterial wilt. Damage caused by pests, small worms or harvesting can facilitate infection as the soft rot pathogen cannot infect healthy tissue on its own. During storage bacteria invades the tubers through wounds or lenticels causing breakdown of the skin and granular surface developing.

Management of black leg

Management of Blackleg or soft rot requires the following practices:

- Using healthy seed not contaminated with the disease or certified seed.
- Crop rotation program of 1 to 7 seasons because the bacterium persists in the soil for long.
- Avoid planting in wet or flooded fields. Improving drainage systems to allow water to flow in and out of the field more easily.
- Destroying sources of the disease, particularly infected plants by burying in a pit which is 6 feet deep or burning.
- Avoiding damage to tubers when weeding, hilling up, at harvesting and during transporting harvested produce. In addition, chitting of seed tubers should be done to develop strong sprouts that will not break off during handling and planting. Break off points become entry points for the bacteria.
- Harvesting in dry weather conditions. Drying of tubers or exposing the tubers to warm dry conditions may prevent further rotting of the tuber through formation of wound periderm forming bacterial hard/pit rots.

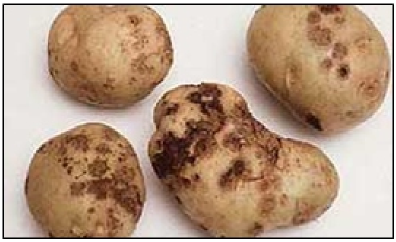
- Sanitation of the field for the whole season, the store and all equipment for handling seed tubers such as trays, machinery and tools.

5.3.3 Potato Common scab

In Kenya common scab, caused by the bacterium *Streptomyces spp*, is common in fields with high soil pH. The Streptomyces bacteria live in the soil and produce volatile compounds that create the typical soil smell. In addition to potato Streptomyces also infects carrot, radish and sweet potato. *Streptomyces* does not reduce the potato production, however, it does affect the visual appearance, and hence quality of tubers. In local markets growers can still fetch almost the same price as unaffected tubers, but problems arise when they are sold to potato processing companies or for export. Tolerances for this disease in harvested seed tubers have been defined in the official seed certification system.

Symptoms of potato common scab

Common scab affects potato tubers. Damaged tubers have rough, cracked skins, with scab-like spots. Severe infections leave potato skins covered with rough black welts. Lesions may be circular or angular and may coalesce into large irregular areas. Severity can range from sparse colorless, corky lenticels to dark brown, raised or pitted scabs covering the tuber surface. Common scab might easily be confused with powdery scab. However, powdery scabs tend to be smaller, have a more round character and when coalescing they tend to merge as discrete eruptions rather than one large scab.



Picture 21. Depicting potato tubers infected with *Streptomyces scabies* (Courtesy of KALRO Tigoni)

Source and spread of potato common scab

Infection on the tubers occurs during tuber set through the lenticels which are immature. Common scab originates from the soil, un-composted manure or seed, and spreads through contaminated soil, seed and water. Soil alkalinity (pH) and soil moisture seem to be the most important factors affecting seasonal incidence and regional distribution of scab. Dry soils or drought periods during the growth phase of tuber formation favour the development of the disease. Common scab may be particularly severe when potatoes are grown in neutral or alkaline soils. Within the range of pH 5.2 to 8.0, the severity of the disease increases with increasing alkalinity. It is generally accepted that the disease is controlled satisfactorily if potato soils are kept at pH 5.0 to 5.5. In case the soil pH is adjusted by liming then this should be done in the crops previous to potato; not just prior to planting potato as this will increase incidence of common scab. Warm and dry soil conditions, particularly during the critical period of susceptibility to scab (i.e. two to five weeks after tubers start to form) can markedly increase the incidence of the disease.

Management of potato common scab

You can control common scab by:

- Avoid planting in fields with intense practice of liming.
- Use certified and healthy seed.
- Apply irrigation at time of tuber set (initiation).
- Rotate potatoes with other non-host crops, such as cabbage or corn, to prevent the disease from spreading to the following season's potato crop.

Observation methodology

Soil moisture at tuber initiation is critical to reduce infection by common scab. Check soil moisture level 5 to 6 weeks from planting. Soil moisture can be determined by taking soil in your hands and rolling into a ball. If the ball forms easily and holds together, moisture is sufficient but if the balls crumbles immediately or does not form, the soil is dry requiring irrigation or water supply. Make observations for common scab just prior to and during harvest time, by taking random tuber samples and inspecting them for symptoms of the disease.

5.3.4 Bacterial ring rot

This is a bacterial disease caused by *Clavibacter michiganensis* and is common in potato growing regions. This disease is spread by potato seed tuber and it has a zero tolerance status in seed certification in Kenya.

Source of inoculum and spread of bacterial ring rot

Source of inoculum is seed tubers, volunteer potato plants, cull piles (potato tubers which have been discarded) and infected plant remains. The disease is spread through contact from infected to uninfected tubers especially during cutting tubers for seed, harvesting, transportation, storage and through tools and equipment.

Symptoms of bacterial ring rot

The leaves turn pale yellow and lower leaves start mottling. The leaf margins roll upwards and cull inwards. Eventually the tissues die forming necrotic areas. When the tuber is cut across, necrotic areas are seen along the vascular tissues. The difference with bacterial wilt is that in bacterial wilt, the bacterial oozes from the vascular ring while in ring rot, cheesy exudate oozes from the vascular ring. In advanced stage, the necrotic areas break down to form grey pockets of decayed tissues around the vascular ring.

Management of bacterial ring rot

- Use of healthy, certified seed.
- Observe field sanitation. All infected plant remains should be burned or buried in a 6 feet deep pit.
- Crop rotation with non- solanaceous crops such as maize, cabbage, fodder grasses or leaving the land fallow.

- Clean and disinfect tools, machinery, handling containers, walls of storage areas with sodium hypochlorite.

5.4 Virus Diseases

About 40 viruses are known to affect the potato crop (Valkonen, 2007). The six important viruses in many countries worldwide including those in Kenya are *Potato leaf roll virus* (PLRV), *Potato virus Y* (PVY), *Potato virus X* (PVX), *Potato virus S* (PVS), *Potato virus A* (PVA), and *Potato virus M* (PVM) (Singh, 1999; Wangai & Lelgut, 2001). Potato viruses cause remarkable reductions in yield and quality of potato crop and several of them have been reported to infect potato in Kenya (Gildemacher et al. 2009). These can debilitate potato production, and sophisticated propagation techniques and certification schemes are in place to ensure freedom from viruses and other pathogens. Viruses are classified according (Fig. 3) to mode of transmission (Oyoo & Hennessy, 2016).

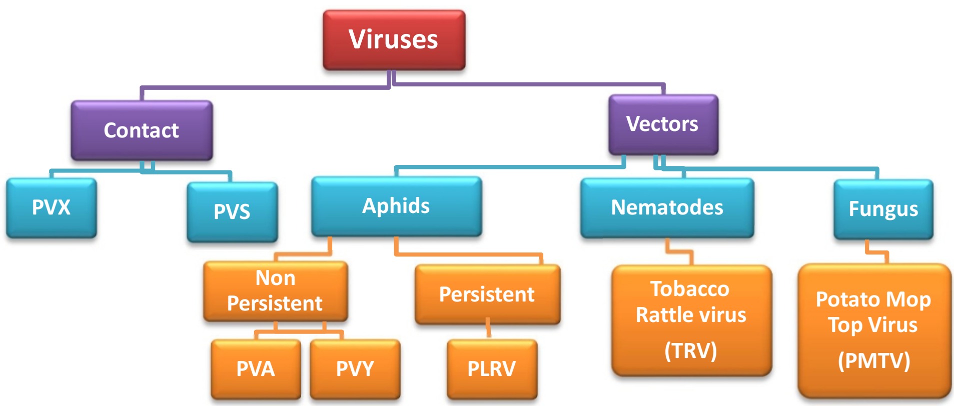


Fig 3. Depicting typical mode of transmission of viruses (Courtesy of Oyoo & Hennessy, 2016)

A common problem when cultivating potatoes is reduced yield from one generation to the next due to high incidence of virus diseases. These diseases are very varied and display a multitude of symptoms. It is difficult for farmers to identify and distinguish virus diseases because:

- Their causal agents are tiny and invisible to the eye.
- Viral infections rarely cause plants to become damaged or die. The visible, symptoms if any at all, are changes in the shape and colour of plants. Consequently, most farmers consider virus diseases harmless.
- Under field conditions symptoms of virus disease are often the result of mixed virus infections.
- It is often difficult to differentiate between symptoms of one virus and another. Thorough testing to determine the particular virus (es) calls for equipment and expertise which can be found in local agricultural extension, research or regulatory service providers such as KEPHIS and KALRO.

Increasing incidence of virus diseases that develop from one generation to the next occurs primarily due to farmers' habit of basing their seed potato selection on the size of the potatoes alone. Generally, virus diseases lead to smaller potato tubers being produced.
Consequently, when tubers are sorted and selected for seed, the majority of seed potatoes chosen are those already infected with virus diseases. Despite variations, management principles are nearly the same for all virus diseases.

Viruses can be controlled by:

- *Using virus free seed*: Farmers are always advised to use virus free certified seed to establish their crops. These can be obtained from registered seed merchants whose seed had been certified by KEPHIS. It is very risky to select seed potatoes based on size alone, as plants infected with virus diseases generally produce smaller tubers.

Picture 22. depicting healthy tubers (left) and virus infected tubers (right) (Courtesy of KALRO Tigoni)

However strict sorting and selection is highly recommended if a part of the harvest will be used for seed.

- *Destroying plants infected with virus diseases*: Plants displaying symptoms of virus diseases must be pulled up (inclusive the newly formed tubers), collected and destroyed by burying in a deep pit or burning. Viruses can spread from one plant to another through vectors, so removing infected plants will also remove the source of disease for other plants.
- *Controlling vectors that can spread virus diseases*: Generally, sucking insects such as aphids, thrips, mites and whiteflies can spread viruses (of which the most important are aphids). Therefore, management of these insects by using recommended pesticides can reduce the spread of virus diseases.

5.4.1 Potato leaf roll virus

Potato leaf roll virus (PLRV) is an important disease in potato plants and can cause reduced yields of up to 90%.

Source and spread

PLRV is transmitted by aphids in a persistent manner. That means that once an aphid acquires the virus it is infective for life. The virus is picked up by colonizing aphids during prolonged feeding for at least one hour on an infected plant. The peach potato aphid (*Myzus persicae*) is regarded as the most efficient vector. PLRV can be introduced into a potato field by infected seed tubers or by all stages of winged aphids which act as vectors spreading the disease from one field to another. A plant developed from an infected seed tuber is already infected and can act as a virus source to neighboring plants. All tubers produced from an infected plant will carry the virus.

Symptoms

Symptoms appear during the early stages of potato growth. Leaves curl, tighten and turn pale green. If you press them they feel brittle and fragile. In advanced infections, plants become stunted while leaves and stems stand upright/erect. Severe infections cause potato plants to produce tiny tubers, or prevent them from producing any tubers at all.

Picture 23. Depicting the upward curling and rolling of leaves due to PLRV (Courtesy *KALRO Tigoni)*

Observation methodology

Make observations by walking along the rows in the field and looking for plants showing symptoms of the disease.

Management

Management practices in seed crops to control PLRV include:

- Use of certified seed for planting
- Rogueing diseased plants and removing any newly formed tubers of those plants starting as early as symptoms are visible.
- Monitoring traps. Place 6 yellow water traps per acre for monitoring the aphid populations.
- Use of registered insecticides at the recommended rates to kill virus vectors (mainly aphids)

5.4.2 Potato virus Y

Potato virus Y (PVY) is the second most important virus after PLRV. It can be passed on through infected tubers or by insects and can reduce yield by up to 80%. PVY mostly affects plants in the family *Solanaceae*. The Solanaceous plants include economically important ones like potato (*Solanumtuberosum*), as well as tomato, green pepper, chili pepper, eggplant, petunia and many weeds, such as the nightshades.

Symptoms

Leaf surfaces become uneven and brittle, leaves shrink and their ribs turn yellow. In mild infections, plants often show no signs of disease at all.

Picture 24. Depicting healthy and PVY infected plants
(Courtesy of KALRO Tigoni)

Picture 25. Depicting PVY in tubers
(Courtesy of KALRO Tigoni)

Source and Spread

PVY is mostly transmitted by aphids which act as vectors in spreading the disease from one field to another. Aphids can acquire the virus within seconds of commencement of feeding on infected leaves and can transmit the virus immediately, in a non-persistent manner. They usually retain the virus for only several hours without continued feeding on infected leave material. The nymph stage causes more damage than the adult stage.

Symptoms

The leaves start dying off beginning at the veins. Mottling and yellowing of the leaflets occurs leading to leaf drop, stunted growth and eventual death of the plants. Tubers may have ring spots on the surface which may coalesce and cover the entire tuber. The rings may be sunken and cracks may develop on the skin. Peeling the skin below the rings may reveal tissues that are thicker than the surrounding areas.

Picture 26. Depicting chlorosis on foliage due to PVY
(Courtesy of KALRO Tigoni)

Observation methodology

Make observations by walking along the rows in the field and looking for plants showing symptoms of the disease.

Management

Management practices in seed crops to control PVY include:

a) Use of healthy, certified seed.

b) Rogueing of diseased plants during active growth as well as removing any newly formed tubers of those plants.

c) Use of resistant cultivars.

d) Application of mineral oils to prevent virus transmission by aphids.

Application of insecticides has little effect on spread of PVY due the rapid (non-persistent) way of virus transmission by aphids.

5.4.3 Potato Virus X

The Potato Virus X (PVX) is found in all potato growing regions though its effects are not as severe as for other viruses. It is transmitted through contact either by humans, animals, plants or machinery or cutting tubers since the virus accumulates in tubers. PVX is very contagious and from the moment that it is attached on something such as clothing or machinery the virus remains infective for many hours as long as the surface is wet. In addition, viruses picked from infected plants by contact can be transmitted to many other plants when moving through a crop. Hence, restricted movement from fields suspected of PVX infection should be observed.

Symptoms

Patterns of light and dark green on leaflets with the lighter small irregular blotches being between the veins may be seen on leaves. Mosaic design on leaves with advanced infections leading to streaks and leaf mottling.

Picture 27. Depicting mosaic pattern due to PVX (Courtesy of *www.teagasc.ie*)

Management

Management practices in seed crops to control PVX include:

1. Use of certified or healthy seed
2. Do not cut seed potatoes
3. Rogueing of diseased plants and removing any newly formed tubers of those plants
4. Field and store hygiene and sanitation
5. Restricted movements in fields suspected to have infection
6. Clean and disinfect machinery and clothing before entering seed crop

5.4.4 Potato Virus S

Potato Virus S (PVS) is the most frequently found virus compared to all the others in potato growing regions.

Source and spread

PVS is commonly spread in the same way as PVX, through contact by human, machinery and plants. Some strains of this virus are also transmitted by aphids, including Peach aphids, *Myzus persicae* and *Aphis nurstatii* in a non-persistent manner.

Symptoms

Potato virus S (PVS) induces no conspicuous symptoms in many potato cultivars. However, symptoms like rugosity of leaf surfaces occur in susceptible cultivars.

Management

Management practices in seed crops to control PVS include:

a) Use of healthy, certified seed
b) Do not cut seed potatoes
c) Rogueing of diseased plants (in case symptoms are visible) and removing any newly formed tubers of those plants
d) Field and store hygiene should be observed
e) Restricted movement from infected to uninfected fields

5.4.5 Potato Virus A

Potato Virus A (PVA) is found wherever potato is grown. PVA symptoms are almost similar to PVX causing mild mottling of leaves but the mottling appears on veins with the leaves looking shiny. It is transmitted by several aphid species in a non-persistent manner.

Picture 28. Depicting mottling and shiny leaves due to PVA *Courtesy of* www.teagasc.ie/Crops

Management

Management practices in seed crops to control PVA include:

1. Use of healthy, certified seed
2. Rogueing of diseased plants and any newly formed tubers of those plants
3. Early harvesting of seed crop
4. Application of mineral oils to prevent virus transmission by aphids.

5.5 Insect Pests

The key pests of potatoes in Kenya include potato aphids, cutworms, potato tuber moth and nematodes.

5.5.1 Aphids

Aphids are pear shaped insects with soft bodies barely 2mm long. They are sucking pests as they pierce the plant tissues and suck the cell sap, infecting the plant with viruses at the same time. Aphid pests are favoured by temperatures above 20°C and drought spells or low rainfall. There are 4 species of aphids that transmit viruses by feeding on potato plants namely green peach aphid (*Myzus persicae*), cotton aphid (*Aphis gossypii*), potato aphid (*Macrosiphum euphorbiae*) and glasshouse aphid (*Aulacorthum solani*). The most important aphid species for potato is the green peach aphid (Lung'aho et al., 2007).

Picture 29. Depicting aphids on a potato leaf (Courtesy of Bayer East Africa)

Management

Management practices in seed crops to control aphids include:

- Use of healthy, certified seed
- Deploy predators such as ladybird, lace wigs and fall midge
- Spray with products such as Decis EC as soon as pest is spotted alternated with systemic insecticides

5.5.2 Potato Tuber moth

Potato Tuber Moth (PTM), *Phthorimaea operculella* is a serious pest of potato that destroys the crop in the field and in storage by mining on foliage and tubers. Adult moths have blackish brown colored front wings. They are active at night and are attracted to light. During the day they hide under sacks or under piles of tubers stored in the storage area. Adults live for around 10-15 days. This pest is favoured by high temperatures and dry spells. The destructive stage is the larvae which bore through the leaves, stems, leaf petioles, shoots and tubers. More destruction is done to the tubers because the larvae create tunnels and leaves excreta on them which attract other pathogens leading to secondary infection and rotting.

Life cycle

Potato tuber moths lay eggs. Their life cycle is divided into egg, larva, pupa and adult moth stages, and lasts for around 20-30 days. Eggs are very small and usually laid on tubers, on the underside of leaves, on storage sacks, on the ground or on waste close to tubers. Eggs hatch after five days. The resulting larvae make holes in tubers and leaves. They bore into the eyes of tubers and grow for about 14 days. Pupae are covered in fine hairs and are found on dry leaves, on the ground, on potato eyes, on the walls of storage areas and on sacks. The pupa stage lasts for eight days.

Damage symptoms

Potato tuber moths affect both tubers and foliage. Larvae eat their way inside tubers either in the field or in the store. However, severe infestation generally occurs in storage. Larvae feces can be seen near boreholes. On foliage, larvae attack the stems and leaves of potato plants. They enter leaves, eat the inside and leave only a dried up outer skin. Severe infestation occurs in some areas, but yield loss is generally limited. The main damage is during storage through loss of tuber quality.

Picture 30. Depicting damage by potato tuber moth (Courtesy of Bayer East Africa Ltd)

Observation methodology

You can make observations of larvae and adult moths. Observe larvae in the storage area by removing holed tubers and cutting them in half. Observe larvae in the field by looking for leaves showing signs of damage and opening them up. Observe and monitor the presence of adult moths by using sex pheromones, which attract male insects.

Management

Management practices to control PTM include:

- After harvesting, sort out the tubers that are already damaged and discard by burning or burying in a deep pit.
- Using healthy seed tubers– Affected tubers with eggs, larvae or pupae still inside them can become the source of infestation in the following crop.
- Crop rotation with non-host (non-solanaceaous) plants.
- Planting at recommended depth (20-25cm deep).
- Proper 'earthing' up or hilling to cover the tubers to prevent them from being infested through adults laying eggs in the tubers.
- Maintenance of soil moisture at field capacity at harvesting.
- Farm and store hygiene should be observed.
- Application of plants rich in essential oils such as Eucalyptus or *Lantana camara* leaves which will repel the pest.
- Rogueing volunteer plants during early growth stage in the seed crop and around.
- Harvesting as soon as dehaulming is done to reduce chances of infestation.
- Using sex pheromones – sex pheromones are useful for monitoring population development of the moths as early indicator. Cutting the foliage at 80 days after planting can prevent larvae on the foliage from moving into the tubers.
- Use of pyrethroid insecticides to destroy the pest.

5.5.3 Cutworms

This pest commonly known as the 'black cutworm' (*Agrotis ipsilon*) is the most common species of cutworms in the region. Young caterpillars feed on leaves and burrow into the ground to pupape and develop into moths. The adult caterpillar has a smooth body 5cm long and a dull brown colour while the moths are grey. The larvae resemble the dark brown 'earth' colour with stripes or colourful spots. The caterpillars usually curl in a semi-circle when disturbed. Cutwormsdamage the crop during the dry season/drought spells since rain prevents the moths from laying eggs and water seepage makes the caterpillars to come out of the deep ground surface where they get preyed upon by natural enemies.

Symptoms

During dry spells the caterpillars cut the emerging shoots at or under the ground level. Foliage with holes is a characteristic symptom of the caterpillar larvae feeding on them. On tubers the larvae cause damage varying from shallow cracks or holes by eating the flesh. The holes in the tuber serve as entry points for secondary infections by fungi and bacteria.

Management

Management practices to control cutworms include:

- Scouting the seed crop to check for foliage damage or dead stems
- Early weeding of seed crop and rogueing of volunteer plants
- Planting at recommended depth to avoid exposed tubers
- Hilling and earthing up to cover exposed tubers
- Chemical control by spraying with contact or systemic insecticides at the recommended rates on product labels.

5.6 Nematodes

5.6.1 Potato cyst nematode

Potato cyst nematodes (PCN) or golden cyst nematodes, probably originating from the potato in South America, are widely distributed throughout potato producing areas all over the world. It was first reported in Kenya in 2014 but has probably been around for several years before that. Although its main host is the potato, it can also reproduce on other solanaceous crops such as tomato and egg plant. The two main species that attack potato are the golden (*Globodera rostochiensis*) and pallid (*G. pallida*) cyst nematode. However, only *G. rostochiensis* has been shown to occur in Kenya.

Life cycle

One life cycle of the golden cyst nematode is completed within each crop cycle. Between subsequent crops, eggs survive within cysts in the soil. When a potato plant is growing, substances exuded by the roots stimulate the eggs to hatch. Each egg contains a second-stage juvenile which hatches, moves from the cyst into the soil and penetrates a host root just behind the root-tip. The juvenile establishes a permanent feeding site in the root and develops to become an adult. After reaching the adult stage, males leave the root and move through the soil to find females. Females remain in the root, expanding and eventually rupturing it, remaining attached by the head and neck only. After fertilization, the female produces 300 to 500 eggs which she retains within her body. The female dies with the root, but her skin hardens and turns brown while forming a protective cyst for the eggs.

Source and spread

The cysts of the nematodes stay in the soil for long periods of time. They can spread to other fields or other areas through soil on machinery, tools, boots and seed tubers.

Symptoms

Picture 31. Depicting cysts of PCN turning brown (Courtesy of KALRO Tigoni)

Potato cyst nematodes do not cause immediate above-ground symptoms. First symptom is poor growth of plants in one or more spots in the field. These spots enlarge each year that potatoes are planted in the same field, since cysts remain in the soil for a long time. Low populations of the nematode may not be noticed but as the number of nematodes increases, plants become stunted, leaves are smaller and yellowish and plants die off early. Plants may show symptoms of water and/or mineral deficiency stress with yellow leaves and wilting. Yields may be reduced by as much as 90%, which is the result of smaller tubers. Tuber quality and number of tubers, however, are not affected.

Management

Of all the crop pests worldwide, the potato cyst nematodes are among the most difficult pests to control. Once they are established in an area, eradication of the potato cyst nematodes seems unlikely. The extremely long survival period of cysts in the soil, which can be over 30 years, limits management options. The best approach to limiting spread once the potato cyst nematodes are introduced into an area is to integrate control measures. In particular, crop rotation, resistant varieties, and bio-fumigation look promising. Crop rotation, however, requires a cycle of five to nine years to achieve relatively low populations in the soil that would allow successful potato production again. Resistant varieties are available in Europe, but these are not necessarily suitable for tropical highland conditions and need to be evaluated first. Chemical control is generally not recommendable since it involves pesticides (nematicides) of high toxicity that kill all living organisms in the soil, including nematodes, fungi, bacteria, plants and insects. A bio-fumigation using brassica residue is a method that should be further explored.

Observation methodology

As with root-knot nematodes, pull up wilting plants and observe their roots and tubers. Roots of infected plants exhibit very small, white balls attached to the root surface, which are the immature females that have erupted through the root epidermis. At very high nematode densities, tubers may become infected, resulting in the appearance of cysts on their surface. Through analysis of soil samples in the laboratory the level of infestation with cysts can be determined.

6 SEED CERTIFICATION

This is an official process of ensuring that the seed potatoes that farmers buy for planting meet the minimum quality standards. It is the responsibility of KEPHIS to inspect all registered seed potato crops in the field, at the handling and storage facilities and also in the laboratory. All inspections are in compliance with the requirements of CAP 326 i.e. Seed and Plant Varieties Act of 2012, laws of Kenya. Only seed potatoes that meet the quality standards of the specified classes are certified by KEPHIS. Certified seed can be recognized by a label attached to the seed potato bag.

6.1 Importance of seed certification

Seed certification assures farmers of trueness to type of the variety and health status of the seed. The use of certified seed together with application of proper agronomic practices is a basic requirement for sustainable potato production that ensures high potato yields of high quality. It is a prerequisite to raising national food and nutrition security and increased income. Any surplus of certified seed may be exported to countries in the region.

6.2 Seed classification system

Seed potatoes are divided into different categories with subdivisions into classes, as follows:

- **Breeders seed:** minitubers, in-vitro plants or healthy mother plants

- **Pre-basic seed:** originating from minitubers or clonal selection
- **Basic seed:** originating from pre-basic class
- **Certified seed:** classes C1, C2, C3 (derived from basic and subsequent certified class)

In table 4, the seed classification system in Kenya is shown as well as the maximum number of generations possible in each seed class. Every season (after each multiplication) the seed potato crops are automatically downgraded one class. Depending on inspection results, further downgrading or rejection may occur. Pre-basic and basic seed classes are to be further multiplied while the certified seed classes are planted to produce ware potatoes.

Table 4. Classification system of seed potatoes in Kenya

Type of material	Seed class	Generation (maximum)
- Healthy mother plants (clonal selection) - *in-vitro* plants, mini tubers	Breeders seed	G0
Tubers	Pre-basic	G1
Tubers	Basic	G2
Tubers	Certified 1	G3
Tubers	Certified 2	G4
Tubers	Certified 3	G5

Source: *CAP 326 i.e. Seed and Plant Varieties Act of 2012*

Note: - Pre-basic and basic seed is produced by KALRO, ADC, Kisima Farm and GTIL.

- Certified seed is produced by seed multipliers.

In tables 5, an example is shown of the classification system of seed potatoes imported from the Netherlands. The first multiplication cycles in the Netherlands follow the Dutch classification system and after export to Kenya the Kenyan classification system is followed.

Table 5. Classification of seed potatoes imported from the Netherlands

Type of material	Seed class	Generation (maximum)	Location of production
- Healthy mother plants (clonal selection) - in-vitro plants, minitubers		G0	Netherlands
Tubers	Pre-basic 1	G1	Netherlands
Tubers	Pre-basic 2	G2	Netherlands
Tubers	Pre-basic 3	G3	Netherlands
Tubers	Pre-basic 4	G4	Netherlands
Tubers	S (basic 1)	G5	Netherlands
Tubers	SE (basic 2)	G6	Netherlands
Tubers	E (basic 3)	G7	Netherlands
Tubers	Certified 1	G8	Kenya
Tubers	Certified 2	G9	Kenya
Tubers	Certified 3	G10	Kenya

***Source**: NAK & KEPHIS, 2016*

Note: Every season seed crops are automatically downgraded one class. Depending on inspection results further downgrading or rejection may occur, so the generations indicated in the table 5 apply to the maximum number of generations possible in each seed class.

6.3 Seed certification procedure

In order to achieve high quality seed several procedures have to be followed. The main certification procedures applied by KEPHIS are:

- Application for certification
- Field inspection
- Post-harvest laboratory testing
- Lot inspection
- Labeling

The application for certification is as below:

A seed grower who is contracted by a registered seed merchant applies to KEPHIS using an appropriate form (SR 5) which must be duly filled (See annex 1).

When the application is received by KEPHIS, it undergoes scrutiny on the source/origin of seed used, ownership, seed field/ location, history of the field where the seed has been planted, date of planting, estimated date of harvesting.

If it complies with all the conditions, and the maximum obtainable class has been defined, the form is recorded and a copy sent to the relevant inspection unit for their inspection planning. The applicant is notified of acceptance of the application. During application the seed merchant is expected to pay the requisite fees for the area planted with seed potatoes.

The seed grower should be knowledgeable in potato production and should have adequate sorting, grading and storage facilities approved by KEPHIS. During the entire period of seed production until the moment that the seed is delivered to the merchant, the seed grower should observe all the rules and procedures as described in the CAP 326 i.e. Seed and Plant Varieties Act of 2012 and the regulations therein as expounded in the approved KEPHIS Inspection Manual.

6.4 Field inspection

Once the forms are received by the inspection unit of KEPHIS, they are arranged based on the planting dates. This then will help KEPHIS to schedule the field inspections accordingly.
Timing of field inspection is very important to ensure that inspectors are able to check for:

a) isolation distance between the seed crop and other potato crops,
b) morphological characters for trueness to type of the variety and for off-types,
c) symptoms and incidence of specified diseases.

A seed crop shall be separated from neighboring ware potato crops or those whose sources are unknown by distances of:

- 100 meters for breeders, pre-basic and basic seed
- 50 meters for certified seed classes I, II and III

However, in cases where the neighboring field has been planted with a seed potato crop, they shall be separated by at least 5 meters for breeders, pre-basic and basic seed and at least 2 meters for certified seed. At least two field inspections shall be made during the active growth stage of the crop; the first being at flowering stage or at canopy close for non-flowering varieties and the second inspection at tuber bulking stage. During inspections, inspectors take scores on the number of off-type plants and plants infected by specified seed borne diseases per count. Off-types are plants that do not conform to the variety being grown. They will then compute and compare with the tolerances for off-types (table 6) and diseases per seed class (tables 7 and 8).

Table 6. Tolerance on off-types during field inspection

Seed Class	**Tolerance (Number of off-types per 100 plants)**
Breeder	0
Pre-Basic	1
Basic	2
Certified 1	2
Certified 2 and 3	3

***Source**: CAP 326 i.e. Seed and Plant Varieties Act of 2012*

A seed crop that does not meet the standard of the seed class for which certification was requested in the application form will be downgraded to a lower class, rejected for sale as seed, or approved for own use by the grower. The inspector may also reject the seed crop if it is excessively weedy or severely lodged to a degree that it adversely affects the inspection and quality of the seed. The results of inspection are communicated to both the grower and the merchant on the same day.

6.5 Sampling for post-harvest laboratory testing

Field inspection is normally carried out by visual assessment of the crop. Inspectors may be supported by appropriate tests when confirmation of the cause of a particular disease symptom is required. For Brown rot (bacterial wilt caused by *Ralstonia solanacearum*) this is done at the second inspection, when the grower is advised on when to de-haulm the seed crop in readiness for tuber sampling. Immediately after de-haulming, a sample of 400 tubers is taken at random per hectare for all seed classes. For seed fields less than 0.5 ha, a sample representing 1 % of the total plant population is taken and delivered in nets or any appropriate bags immediately to the laboratory for the Brown rot (bacterial wilt) test. Normally, the results of the tests are available 14 days after sample delivery at either Plant Quarantine and Biosecurity Station-Muguga or KEPHIS-Nakuru. Positive test results on bacterial wilt or any other disease shown in table 7 leads to rejection of the seed crop. The merchant is allowed to dispose the rejected potatoes appropriately to avoid spread of such diseases.

Table 7. Seed borne potato diseases that have zero tolerance

Disease	**Tolerances in all seed classes**
Bacterial wilt or Brown rot (*Ralstonia solanacearum*)	Nil during any inspection
Wart disease (*Synchytrium endobioticum*)	Nil during any inspection
Golden nematode (*Globodera rostochiensis*)	Nil during any inspection
Ring Rot (*Clavibacter michiganesis*)	Nil during any inspection
Potato Spindle Tuber Viroid	Nil during any inspection
Mycoplasma	Nil during any inspection

Source: *CAP 326 i.e. Seed and Plant Varieties Act of 2012*

Table 8. Seed borne potato diseases and their tolerances per seed class during field inspection

Potato diseases	**Tolerance (number of diseased plants per thousand plants)**				
	Breeder / Minitubers	Pre-basic	Basic seed	Certified seed 1	Certified seed 2 and 3
Blackleg (*Pectobacterium* spp. and *Dickeya* spp.)	0	0	0	0	0
Severe virus disease e.g. PLRV, Y group of viruses, severe mosaic	0	1	4	8	10
Mild mosaic visible in the field (e.g. PVX, PVS)	0	0.3	0.3	2	5
Fusarium wilt	0	0	0	2	5
Verticillium wilt	0	0	0	0.5	1
Bacterial wilt or Brown Rot (*Ralstonia solanacearum*)	0	0	0	0	0
Wart disease (*Synchtrium endobioticum*)	0	0	0	0	0
Nematodes (*Meloidogyne* spp., *Ditylenchus* spp.)	0	0	2	3	4
Golden nematode (*Globodera rostochiensis and Globodera pallida)*	0	0	0	0	0
Ring rot (*Clavibacter michiganensis subsp. Sepedonicus)*	0	0	0	0	0
Potato spindle tuber viroid	0	0	0	0	0
Phytoplasma diseases e.g. Potato stolbur and potato purple top	0	0	0	0	0

***Source**: CAP 326 i.e. Seed and Plant Varieties Act of 2012*

6.6 Lot inspection and labeling

Once the results of the laboratory tests show that the seed is free from the stated diseases, the grower is allowed to sort tubers to ensure that the damaged, rotten, misshapen and diseased tubers are removed from the seed lot. Then, the tubers are sized into size I (25-35mm), size II (36-45mm) and size III (46-55mm) and packed in 50 kg new sisal bags. During lot inspection, the inspector picks bags of seed at random and empty's the seed on to clean polythene sheet and checks for:

- conformity to specified seed size (Size I i.e. 28 to 45 mm and Size II - 45 to 60 mm)
- diseases and defects (as per table 9 below)
- physiological condition (soft tubers)

In terms of seed size, not more than 5 tubers are allowed to deviate from the indicated seed size per bag of 50 kg. If it exceeds this number, the grower is advised to repeat the size grading of the seed lot and recall the inspector for confirmation.

Table 9. Tolerances for diseases, pests and defects during lot inspection

Disease/pest/defect	**Tolerance (number of tubers per 50 kg bag)**	
	Basic seed	Certified seed
Scab (Streptomyces spp, *Spongospora subterranean*)	25	50
Rhizoctonia (*Rhizoctonia solani*)	10	30
Pink rot (*Phytophthora erythroseptica*); Soft rot (*Erwinia* spp)	0	1
Severe tuber moth	2	5
Mis-shapen and damaged tubers	0	5
Late blight (*Phytophthora infestans*)	3	3
Early blight (*Alternaria Solani*)	6	6
Gangrene (*Phoma* spp.)	6	6
Wet rot (*Erwinia spp*)	6	6
Dry rot (*Fusarium spp.).*	6	6
Nematodes (i.e. *Meloidogyne* spp. and *Ditylenchus* spp.)	5	5

***Source**: CAP 326 i.e. Seed and Plant Varieties Act of 2012*

When size grading has been completed and the seed meets the lot standards, labels are then ordered from KEPHIS by the merchant according to number of bags of each size.

6.7 Labeling and sealing

It is the duty of the inspector to affix the official label to the seed bag at the appropriate position as a mark of quality. Only seed lots that meet the standards referred to in CAP 326 i.e. Seed and Plant Varieties Act of 2012 are labeled and sealed. Such labeled seed can be offered for sale as certified seed.

6.8 Dispute resolution

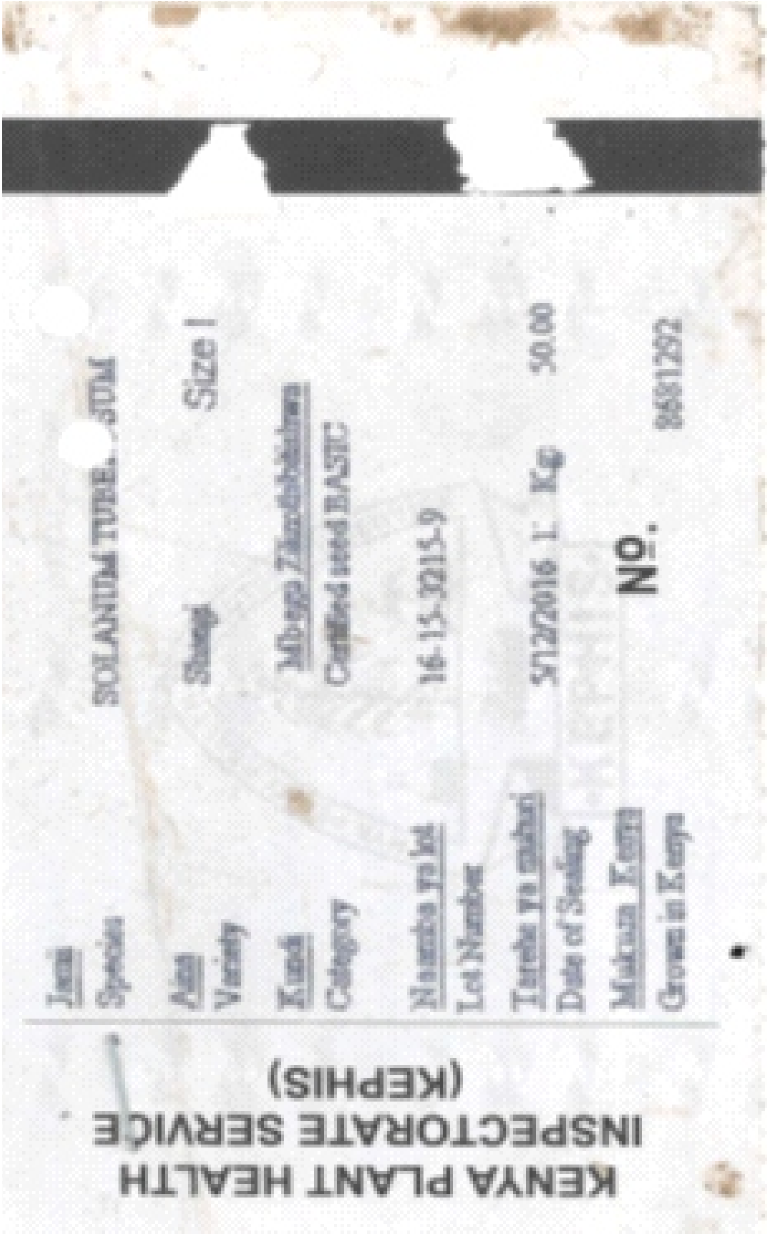
In cases where the merchant disputes the verdict of the inspector at any stage of inspection, a senior team of inspectors is constituted by KEPHIS management to review the case. However, where such disputes are not resolved, the Seed and Plant Tribunal will be called to arbitrate under CAP 326 i.e. Seed and Plant Varieties Act of 2012. If it fails to do so, then the case is filed at a law court. Usually most technical aspects are resolved at senior team level.

6.9 Seed classes, colour of labels and details on the label

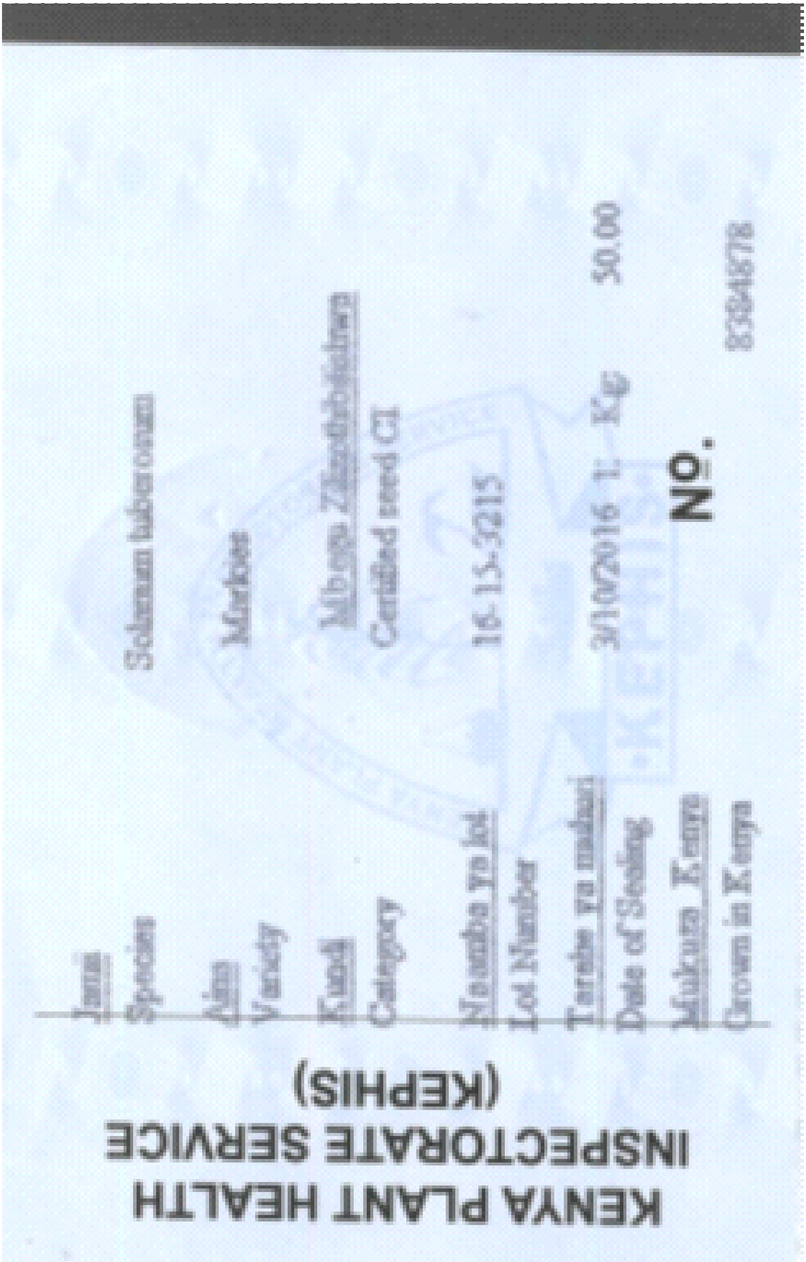
Labels (Fig. 4) have different colours based on the class of seed being labeled according to OECD Seed Scheme as follows:

- Breeder, Pre-basic and Basic seed: White
- Certified seed I: Blue
- Certified seed II and III: Pink

The details on the label include: crop species, variety, seed class, seed size grade in mm, grower number, lot number, packaging unit (kg), year of production, date of certification, country of production, unique certificate's number.



Pre-basic and basic seed class


KENYA PLANT HEALTH INSPECTORATE SERVICE (KEPHIS)

Jamii / Species: Solanum tuberosum
Aina / Variety: Markies
Kiasi / Category: Mbegu Zilizothibitishwa / Certified seed C1
Nambari ya lot / Lot Number: 16-15-3215
Tarehe ya muhuri / Date of Sealing: 3/10/2016 1 Kg 50.00
Mukuza Kenya / Grown in Kenya
NO. 8384878

Certified seed class, first generation (C1)

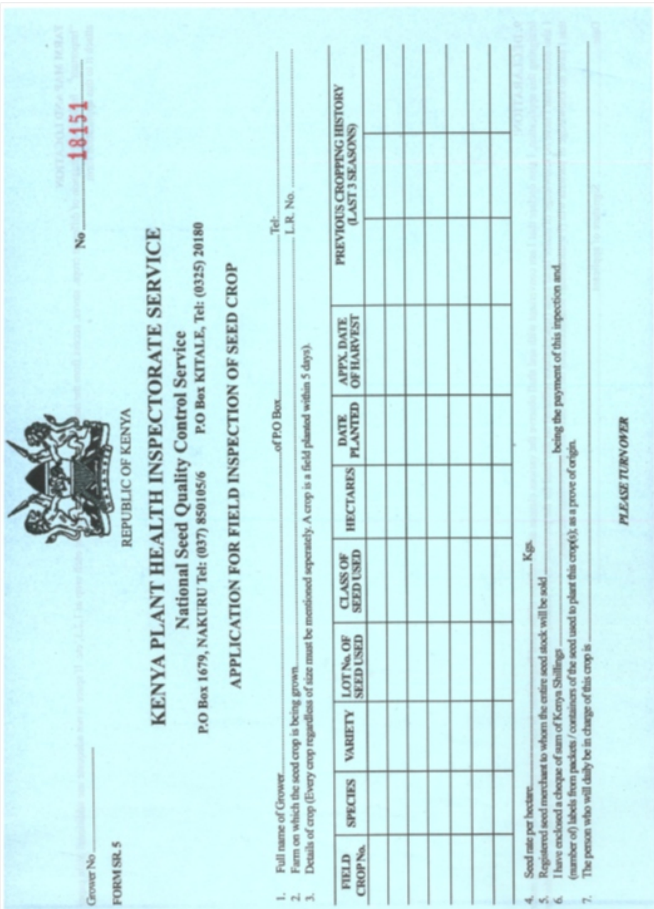
Certified seed class, second and third generation (CII and CIII)

Fig.4. Depicting various labels for the different seed potato classes (i.e. Pre-basic and basic seed class, C1, CII and CIII)

Note: For further reading on principles and practices of seed potato production and certification the reader is referred to the book on Seed Potato Technology (Struik and Wiersema, 1999).

7 ANNEXES

7.1 Annex 1 Application form for Field Inspection of Seed Crop (SR 5)



Grower No. ______ No. 18151

FORM SR 5

REPUBLIC OF KENYA

KENYA PLANT HEALTH INSPECTORATE SERVICE

National Seed Quality Control Service

P.O Box 1679, NAKURU Tel: (037) 850105/6 P.O Box KITALE, Tel: (0325) 20180

APPLICATION FOR FIELD INSPECTION OF SEED CROP

1. Full name of Grower .... of P.O Box .... Tel: ....
2. Farm on which the seed crop is being grown .... L.R. No. ....
3. Details of crop (Every crop regardless of size must be mentioned seperately. A crop is a field planted within 5 days).

FIELD CROP No.	SPECIES	VARIETY	LOT No. OF SEED USED	CLASS OF SEED USED	HECTARES	DATE PLANTED	APPX. DATE OF HARVEST	PREVIOUS CROPPING HISTORY (LAST 3 SEASONS)

4. Seed rate per hectare .... Kgs.
5. Registered seed merchant to whom the entire seed stock will be sold ....
6. I have enclosed a cheque of sum of Kenya Shillings .... being the payment of this inspection and (number of) labels from packets / containers of the seed used to plant this crop(s); as a prove of origin.
7. The person who will daily be in charge of this crop is ....

PLEASE TURN OVER

FARM MAP AND LOCATION

"Important" - Indicate the situation of different crops, stores, access from the nearest road and then number each crop as 1,2,3, etc. If space is not adequate use additional plain paper a attach it to this application form.

9. DECLARATION!

In signing this application, I also declare that I am conversant with and shall observe the various clauses and condition of the seed Regulation. In case this application is for seed maize I also declare that I have no knowledge of maize head smut (spacelotheca reiliana) on this land for the previous three seasons. In case this application is for seed potatoes, I also declare that I have no knowledge of bacteria wilt (Pseudomonas solanacearum) on this farm for the previous six years.

Date.................................... Signature of applicant..

8 REFERENCES

Gildemacher, P.R., Paul, D., Baker, I. Kaguongo, W., Woldegiorgis, G., Wagoire, W.W., Wakahiu, M., Leeuwis, C. & Struik, P. C. (2009). A description of seed potato systems in Kenya, Uganda and Ethiopia. Potato Research, 86, 373-382.

Janssens, S.R.M., Wiersema S.G., Goos H., &. Wiersma, W. (2013). The value chain for seed and ware potatoes in Kenya. Wageningen UR, Den Haag: LEI.

Lung'aho C., Lemaga, B., Nyongesa, M., Gilemacher, P., Kinyae, P., Demo P. & Kabira, J. (2007). Commercial seed potato production in eastern and central Africa. Nairobi.

Machangi J. M., Gathumbi, M., Onchieku, P., Nga'nga, N., Kagundu A., Kibet, S., Muchoki, J., Dinah, B. (2016). The National Potato Strategy 2016 – 2020. Nairobi: Ministry of Agriculture, Livestock and Fisheries.

Ministry of Agriculture, Livestock and Fisheries. (2015). Draft Root and Tuber Crops Policy. Nairobi: State Department of Agriculture, Crops Directorate, Kilimo house.

NPCK. (2015). The potato variety catalogue 2015. Nairobi: Eagle Creations.

O'Connor, A. F., & Wamache, A. K. (2012). Kenya Seed Industry study. Nairobi: Agri-Experience.

Oyoo J. & Hennessy, M. (2016). Diseases and Physiological Disorders of Potatoes in Ireland. A Potato Factsheet. Retrieved from www.teagasc.ie.

Seeds and Plant Variety Act, CAP 326. (2012). Nairobi.

Singh, R. P. (1999). Development of the molecular methods for potato virus and viroid detection and prevention. Genome, 42, 592-604.

Struik,P.C., & Wiersema, S.G. (1999). Seed Potato Technology. Wageningen: Wageningen Press.

Teagasc. (2016). Irrigation Fact sheet. 31 Deansgrange Road, Blackrock, Co. Dublin: IFP Media.

United Nation Economic Commission for Europe, (2015). Guide to Seed Potato Field Inspection: Recommended Practices. New York.

Valkonen, J. P. T. (2007). Viruses: Economical losses and biotechnological potential. In Potato Biology and Biotechnology (pp. 619-641). San Diego. CA: Elsevier Academic Press.

Wangai, A. & Lelgut, D. (2001). Status of potato viruses in Africa. In J. d'A Hughes, & B. O. Odu, (Eds.), Proceedings of a conference on Plant virology in sub-Saharan Africa organized by IITA, June 4-8 2001, Ibadan, Nigeria (pp. 458- 465).