



A GUIDE TO POTATO PRODUCTION AND POSTHARVEST MANAGEMENT IN KENYA

2013

TABLE OF CONTENTS

Foreword.....	1
Acknowledgement	2
1) Introduction	3
2) Land preparation and management.....	5
2.1) Site selection	5
2.2) Land preparation	6
2.3) Variety selection.....	7
2.4) Seeds	7
3) Planting practices	7
3.1) Planting and spacing	7
3.2) Fertilizer and manure application	8
4) Crop management.....	9
4.1) Weed Control	9
4.2) Ridging/earthing up	9
4.3) Water management and irrigation.....	10
4.5) Potato diseases	10
4.4.1) Late blight.....	11
4.4.2) early blight.....	12
4.4.3) Black Scurf.....	14
4.4.4) Blackleg and soft rot	15
4.4.5) Bacterial wilt	17
4.5) Virus diseases	18
4.6) Insect pests and nematodes.....	21
4.6.1) Aphids.....	21
4.6.2) Potato tuber moth.....	22

4.6.3) Cutworms	25
4.6.4) Leaf eating caterpillars, beetles and spider mites.....	27
4.6.5) Root-knot nematodes.....	27
4.7) Crop rotation.....	28
4.8) Elimination of volunteers.....	30
5) Harvest Management	31
5.1) Dehauling.....	31
5.2) Harvesting.....	31
6) Postharvest practices	32
6.1) Drying and Curing	32
6.2) Sorting, grading, storage and packaging	32
7) Profitability analysis.....	36
8) Support services.....	38
8.1) Financial	38
8.2) Extension and advisory services.....	38
8.3) Laboratories	38
8.4) National Potato Council of Kenya.....	38
8.5) Kenya National Potato Farmers Association	39
8.6) Kenya National Federation of Agricultural Producers (KENFAP).....	39
9) References	40

Foreword

As an important food and nutrition security crop; Potato is a high yielding productive vegetable providing jobs for millions of people in Kenya. The crop produces more food per unit area and per unit time than wheat, potato rice and maize. It has a short and highly flexible vegetative cycle, and is ready for harvesting within 3-4 months of planting. It also fits well with double cropping and intercropping systems. One of the crop's many other assets is its adaptability which enables it to grow at most altitudes and as an off-season crop. Moreover it is rich in protein, calcium, potassium, and vitamin C with good amino acid balance.

Unlike major cereal commodities, potato is thinly traded in the global food markets. Only a fraction of its total production enters foreign trade, mainly as processed products. Thus, potato prices in Kenya are determined by local demand and supply conditions, not the vagaries of international markets. Potato is therefore, a highly dependable food security crop that can help ease imbalances in Kenya's food supply and demand.

Potato forms a major ingredient in weaning foods for young children. The crop is very important in generating employment along the value chain including production, marketing and processing sectors and has a high potential as an industrial crop in the manufacture of starch, alcohol and animal feeds. Potato starch can find numerous uses in manufacturing of foods and other products.

This manual is a guide in the production of potatoes in Kenya, focusing on ware potato production. In general, however, any advice that relates to high yield and quality tuber production is applicable to seed potato seed production too. The manual will therefore be useful to all stakeholders in the potato industry wishing to learn more about the crop.

Acknowledgement

We wish to acknowledge various contributions made to this manual without which this document would not have been a reality. Broadbased Exploration Studies Consortium (BESC) conducted the review of current ware potato production practices in Kenya. The USAID funded Kenya Horticulture Competitiveness Project (KHCP) provided resources for carrying out the study. The manuscript was reviewed by Dr. John Mutunga (KENFAP), Ms. Daphne Muchai (KENFAP), Dr. Jackson Kabira (KARI-Tigoni) and Professor John Huria Nderitu (NPCK), Mr. Peter Mwangi (BESC) and Mr. Amos Waweru (BESC). Special thanks go to the study coordinators, Mr. Livingston Ochwada (KHCP) and Wachira Kaguongo (NPCK) for guidance and advice.

1) Introduction

Produced in the Kenyan highlands, potato in Kenya continues to gain importance being the second most important food crop after maize while globally it comes fourth after rice, wheat and maize. With the current maize necrotic virus disease and food insecurity, the crop is likely to take precedence with the current per capital consumption rate being estimated at 33 kg per person. The crop requires wet climatic conditions and slightly acidic soils, therefore the main potato growing counties in Kenya include; Nyandarua, Bomet, Meru, Nakuru, Uasin Gishu, Kiambu, Narok, Nyeri, West Pokot and Keiyo Marakwet.

With high urban population in the world, potato has become the most consumed food due to its ease of cooking and its presentation in fast food outlets. The crop has many uses which include: culinary of alcoholic beverages; feed for domestic animals; industrial states for food thickening and binders in soups and sauces adhesives, in the textile industry, manufacturing of papers and boards. The importance of potato as a food crop is due to its ability to be converted into many forms of food varieties ranging from chips, crisps, baked potatoes, and mashed potatoes, amongst many others. These potato dishes are easy to prepare and consume very little time and energy. Furthermore, potatoes are rich in vitamins and minerals. It is believed that humans can survive on a potato diet with milk and butter supplements which contains vitamins A and D that potatoes do not provide. They are commonly known for their carbohydrates that are converted to starch useful in the body and even at industrial level for many uses as discussed earlier.

In addition, potato peelings and stems can be incorporated into animal feeds making it nutritious and cutting on the cost of feeds. Moreover, as an agricultural waste, potato peels could be an important source of household energy through decomposition in production of biogas.

The crop can be produced commercially and this poses business opportunity for anyone wishing to venture into farming. There is a lot required at this level for it to be a worthwhile investment. To start with, one requires appropriate choice of varieties so as to maximize on production within the shortest duration of time possible. There are many high yielding varieties that have

been introduced in the market which include Sherekea producing approximately 160 bags on an acre of land and Kenya Mpya yielding approximately 140 bags per acre. These are just a few examples of the many superior varieties released in the market by KARI. They are known to be fast maturing, taking around 3 months to fully get ready for harvesting.

Good agricultural practices (GAPs) are another essential aspect, since potatoes are a very sensitive crop requiring maximum care and attention. Most farmers, however, ignore this demand thus registering very low yield that makes it unprofitable and demoralizing to most. It is tedious and costly but the returns are rewarding. Potato cultivation involves proper land preparation, appropriate furrow and tuber spacing, weeding, earthing-up, integrated pest management, and appropriate harvest time. It is important to have a cropping calendar that guides a farmer in the appropriate time to plant and also harvest. This is necessary because it is possible to produce the crop three times in a year with appropriate timing. Furthermore potato prices fluctuate considerably, at times being as low as Ksh 500 per bag during peak season and Ksh 3,000 during the off- season.

The major crop diseases affecting potato production are potato late blight, bacterial wilt and a variety of viral diseases. Other potato diseases include black leg and powdery mildew. Insects that commonly transmit potato diseases or damage the plant include the potato beetle, the potato tuber moth, the green peach aphid the potato aphid, beet leafhoppers, thrips, and mites. The potato root rot nematode is a microscopic worm that thrives on the roots, thus causing the potato plants to wilt. Since its eggs can survive in the soil for several years, crop rotation is recommended. There exist fungicides and pesticides for their control and great care is important when choosing them due to pest or disease resistance.

The other crucial aspect is potato storage which can range from cheap indigenous local storage techniques to costly sophisticated cold stores. The choice depends with the farmer among other things and this would affect the duration of storage. Sophisticated cold rooms, coupled with proper variety and appropriate hygiene could store potato tubers for up to 12 months when stored at home, mature potatoes optimally kept at room temperature lasts 1 to 2 weeks in a paper bag, in a dry, cool, dark, well ventilated location. It is important to note that, storage

facilities need to be carefully designed to keep the potatoes alive and slow the natural process of decomposition, which involves the breakdown of starch. It is crucial that the storage area is dark, well ventilated and for long-term storage, maintained at temperatures near 4 °C , in case of short-term storage before cooking, temperatures of about 7 °C to 10 °C are ideal.

Small-scale farmers produce well over 60% of the potatoes produced in Kenya there is therefore need for a farmer friendly guide to provide the much needed information towards enhanced productivity of the crop.

2) Land preparation and management

2.1) Site selection

The most favourable climatic conditions are found in areas with an annual rainfall of between 850 mm and 1200 mm and at altitudes between 1400 m and 3000 m above sea level. These areas are situated mainly in the Central, Rift Valley and Eastern provinces of Kenya. Where possible, potatoes should be grown on land where potatoes and other solanaceous crops (such as tomatoes) have not been in the previous season. This is necessary to avoid volunteer crops (potato crops are plants from the previous crops which could harbour pests and diseases) and for control of soil-borne pests such as nematodes and diseases such as bacterial wilt.

For a growing site, soil structure, nutrition, pests and disease status is important. Recognizing of this factor ensures that the soil are suitable in order to have pest and diseases risks well managed. Regular laboratory and field testing of soil to determine fertilizer requirements is important and an agricultural extension officer or an expert should be consulted.

2.2) Land preparation

Being a tuber crop, potato requires soft soil for the development of uniform, large and smooth tubers. To achieve these requirements, raised seedbeds are made after a thorough and deep cultivation of soil. All stubbles and organic matter that is feared not to decompose quickly must be removed. Ploughing the land 20 cm deep and breaking clods to obtain fine, firm and weed-free surface is very important. In general, it is easier to work the land before onset of rains. Proper soil preparation also allows for aeration, free drainage and management of weeds. It also aids the decomposition of other crop residues. A well prepared field and a poorly prepared field have been illustrated in the picture below (Fig. 1 and Fig. 2).



Fig 1: A well-prepared field



Fig 2: A poorly prepared field

2.3) Variety selection

Variety selection depends on many factors. The primary determinant is the purpose for which the potato is grown. For example, if the variety is meant for production of ware potatoes, the choice will favour those that give maximum returns in the local market. The variety for contract farming is selected by the organization that will receive the potatoes ware. Examples of potato varieties in Kenya can be found in the seed potato catalogue published by the National Potato Council of Kenya (NPCK).

2.4) Seeds

Farmers should obtain seed stock from recognized sources such as research stations and registered seed producers. Good quality seed will minimize build-up of diseases and pests will result in high yields. Growers should contact agricultural experts for advice on the type of seeds to grow in an area and on where to source the seeds from. The seed to be planted must be of a variety adapted to the area, should be uncut and should be free from seed-borne diseases, like bacterial wilt (*Ralstonia solanacearum*) and viral diseases. The soil-borne disease organisms, once introduced, can persist in the soil especially when crop rotation is not possible or not practised.

3) Planting practices

3.1) Planting and spacing

Planting should coincide with start of the rains so as to maximize on water utilization. The seeds should be placed on the furrows with the sprouts facing up. The planting and furrow depth should be 8 to 12 cm. Plant seed tubers in furrows at a spacing of 75cm between rows and 30 cm within rows with the sprouts facing up for faster and uniform germination (see Fig 3 below). This gives a plant population of 44,400 tubers per hectare (18,000 plants per acre). This spacing allows for cultural practices such as scouting for diseases and pests, spraying, rouging and harvesting to be

carried out easily. Potatoes should be planted in ridges at a height of 25 cm to allow for tuber expansion and easy harvesting.



Fig: 3. Recommended plant spacing (75cm between rows and 30cm within rows)

3.2) Fertilizer and manure application

Soil testing is very important in the determination of a fertilization scheme. The following recommendations are blanket recommendations for fertilizers. Farmers ought to obtain expert advice on fertilizer application. Di-ammonium phosphate (DAP18:46:0) at 500 kg per hectare should be applied in the furrows. Thorough mixing of the fertilizer with soil before planting prevents scorching of sprouts by the fertilizer. Single or triple superphosphate (TSP) can also be applied as source of Phosphate. Calcium ammonium nitrate (CAN) can be top dressed during ridging as a source of nitrogen (N) at 300 kg per hectare. Acidic soils require application of lime to neutralize the acidity. Other fertilizers that can be used are triple super phosphate (TSP) at 500 kg per hectare with 300 kg CAN per hectare as a top dress after crop emergence. Where potassium levels are low, Muriate of Potash should be applied at 50 kg per hectare in addition to the N and P fertilisers.

Only well decomposed manure could be used so as to avoid the spread of black leg and sprout scorching. In general, the application rate of manure is 2-4 tones/acre when there is a lot of rain, side dressing may be re-done to replenish nutrients that are leached away by rain. The advice of an agricultural expert should be sought for whenever clarity on such issues is done. For top dressing, the fertilizer should be placed at the side of the plants and this is best done in wet conditions. Heavy fertilization of potatoes with nitrogenous fertilizers should be avoided because it encourages excessive foliage growth, delays tuber growth and may produce tubers with hollow centers.

4) Crop management

4.1) Weed Control

Weeding commences 2 to 3 weeks after planting. It is important to note that the weed situation is an important determinant of when weeding should be done. Weeds are usually removed to prevent them competing with the potato crop for moisture, light, nutrients and space, thereby reducing yields. Contact herbicides can also be used for weed control and prior tests of herbicides should be done before whole farm application is done. It is extremely important to consult an agricultural expert before use of any herbicides.

4.2) Ridging/ earthing-up

Ridging, which is usually done during the second weeding, prevents greening of exposed tubers, infestation by potato tuber moth and reduces internal brown spot caused by high soil temperatures. Ridging also prevents tubers from water logging in flooded fields. Ridging or earthing-up should be done along the rows as the potatoes grow and preferably during weeding. The final ridge should be about 25 cm high. Ridging should be avoided when the soil is too wet to minimise soil compaction and spread of fungal diseases like late blight. Regular inspection of tuber development will determine when earthing up should be stopped.

4.3) Water management and irrigation

Potatoes require good soil moisture levels throughout the year. The crop requires between 400mm to 800mm of water in a growing season. Most of the water used by the plants is taken up from the top 30 cm of the soil. Mulching around the plant will conserve soil moisture. Irrigation should be done such that moisture goes deep into the soil. Irregular watering (over or under watering) can cause abnormal tuber growth like knobs and cracks. Towards the end of the season when the plants begin to yellow and the leaves start dying, the amount of water applied via irrigation should be reduced gradually as the crop water requirement reduces. It should be noted that wet conditions late in the season contributes to tuber rot in storage.

Potatoes are sensitive to water stress after tuber initiation which is also the time when flowering commences. Water shortage during tuber initiation, flowering and when haulms start browning, will lead to misshapen tubers. Overhead irrigation when used should be done during the early hours of the day to reduce evaporation and to avoid wetting plants before nightfall. If possible, irrigate with 25-30 mm in one application since soils used to grow potatoes have a high infiltration rate and are not very prone to crusting. The crop should be watered thoroughly during dry spells or low rainfall, especially during tuber enlargement. Moist soil helps keep tubers cool during excessively hot weather. Furrow irrigation should be avoided in favour of sprinkler or drip irrigation.

4.5) Potato diseases

There is a relationship between the susceptibility of the crop, environmental factors and the presence of disease inoculum in a growing situation. Understanding and control of plant diseases therefore means that the farmer should understand these interrelationships. Crop diseases incidences increase when the environment is suitable and when the crop is susceptible. Suitable environment for plant diseases are usually temperature and relative humidity conditions. Susceptibility of the crop could be due to natural susceptibility, water stress and any other kind of stress.

Regular field inspections to monitor growth and performance of the crop should be carried out. Rouging which involves uprooting and destroying diseased plants and host weeds reduces build-up of pathogens in soil and the number of infected tubers thus reducing the inoculum level in the field. Rouging will target plants with bacterial diseases and viral diseases. These diseases cannot be cured and rouging will protect the healthy crop. Heavy presence of pests and infection by fungal diseases may require particular sections to be uprooted. Please see the section on pest and disease management for guidelines on identification of infected and infested plants. It should be noted that uprooted plants should not be used as animal feed or to make manure as they may return to the field in form of infected manure. The major diseases that affect potatoes are outlined below.

4.4.1) Late blight

4.4.1.1) Description of late blight

Late blight (*Phytophthora Infestans*) is the most economically important potato disease in Kenya. It spreads rapidly under cool humid weather through infected tubers and causes big economic losses particularly during the long rains seasons. Symptoms include water soaked lesions on the foliage, which turn brown when dry and black when wet. The spots can also occur on the tips of the stems, which turn black and die. On the underside of the leaf the fungus produces a white mouldy growth that is seen more clearly at the edges of the spots.

4.4.1.2) Damage by late blight

The disease attacks leaves and stems and in advanced stages of infection it may enter tubers (Fig. 4). An infected crop loses all foliage in a few days while infected tubers have sunken, grey spots, slightly depressed brown-purplish skin that reveals a reddish-brown rot below the surface when cut.



Fig. 4: Symptoms of Late blight on plant and tubers

4.4.1.3) Control of late blight

The disease is controlled using fungicides on the advice of agricultural officers. Spraying should begin when the plants are 10 cm tall. Spraying should be carried out as a preventive measure, especially if the variety grown is susceptible. For those varieties with some resistance, spraying should commence when the first disease symptoms are noticed. It is important to spray on the underside of the leaves since wetting the topside of the leaves only does not give effective control because of inadequate coverage.

4.4.2) Early blight

4.4.2.1) Description of early blight

Early blight (*Alternaria Solani*) is often more severe during the end of the growing season. Symptoms include dark brown spots, also called target spot, with concentric rings on the oldest leaves (Fig. 5). These spots enlarge when it is damp and spots appear to have a series of slightly raised target-like rings. The disease thrives in heavy dew, frequent rainfall and warm conditions. It occurs in dry spells, particularly when the crop is under irrigation. The disease is spread by air, rain splash or irrigation.

4.4.2.2) Damage by early blight

In humid areas, all leaves may be affected but in dry areas only the lower leaves are affected. The plant is defoliated when the infection is severe.



Fig. 5: Symptoms of early blight

4.4.2.3) Control of early blight

Cultural control of late blight

The disease can be avoided by maintenance of field sanitation, crop rotation, use of clean seeds, and rouging.

Chemical control of early blight

Contact fungicides are used to prevent the establishment of the disease by providing a surface

coating. Systemic chemicals are usually used for curative purposes where disease symptoms have been noticed. Systemic chemicals usually have preventive effects too

4.4.3) Black Scurf

4.4.3.1) Description of Black Scurf

Black scurf (*Rhizoctonia Solani*) is present in many soils and causes damage to many crops. The disease is common in potatoes planted next to organic matter. Symptoms include irregular emergence with a number of poor uneven stands, stunted growth, and development of aerial and deformed small tubers. A white mass of fungus develops at the base of the stalks particularly in dense crops. Mature tubers have black specks (called sclerotia) which fall off with the skin when rubbed.

4.4.3.2) Damage by black scurf



Fig. 6: Symptoms of Black Scurf

The disease damages emerging sprouts when conditions do not favour rapid emergence such as cold or wet soil. Rolling of the base of leaves of infected plants occurs leading to poor crop establishment and performance.

4.4.3.3) Control of black scurf

Cultural control of black scurf

The disease can be avoided by crop rotation with non-host crops as described in the crop rotation section. Avoiding water logging, planting certified seed or good quality seed, or treating seed before sprouting also controls black scurf. Well-decomposed farmyard or compost manure should be well mixed with the soil before planting. Pre-sprouting of seed reduces the risk of the disease.

Note: Avoid dipping sprouted tubers in chemicals since chemicals can damage sprouts.

Chemical control of black scurf

Fungicides are used as seed dressing before planting or for application on a growing crop.

4.4.4) Blackleg and soft rot

4.4.4.1) Description of blackleg and soft rot

Blackleg (*Erwinia Carotovora*) affects potato plant while soft rot affects tubers. The disease can occur at any stage of crop development when moisture is excessive. Symptoms include yellowing and upward rolling of leaflets, finally wilting and dying. Due to interaction with soft rot causing bacteria, the rot caused by blackleg may turn into soft rot following mechanical tuber injury by pests and diseases when tubers are in transit or in storage or by field implements.

4.4.4.2) Damage by blackleg and soft rot

Wilting of plant stems occurs and rotting of tubers occurs. This reduces yield significantly.



Fig. 7: Symptoms of black leg and soft rot

4.4.4.3) Control of blackleg and soft rot

Cultural control of blackleg and soft rot

The disease can be avoided by planting certified seed and avoiding tuber injury, not injuring tubers, planting at wide spacing for good aeration and proper nitrogen and calcium nutritional planting. Furrow irrigation should be avoided in favour of drip and sprinkler irrigation. Rouging removes diseased plants from the crop.

Chemical control of blackleg and soft rot

The use of fungicides can effectively control black leg. The grower should read and follow label instructions.

4.4.5) Bacterial wilt

4.4.5.1) Description of bacterial wilt

Bacterial wilt (*Ralstonia Solanacearum*) affects more than 30 plant species, the most susceptible being potato, tomato, eggplant, pepper, banana, and roundnut. Bacterial wilt is spread by infected seed tubers, crop residues, contaminated irrigation water, contaminated soil adhering on shoes, and tools as long as machinery. The disease enters potato roots through wounds made by tools during post-emergence cultivation and through attack by nematodes and insects.

4.4.5.2) Damage by bacterial wilt

Infected plants wilt even when the soil has sufficient moisture. The leaves droop and eventually the plants die (See Fig. 8 below).



Fig. 8: Symptoms of Bacterial wilt on plants and tubers

4.4.5.3) Control of bacterial wilt

Bacterial wilt has no known chemical control measure. Bacterial wilt can only be controlled (or even eradicated) using an integrated disease management approach involving the planting of healthy seed in clean soil, rotation with non-susceptible crops and in fields previously not

occupied by solanaceous crops. To ensure that the damage is not due to insects, cut a tuber from the wilted plant and squeeze it. If a white mass of bacteria oozes out, this shows that bacterial wilt is the likely cause of the wilting. Latent infections however cannot be detected by this test and may require the use of more advanced tests including laboratory investigations. Many weeds are alternative hosts for bacterial wilt and must be removed to reduce the pathogen load in the soil. Rouging of volunteer potato plants during crop rotation before planting potato is equally important. In cool conditions especially at altitudes above 2500 m, infected but symptomless plants may harbour the bacterium and transmit it to progeny tubers as latent infection, leading to severe disease outbreaks when the tubers are grown at warmer lowland locations.

4.5) Virus diseases

Virus diseases cause degeneration of seed potatoes. Leaf roll and several mosaic viruses are the main causes of seed degeneration. Infected seed produces tubers with low yields at each successive season. Areas meant for seed production must be carefully selected to minimise infection.

4.5.1) Description of Potato Leaf Roll Virus

Potato leaf roll virus is spread by aphids. The virus is also spread through infected tubers, aphids and diseased volunteer plants. Symptoms in full appear 2-3 weeks after crop emergence. In primary infections, symptoms first appear at the top of the plant where the leaves roll inwards and turn pale yellow; some may develop yellow margins. In secondary infections, the entire plant is affected; all the leaves roll inward, especially at the base of the plant, than at the top where the old leaves are clearly rolled. Young leaves are smaller than healthy ones.

4.5.2) Damage by Potato Leaf Roll Virus

Growth is stunted and plants develop small tubers. If the resulting tubers are used as seeds, the plants are stunted and the crop produces very low yields.



Fig. 9: Symptoms of Potato Leaf Roll Virus

4.5.3) Control of Potato Leaf Roll Virus

Ensure proper control of aphids.

4.5.4 Description of Mosaic Viruses

Potato virus Y (PVY) is transmitted by aphids and is spread through infected tubers. It is easily transmitted and can cause major yield losses alone or in combination with other viruses such as Potato Virus A, Potato Virus X or Potato Virus. Mild mosaic, caused by potato virus A (PVA) is common in all potato producing areas. High yield losses may occur in some varieties when PVA occurs in combination with PVY or PVX. Potato virus A is similar to PVY in many aspects and is generally less severe in certain cultivars. Potato virus X is transmitted through infected tubers and by contact (not by aphids) and usually causes mosaic. Infection may be mild in certain cultivars and is frequently latent. Potato virus S is common and may cause mild symptoms. It has little effect on yield. It is transmitted through infected tubers, by contact and by aphids. Infection is usually latent, although some cultivars react with mild mosaic. Potato virus M is less common than Potato Virus Y, Potato Virus X or Potato Virus S, and little is known on its effects on yield. It is spread by infected tubers and transmitted through contact and by aphids. The virus is latent in some cultivars although in others it causes a mild mosaic or severe mosaic and leaf crinkling.

4.5.5) Control of mosaic viruses

While Potato Leaf Roll virus can be avoided by planting good quality seed and eliminating diseased plants through rouging mosaic viruses can be avoided by clonal selection during seed multiplication. Rouging is useful only when obvious symptoms develop. Volunteer potatoes that can harbour insects must be eliminated. Diseased plants should be removed early and haulms removed and destroyed early as well. Keeping the field disease free throughout the season is the best way to control insect borne viruses.

4.5.6) Damage by mosaic viruses

The viruses cause mosaic (speckled appearance-see Fig.10 below) as well as crinkling and leaves may appear shiny. Plants are stunted and productivity drops. In subsequent generation production drops to very low level that are unsustainable.



Fig. 10: Mosaic on potato

4.6) Insect pests and nematodes

Insect pests attack ware and seed potato in the field and in storage. The most important ones include aphids, potato tuber moth, cutworms, leaf eating caterpillars, beetles and spider mites. Nematodes are major potato pest affecting potato production.

Insecticides can be contact, systemic or a combination of these. In general, systemic insecticides are used to control sucking insects and are a good option where the behaviour of the insect prevents proper contact of the insecticide with the insect. However, systemic chemicals can be slow acting compared to contact insecticides. The use of one type or the other depends on the insect situation and professional advices should be sought.

4.6.1) Aphids

4.6.1.1) Description of aphids

The most destructive insect vector for potato is the green peach aphid (*Myzus Persicae*). Winged aphids travel long distances aided by wind. Aphids infest the leaves, flowers, stems and sprouting tubers, usually causing physical damage to the crop, especially as carriers of virus diseases (Fig. 7). Aphids suck the hosts' sap, weaken the plant and are efficient disease vectors. Aphid colonies can easily be identified in plant terminals and on underside of leaves in the field. They also appear in tuber sprouts in storage where they transmit viruses to seed potatoes.

4.6.1.2) Damage by aphids

While feeding on the sap of the potato plants, aphids infect a crop with viruses such as potato leaf roll virus, mosaic virus, and potato viruses Y, A, S and M. Virus-infected seed tubers produce poor stands and few tubers. With each successive planting, the quality of the seed stock degenerates until yields are so low that growers have to buy clean tubers.

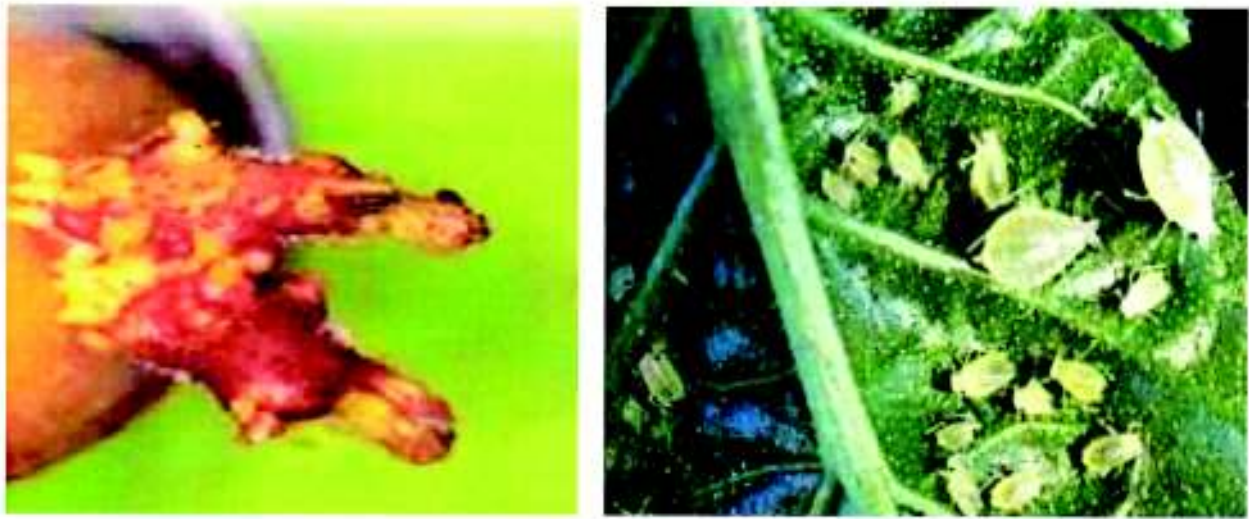


Fig. 11: Aphids attack sprouting tubers. Wingless ones start colonies on underside of leaves while the ones with wings individuals start infestations

4.6.1.3) Control of aphids

Infestation can be avoided by planting certified and healthy seeds and maintaining recommended field sanitation practices such as rouging and proper waste management. Controlling aphids in the field does not prevent re-infestation from outside sources. Manufacturers' instructions on pesticide containers should be followed as well as use of personal protective equipment during insecticide application. Since young plants are more susceptible to infections, measures aimed at accelerating the development of a crop such as pre-sprouting are also important in aphid damage management. Selection and rouging must be done under aphid-free conditions. Use of selective pesticides which do not kill natural enemies to aphids is useful. In general spray after one or 2 aphids have been seen on every 100 leaves on the seed crop at 2-week intervals, depending on severity. Both systemic and contact insecticides can be applied.

4.6.2) Potato tuber moth

4.6.2.1) Description of Potato Tuber Moth

Potato tuber moth (*Phthorimae Operculella*) attacks potatoes both in fields and in storage. The pest is more common in warm, dry and high altitude areas. Moth larvae bore through

plant terminals and stems, mine leaves and bore leaves, leaf petioles, shoots, and potato tubers especially towards the end of short rains. The main damage is caused when the larva burrows or tunnels through tubers leaving tunnels with excreta (Figs. 8 and 9). The tubers become exposed to fungal and bacterial infection which leads to rotting. After tuber formation, larvae enter and feed on stems. Pest incidence in the field can be reduced through cultural practices such as proper hilling-up to cover the tubers with soil, using pheromone traps to capture and monitor field populations, and by spraying foliage with an insecticide at regularly ensuring that all parts of the plants are wetted.

4.6.2.2) Damage by Potato Tuber Moth

In heavy attacks potato tuber moth, destroys pulp and eye buds of tubers. The damage is more severe in storage when not controlled and can cause the tubers to rot. Only healthy potatoes should be stored for seed. It is important to ensure that the store is always pest free to control potato tuber moth. Repellent plants such as chopped *Lantana Camara* spread on potatoes is used to repel moths. Pheromone traps may also be used to trap and monitor moth movement.

Other control measures include;

- Destruction of all harvest residues that may harbour tuber moth pupae
- Sorting and discarding infested tubers before storage
- Applying leaves of plants rich in essential oils such as Eucalyptus and lantana camara to repel the potato tuber moth
- Storing in diffused light instead of dark storage to induce greening (with glycoalkaloid formation) which is unfavourable for the tuber moth
- Ensuring that the store is free from any tuber moths
- Use of insect screens to prevent entry of insects in stores.



Fig. 12: Symptoms of potato tuber moth on tubers

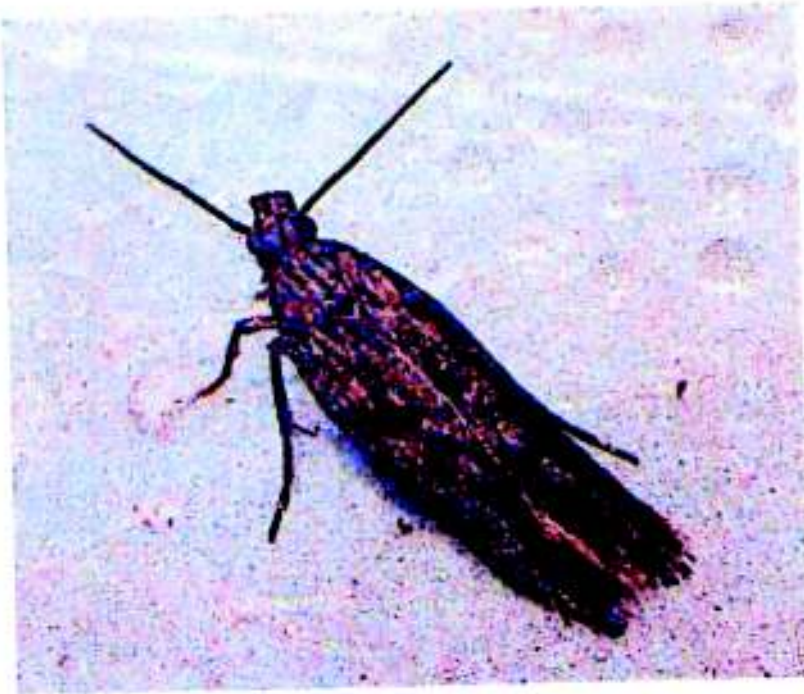


Fig. 13 Adult potato tuber moth



Fig 14: Symptoms of potato tuber moth on plant leaves

4.6.3) Cutworms

4.6.3.1) Description of cutworms

Cutworms (*Agrotis* spp.) stay buried in the soil near the plants from where they move to the plants and cut the stems of young sprouts and shoots at soil level after emergence especially in dry conditions.

4.6.3.2) Damage by cutworms

Apart from cutting the stem, cutworms feed on potato plants. The wounds that they cause serve as entry points for other organisms such as the bacteria that cause soft rot (Fig.10). The stems are injured underground or just above the soil. Young caterpillars first feed on the leaves and then burrow into the soil from where they develop into moths.



Fig. 15: Damage by cutworms on tubers and plants

4.6.3.3) Control of cutworms

Spraying with either contact or systemic insecticides is recommended immediately signs of damage are noticed of cutworms and beetles that consume the leaves like the vegetarian ladybirds (*Epilachna* spp.).

4.6.4) Leaf eating caterpillars, beetles and spider mites

Some caterpillars, beetles and spider mites damage potatoes by defoliating leaves. In serious cases only the veins are left. In severe infestations, the crop may be completely destroyed. Leaf eating caterpillars, beetles and spider mites are controlled using insecticides.

4.6.5) Root-knot nematodes

4.6.5.1) Description of root-knot nematodes

Nematodes are microscopic, slender, transparent worms that live in the soil. The common species are *Meloidogyne Javanica* and *Meloidogyne Incognita*. They attack roots or tubers causing lesions that increase susceptibility to bacteria or fungal attack. They also cause knotty swelling (galls) on roots, resulting in stunted plants with poor and premature yellowing, leaf fall and wilting. The roots become swollen or galled and have a beaded look. The surface of infested tubers is covered by small pimple like-swellings. Nematodes increase incidence of infection by bacterial wilt and other pathogens.

4.6.5.2) Damage by root-knot nematodes

Infected roots have knots or galls of various sizes depending on the extent of damage. Infected tubers have galls and are deformed (Fig. 11). Severe infestations cause premature plant death.



Fig. 16: Root knot nematodes

4.6.5.3) Control of root-knot nematodes

Treatment with soil fumigants is costly and nematicides have only a temporary positive effect. Nematode populations and damage can be reduced by crop rotation, long fallow periods, and destruction of crop residues and removal of volunteer plants.

4.7) Crop rotation

Crop rotation is important to avoid spread of soil borne diseases and pests. Rotation should be done with crops outside the family that potatoes belong to. Land can be left fallow for one or several seasons where possible. Crop rotation helps improve soil fertility, soil water retention, reduction of soil erosion and management of weeds. Crop rotation is probably the best known method for control of bacterial wilt in potato. Crop rotation control speed of other diseases by elimination of volunteer potato crops which plants are growing from left over tubers in the field after seasonal harvest. Where this is not possible, like in intensive agriculture, soil sterilization by steaming, solarisation or use of appropriate fumigants is important at the beginning of every season.

Table 1: Summary of guidelines for disease and pest control in potatoes

Disease	Symptoms	Control
Bacterial wilt	Soil is contaminated through constant potato cropping. The plant wilts and a cut tuber when squeezed will exude a white bacterial mass. Main hosts are potatoes and tomatoes	Practice crop rotation. Use certified seed or seed from a reliable supplier. Burn infected plants
Late blight	Irregular, brown, dead patches on leaves, which spread rapidly in overcast weather. Spread by infected seed, soil debris and from host plants of <i>Solanum</i> species	Use resistant varieties. To prevent blight, spray with contact fungicides every 2 weeks in dry weather and more frequently in wet weather. To cure blight, spray with systemic fungicides, following manufacturers' the instructions
Early blight	Brown and ringed spots on leaves. Occurs in dry spells when crops are under irrigation	Spray with appropriate fungicides according to manufacturers' instructions
Black leg	Occurs in very wet seasons. Plants wilt and the stem is reduced to a rotting, black mass	Use certified seed. Control soil moisture
Root-knot nematodes	Spots, warty galls on tubers and roots	Practice crop rotation, and destruction of crop residues, soil sterilization and the use of nematicides.

Table 2: Summary of guidelines for insects and pests control in potatoes

Pests	Identification	Control
Aphids	Green or black soft-bodied insects that feed on underside of leaves. Aphids transmit virus diseases that affect the plant growth. Leaves curl.	Use insecticidal soaps, appropriate Insecticides.
Potato tuber moth	Caterpillars that burrow in the tubers making black tunnels filled with excreta.	Plant as deeply as possible and ridge at least twice during the growing season. All dug tubers must be stored by late afternoon to prevent dusk-flying moths laying their eggs in them. Keep tubers in clean cool stores; spray tubers with approved insecticides
Vegetarian ladybird beetles	Both larvae and adults feed upon the leaf tissue leaving a network of veins	Spray with approved insecticides

4.8) Elimination of volunteers

Volunteers are tubers which remain in the ground after harvesting and will eventually grow into potato plants. They can be a major source of diseases and pests in subsequent crops, and their existence is a permanent threat to production of healthy potato crops. Volunteers also cause varietal impurities if not eliminated early enough, preferably within 2-3 months of harvesting using forked hoes. The remaining tubers that start to grow during rains should be removed at weekly intervals. Although hand labour is used in small-scale farms, tractor drawn cultivators are appropriate in large-scale farms. Crop rotation is one of the most effective strategies to control volunteers and soil-borne pathogens.

5) Harvest Management

On maturity, when leaves begin turning yellow, a few plants are taken at random and checked whether the tubers have reached the required size. Often, this is determined by market requirements.

5.1) Dehaulming

Dehaulming is the cutting of haulms i.e. the aerial parts of the potato plants by sickle or use of chemicals when the crop attains 80-90 days. This is usually done when the aerial part of the plant turns yellow. Irrigation should be discontinued about two weeks before dehaulming. Dehaulming helps to harden the potato tubers improving their durability.

5.2) Harvesting

Harvesting should start 10-15 days after destruction of haulms when the skin has hardened and the tubers are least likely to be damaged. The potatoes should be harvested by hand tools or machines. The entire crop should be removed from the field to prevent re-sprouting of volunteers that may harbour pests and diseases. When hot dry weather prevails, late varieties may mature and the tops die naturally in marginal areas. As mentioned earlier, over-fertilisation prolongs top growth and delays maturity. The tubers should be carried in padded boxes indoors or cardboard containers. Relatively cool and overcast days are preferred times for harvesting. Tubers should not be exposed to sunlight for a long time so as to prevent them from drying out quickly, thus reducing their keeping quality. The tubers should be dried in shades in the open for 2-3 hours to harden the skin. Harvesting when the soil is dry and avoiding wet soil, avoids rotting organisms sticking on tubers. Harvested tubers should be shielded from rain to avoid rotting and poor keeping. Tubers should also be sorted and graded based on market needs. The rest should be packed in wooden crates that allow sufficient ventilation of the tubers in open stores. It is recommended to uncover un-dug potatoes after harvesting by using a cultivator or spring tooth harrow. Such

tubers (ground keepers) become volunteers and may host various pests and diseases. Those that are not uncovered still grow and should be rouged 8-10 weeks after harvesting.

6) Postharvest practices

6.1) Drying and Curing

The following care should be taken during drying;

- The harvested tubers should be dried quickly to remove excess surface moisture for improving their keeping quality.
- The harvested tubers should always be dried in storage shed to avoid tuber greening.
- The harvested tubers should be sheltered from rain and water run-off.

6.2) Sorting, grading, storage and packaging

6.2.1) Sorting

Sorting is the process of separating good from the damaged or diseased tubers. Sorting prevents spreading of diseases to the rest of the tubers which are in good condition. Sorting involves removal of diseased, damaged and misshapen tubers.

6.2.2) Grading

Grading is an important factor in the marketing process of potatoes. Grading can be done in sizes, shape or any other predefined quality parameter. Rejected tubers can be used for non-primary purposes such as livestock feed and for domestic use as long as they are suitable for this.

6.2.3) Storage

The process of storing potatoes is influenced by crop husbandry methods such as fertilisation, weeding, ridging, irrigation, pest and disease control and the time and methods of harvesting. Damaged tubers (cut and bruised), those with foreign materials such as stones, soil, haulms and rotten ones should not be stored. The practice of storage helps to stabilize the prices in the market. At optimum condition, the quality of potatoes remains good in storage for 3-6 weeks at outside ambient air conditions. The best temperature and humidity condition for storage of potatoes are indicated below.

Table 3: Temperature and relative humidity guidelines for potato storage

Intended use	Temperature (°C)	Relative Humidity (%)
Seed purpose	2-4	95
Table purpose	7-8	95
Processing purpose	8-12	95

The condition and health of the tuber while in storage coupled with good management during storage is very important. It is recommended to store potatoes in specially constructed rooms which are well ventilated and all sources of light are blocked. Some important guidelines for storage of potatoes are listed below.

- Store tubers in dark stores
- Store each variety separately
- Pile tubers on the floor or within the racks
- Inspect the tubers in storage regularly removing rotten and sprouting ones if any

6.2.4) Benefits of proper storage:

- Minimum tuber losses and quality deterioration.
- Preserve appearance by inhibiting development of surface blemishes.
- Minimize moisture loss and softening.

- Improves sprouting (if for seed use)
- Prevent damages,
- preserve tuber

6.2.5) Storage classification

a) Small scale storage

On-farm naturally ventilated wooden storage structures are generally used to for ware potatoes. In general, *in situ* and heap storage are used in small scale agriculture.

In situ storage refers to a situation where farmers do not harvest the tubers but allow them to remain in the soil after maturity. This method is used for short term storage of 2-3 months. Covering the potato beds with grass provides shade and cooling effect to the potatoes.

In heap storage method, potatoes are heaped under the shade of trees, where 6-30 tones of potatoes can be stored. The heaps are covered with a layer of available straw material (about 30cm thick). In heap storage, following practices are recommended for safe heap storage:

- Select storage site in a shaded place (preferably in an orchard).
- Raised sand or soil platform of height of at least 0.2-0.25 meters.
- Spray a fungicide (e.g. Mancozeb 0.3-0.5% solution) on the soil/sand at the storage site which helps in reduction of rotting during storage.
- Remove cracked, cut, bruised, damaged, green and rotten tubers before storing.
- Use a polythene sheet for covering the heaps, which protects potatoes from rains.

Cover the heaped potatoes with 0.3-0.45 m straw material (wheat, paddy) and by placing two layers of locally made mat in crosswise direction can also be used in heap storage.

b) Large scale storage

In private / co-operative / public storage sectors, large scale storage of potatoes uses cold storage at low temperature and high relative humidity (see table 3 below for guidelines).

6.2.6) Packaging

The recommended packaging of ware potatoes in Kenya is in 110 kg jute or sisal bags.

6.2.7) Pricing and marketing

Pricing should be done in accordance with the market prices. It should also consider the total costs incurred by the farmer; the market demand and the grade of the tuber. Market for ware potatoes can be local, regional or international.

6.2.8) Contract farming

In contract farming, pricing depends on the agreement between the farmer and the contracted buyer based on the agreement they had. Contract farming protects farmers from uncertainties of demand and prices since the farmer is assured of demand for his produce and is certain of the selling price.

6.2.9) Collective marketing

Associations or groups are formed to enable farmers market their products collectively. In doing this, the farmers have a better bargaining power and benefit from all advantages of marketing as a group. These associations include cooperatives, farmers' associations and producer marketing groups.

6.2.10) Timing

The farmer should put measures to ensure harvests as planned and in a period of high demand. Planning all the production and marketing activities is important for proper timing of the marketing to ensure high returns at the best price possible.

7) Profitability analysis

Cost benefits analysis for 1 acre of ware potato

Profit = total revenue – (minus) total costs

Total revenue = output in bags * market price per bag

Total costs = land rent + total input costs + total labour costs+ other expenses (transport, promotion, marketing e.t.c directly associated with the crop)

Total costs include the following:

	COST PER ACRE (KSHS)
Land rent (per season)	3,000
First ploughing	3,000
Second Ploughing	2,500
Harrowing	2,000
Rent and ploughing cost	10,500
Input costs	
• Seeds (16 bags of 50 kg @ Kshs 2,500)	40,000
• Fertiliser (DAP- 4x3500)	14,000
• Pesticides, fumigants, insecticides (Ridomil-0.5kg x 1000, Dithane M-45, 2kg x 900, Bulldog-0.5lts x 1800)	3,200
• Other inputs (disinfectants, packaging e.t.c)	2,000
Total input costs	59,200
Labour costs	
• Making ridges (15x200)	3,000
• Planting and weeding (Planting- 2000, Weeding- 3000)	5,000
• Fertiliser application	1000
• Spraying and topdressing	2,000
• Harvesting and handling	3,000
Total labour costs	14,000
TOTAL COSTS	83,700

Notes

- ✓ Labour costs should include hired labour and opportunity costs for family labour.
- ✓ The Cost of production may vary from Kshs 83,700 to 100,000 based on number of ploughing (if the land is virgin), transportation of seed and number of splaying etc.

7.1) Profitability from one acre plot

Under suitable climatic conditions for potato farming and good farming practices, one ha piece of land can yield over 45 metric tonnes of potatoes per season depending on the variety. This translates to about 18 metric tonnes of potatoes per acre and over 150 bags of 110 kg.

Below are calculations of a case study of the Asante variety under optimum climatic conditions and good farming practices in 2012.

- **Total revenue**

Output x market price

$$150 \text{ bags} \times 2500 = \text{Ksh. } 375,000$$

- **Total cost**

Land rent	+ ploughing	+ input costs	+ labour costs	
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Ksh 2,500	+ 7,500	+ 59,200	+ 14,000	= Ksh.83,200
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- **Profit**

Total revenue – (minus) total cost

$$\text{Ksh.} 375,000 - 83,200$$

$$= \text{Ksh. } 291,500$$

Assumptions

- Labour is casual and includes 4 (four) units (labourers)
- Farmer doesn't incur further costs after harvesting including transportation costs to the market.

8) Support services

8.1) Financial

Service providers include commercial banks, micro finance institutions and other financial institutions. These institutions offer loans, asset financing and financial advice to the farmers

8.2) Extension and advisory services

Extension services can be sought from the government or educational institutions. Farmers ought to know the support that is available to them and proactively seek the service. Similarly, there are many consultants and consulting organizations that can provide advisory services to growers. This may be individual, cooperate and even not-for-profit organizations. The National Potato Council of Kenya (NPCK) and Kenya Federation of Agricultural Producers (KENFAP) also provide farming and marketing information and advice to farmers.

8.3) Laboratories

Laboratories exist in Kenya to offer various services. These include soil testing, plant tissue testing, water quality testing, and fertilizer analysis, pesticide efficacy testing and pathological testing facilities. Often, testing is done at a small fee. The information and advisory services that is obtained from these laboratories is invaluable and should be utilized for best potato growing results.

8.4) National Potato Council of Kenya

The National Potato Council of Kenya (NPCK) is stakeholder organization with wide membership representing researchers, extensionists, farmers, traders, processors, exporters, and development

partners. It is charged with revitalizing and developing a self-regulating potato industry by engaging industry stakeholders to produce regulatory standards, by lobbying and advocacy, and by providing a platform for negotiation and conflict resolution. The Council is strategically placed to serve as a catalyst, organizer, and coordinator for its members and thereby improve the livelihoods of farmers, help grow the economy, and enhance food security in Kenya. Within NPCK's mandate is the objective of raising the awareness and training of farmers and other stakeholders in modern agribusiness practices. This will have a positive impact on the development of the potato industry, as well as on the economic development of the nation.

8.5) Kenya National Potato Farmers Association

Kenya National Potato Farmers Association (KENAPOFA) was formed in 2003 with the objective of addressing issues affecting potato farmers. Members are drawn mainly from the potato growing counties. Its Mandate is to promote the interests of potato farmers through lobbying and advocacy as well as providing other support services to improve the economic gain of potato farmers.

8.6) Kenya National Federation of Agricultural Producers (KENFAP)

Kenya National Federation of Agricultural Producers (KENFAP) is the umbrella farmer's federation representing interest of 1.84 million farm families and the legitimate farmers' voice in Kenya. It was established to lobby and build capacity for smallholder farmers to engage with the government and other stakeholders in Agricultural development. KENFAP is a non-political, non-commercial, democratic federation of Kenyan farmers. The federation operates through networks locally, nationally, regionally and internationally.

KENFAP membership consists of 9,000 farmer groups, 60 District Federations (AB) Commodity Associations, 36 Commodity Associations and 16 cooperatives. The membership is represented at all levels based on the KENFAP structure

Foreword

As an important food and nutrition security crop; Potato is a high yielding productive vegetable providing jobs for millions of people in Kenya. The crop produces more food per unit area and per unit time than wheat, potato rice and maize. It has a short and highly flexible vegetative cycle, and is ready for harvesting within 3-4 months of planting. It also fits well with double cropping and intercropping systems. One of the crop's many other assets is its adaptability which enables it to grow at most altitudes and as an off-season crop. Moreover it is rich in protein, calcium, potassium, and vitamin C with good amino acid balance.

Unlike major cereal commodities, potato is thinly traded in the global food markets. Only a fraction of its total production enters foreign trade, mainly as processed products. Thus, potato prices in Kenya are determined by local demand and supply conditions, not the vagaries of international markets. Potato is therefore, a highly dependable food security crop that can help ease imbalances in Kenya's food supply and demand.

Potato forms a major ingredient in weaning foods for young children. The crop is very important in generating employment along the value chain including production, marketing and processing sectors and has a high potential as an industrial crop in the manufacture of starch, alcohol and animal feeds. Potato starch can find numerous uses in manufacturing of foods and other products.

This manual is a guide in the production of potatoes in Kenya, focusing on ware potato production. In general, however, any advice that relates to high yield and quality tuber production is applicable to seed potato seed production too. The manual will therefore be useful to all stakeholders in the potato industry wishing to learn more about the crop.

