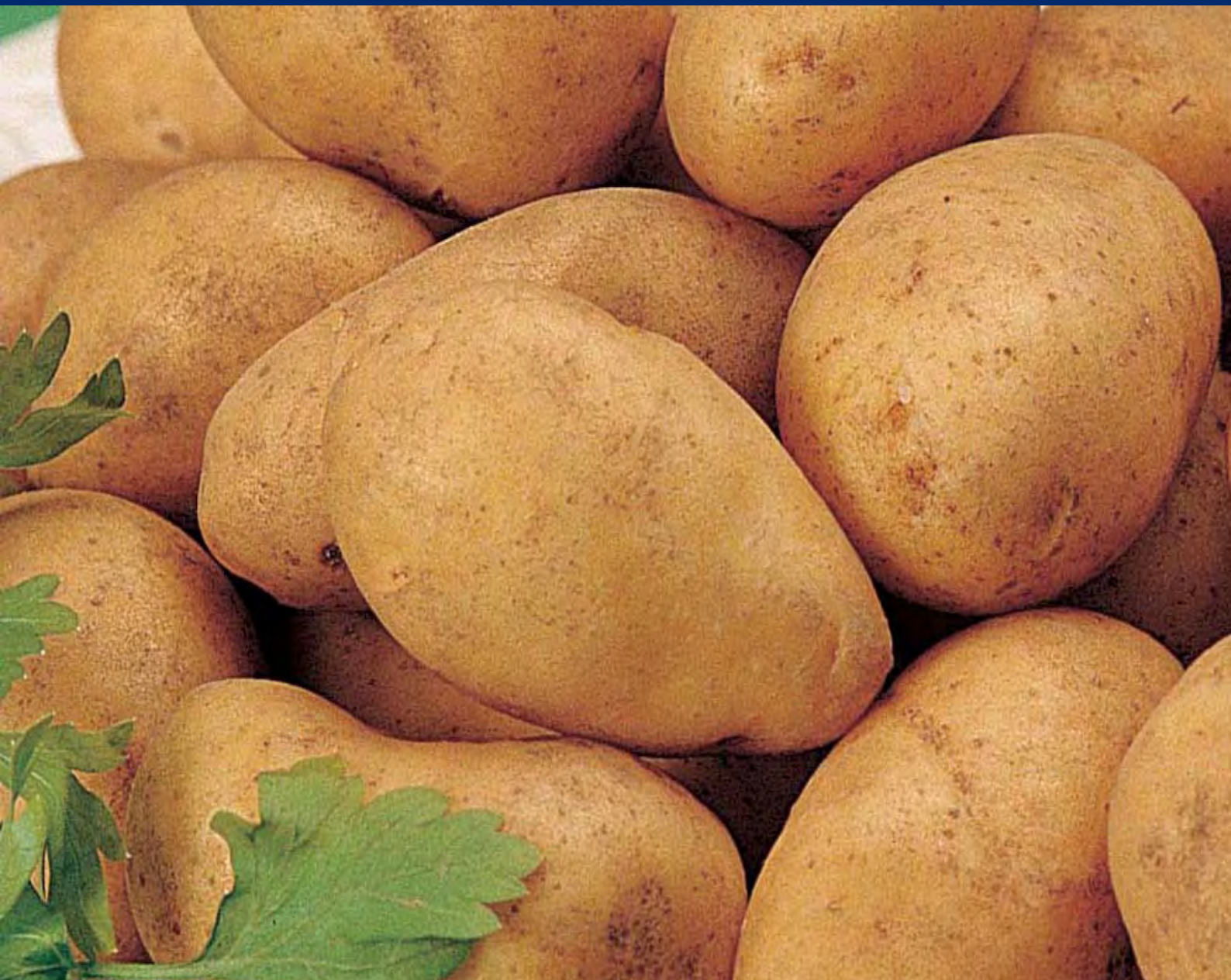




**USAID** | **IRAQ**  
FROM THE AMERICAN PEOPLE

# POTATO PRODUCTION: PLANTING THROUGH HARVEST



**2011**

This publication was produced for review by the United States Agency for International Development. It was prepared by USAID-*Inma* Agribusiness team for a consortium led by The Louis Berger Group, Inc.



# POTATO PRODUCTION: PLANTING THROUGH HARVEST



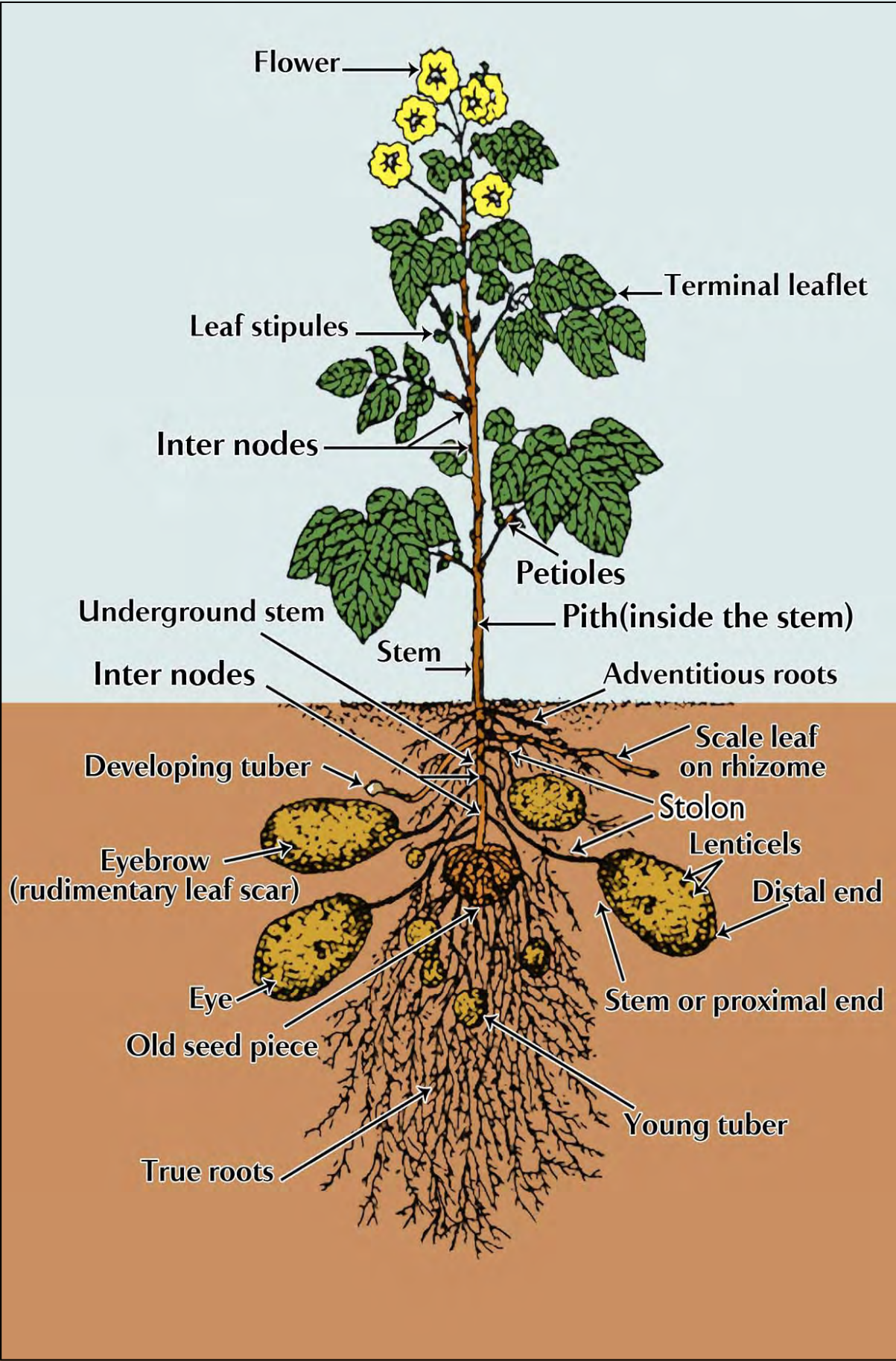
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## **DISCLAIMER**

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# Table of Contents

Stage one: Land Preparation.....2  
Stage two: Planting.....13  
Stage three: Post Planting Operations.....22  
Stage four: Post Emergency Cultural Care....26  
Disease and Pest Control.....39  
Stage five: Harvest.....85



Dear farmers:

- Crop rotation is very important to control insects, diseases and weeds.
- Fertilizing crops will enhance the soil and increase yield.
- Planting potatoes under drip irrigation system will enhance the quantity and quality of production
- Planting certified and treated seed protects against seed borne diseases and assures varietal consistency.

This Potato Production Manual is dedicated to providing you information that will assist you to manage your potato production to receive the best yields and quality possible with current technology.

Sincerely,  
USAID-*Inma*  
*Horticulture Value Chain Team*

# **Potato Production Planting through Harvest**

This manual covers recommended practices for: site selection, planting, bed preparation, pre-emergence practices, irrigation, post emergence care, row closure, tuber sizing, disease management, pest management, vine killing and harvest phases of seasonal production under Iraqi conditions.

## **First Stage: Land preparation**

### **Site Selection**

Potatoes need a well drained soil. Sandy or sandy loam soils are better than heavy clay soils for quality potato production. Potatoes do better on neutral to slightly acidic soils with a pH range of 6 to 7.

Acidic soils will not be found in Iraq, but every effort should be made to find soils with a pH in the low 7's. Soil sulfur might be considered as a soil amendment in the future to further reduce pH of otherwise good potato soils with a pH of around 7.5.

A well leveled field with an appropriate grade for the soil type is necessary, especially if furrow irrigation is to be used. It is best to rotate potato production to different fields so that potatoes are not grown in consecutive years on the same field. Potatoes produced continually in the same fields can cause a buildup of disease organisms, soil insects, and weed problems, which can increase production costs and decrease yields.

## **Soil Preparation**

The field should be opened up with some type of **deep tillage** to allow drainage and the removal of accumulated salts to below the root zone. Plows are commonly used in



Iraq, but they have several problems especially in saline conditions;

- Plows do not open the soil deep enough for the drainage required
- Plows tend to create a plow sole, or a compacted layer
- Turning the soil under saline conditions brings salt that has been leached down to the plowing depth, back up to the surface.

Under saline conditions limit the use of a plow to situations that require burying a lot of trash material or to destroying a perennial, deep rooted crop such as alfalfa.



**Chisel Plow**



**V ripper**

Use a **chisel** or **ripper** for deep tillage. Chisels and rippers can open and shatter the soil to a depth of 60 cm to 70 cm without turning the soil over. Under severe compaction or salinity conditions a larger ripper may be used to open the soil to a depth of about one meter.

Ideally the field would be planned smooth with a landplane. The purpose of this is to smooth out low and high spots which can cause over or under irrigation. This is particularly useful if you are furrow irrigating. Some farmers deep rip before the landplane

and some farmers deep rip after the landplane. Ripping before the landplane may create some new compaction, on the other hand deep ripping after the landplane will undo some of the smoothing. The USAID-*Inma* specialist usually rips prior to landplaning.



**Previous photos show the results of proper leveling and land planning, notice how well distributed the flood irrigated water is over the field. This photo is of a new seeding of alfalfa, but landplanning is equally as useful in any furrow or flood irrigated crop.**

The information above refers to a different way to prepare the soil than is currently in use in Iraq. This may not be possible until such equipment become available.

Therefore USAID-*Inma* recommends that the soil be worked as deep as possible and smoothed the best as possible with the equipment available. One method to do some smoothing is to drag a heavy piece of 20cm to 30cm iron pipe or a heavy beam of wood behind the disc harrow whenever it is used for field preparation.



**Disc harrow with drag**

## **Pre-irrigation**

It is best to plant potatoes into a soil with sufficient moisture to get the crop started. Irrigating newly planted potatoes will cool the soil, seal the soil to aeration, and get weeds started. Under warm conditions it will permit anaerobic bacteria to start seed breakdown. Unless there has been sufficient rainfall to wet the soil to a depth of 30 cm, it is useful to pre-irrigate. Having sufficient moisture will also make the soil easier to till,

prevent clod formation, and assist in early season weed control. Soil moisture of 70% to 80% field capacity is considered ideal for most soils. Temporary borders can be made and the field flooded. Then when the field is dry enough for tillage, it can be disc harrowed to air out the soil and kill germinating weeds.

Since water requirements vary according to the size and growth stage of crops as well as the length of their maturity and time of year of maximum growth, irrigation scheduling is intended to apply water in the appropriate amount in the right time. To do this, **tensiometers** and **granular matrix sensors (GMS)** are very helpful and easy to use.



IRRIGATION GUIDELINES FOR POTATOES																		
<b>Province</b>	Anbar (Fallujah)																	
<b>Farmer</b>	Ahmed Mahmood																	
<b>Soil type</b>	Clay loam																	
<b>Irrigation Interval given in days</b>																		
		<b>Jan</b>	<b>Feb</b>	<b>Mar</b>	<b>Apr</b>	<b>May</b>	<b>Jun</b>	<b>Jul</b>	<b>Aug</b>	<b>Sep</b>	<b>Oct</b>	<b>Nov</b>	<b>Dec</b>					
	<b>Interval</b>	0	14	6	4	4	0	0	0	0	0	0	0					
													<b>Irrigation time in hours</b>					
<b>Irrigation application gross depth month1</b>			15.75	39.38 m3/donum					<b>Volume of water necessary to apply (m3) in 3 donums</b>				118.13	<b>3.28</b>				
<b>Irrigation application gross depth month2</b>			26.25	65.63 m3/donum									Month 1	Month 2	Month 3	Month 4	196.88	<b>5.47</b>
<b>Irrigation application gross depth month 3</b>			42.00	105.00 m3/donum													315.00	<b>8.75</b>
<b>Irrigation application gross depth month 4</b>			47.25	118.13 m3/donum													354.38	<b>9.84</b>
<b>Area</b>	<b>3</b>	<b>donums</b>				<b>Q =</b>	<b>10.00 l/s</b>											

The use of simple **Irrigation Charts** for furrows and sprinkler irrigation based on the soil and climate conditions constitute powerful tools for irrigation scheduling.

## **Pre-Plant Fertilization**

If animal manure or a soil amendment is applied to the field, USAID-*Inma* recommends that it be applied to the field after the irrigation and before the disc harrow. The disc harrow would then incorporate the manure into the soil as it is aerating the soil and killing the weeds.

A soil amendment such as gypsum or sulfur could also be applied just ahead of the pre-irrigation, so that it would begin to activate and be carried into the soil with the water.

If a potato planter with a fertilizer attachment is not available USAID-*Inma* recommends that a broadcast application of the appropriate fertilizer be made immediately



ahead of the planter. A mechanical fertilizer spreader or hand broadcast fertilization can be done. The planting process will mix the fertilizer into the bed where it can be picked up by the developing potato roots.

The type of fertilizer recommended will be based on the results of soil tests. In Iraq, 18-18-18 is commonly used for potatoes. If phosphorus and potash are required for the fields this is a good program. USAID-*Inma* recommends an application of 175 kg to 225 kg per donum with the final recommendation depending on soil analysis.



## **Stage Two: Planting**

### **Timing planting**

Iraqi farmers plant potato in two seasons:

Spring planting, this is the most favorable time for potato planting. It starts from December to mid January for the middle region and late January to mid February and early March in the northern region where there is a higher risk of frost.

Fall planting, starts from late August to mid September for the middle region and early in August for the northern region, where frost

Risk is higher.

## Effect of temperature in potato germination

Temp. C°	Effects
7-8	Germination starts slowly in soil
10-12	In the soil, buds appear after 23 days
14-15	In the soil, buds appear after 17-18 days
18-25	It is the ideal temperature for germination as buds appear after 12-13 days, above 25 C° will cause delay in germination
20-25	It is the best temperature for photosynthesis and development of stems, leaves and flowering
16-18	In the soil is the best for tuber formation
2	In the soil, stops buds growing
29	In the soil, stops buds growing
20-23	In the soil, inappropriate and harmful

*Reprinted with the permission of the Ministry of Agriculture, Plant Protection Institute*

## Planter

A potato planter that can be set to 80cm to 85cm row spacing is ideal.



## **Quantity of Potato Seed**

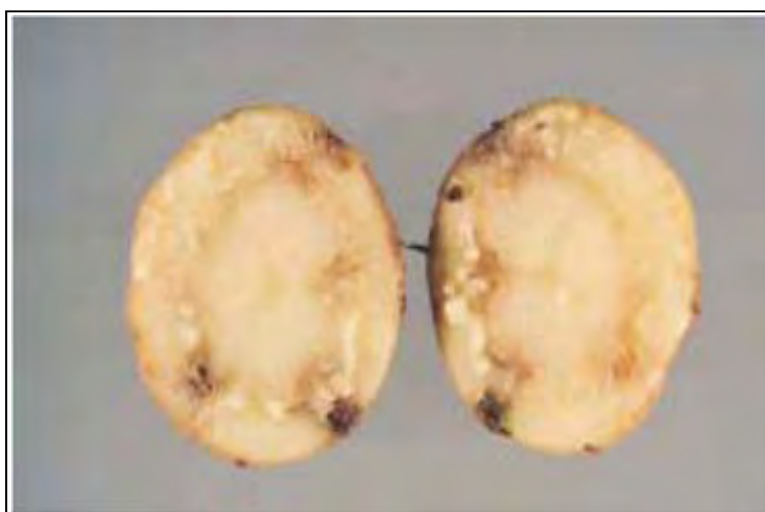
One Donum requires 550- 750 kg or more of potato seed depending on the planting method (manual or mechanical) and on the variety of seed as well as the final use intended for the harvest.

## **Cutting**

Depending upon the size, it will probably be necessary to cut all or some portion of the

seed provided. Seed potatoes above about 80 to 90 grams should be cut, ensuring a seed piece weight average of 40 to 50 grams with at least one eye per seed piece. Cutting knives should be kept sharp and sanitized.

If different seed lots are available, cut the lots showing the most sprouting first. Clean and disinfect cutting equipment at least once every one or two hours and definitely between seed lots. This will reduce the spread of bacterial disease such as **ring rot** and **blackleg**. Inspect cut seed for disease, especially ring rot.



**Ring Rot**

**If ring rot is discovered, the seed lot should not be planted.** Remove and destroy that seed lot, and thoroughly disinfect all cutting equipment and facilities. Provide workers with disinfectants and wash facilities to prevent bacteria from entering the seed cutting area.

## **Planting**

The following checklist of cultural practices to follow when planting seed potatoes will minimize disease and maximize emergence and stand:

- Purchase good seed potatoes,
- Handle seed potatoes gently and carefully,
- Use cultural practices that encourage quick emergence
- Avoid wet, soggy soils
- Plant shallow and hill plants as they emerge

Seed piece decay can be a major problem in some years. The two major causes of decay are bacterial and fungal. The fungus *Fusarium* and the bacterium *Erwinia carotovora* cause seed piece decay.



***Fusarium*** tends to be dry, slow-moving decay.



***Erwinia carotovora*** seed piece decay tends to be a wet, fast-moving decay. Both forms are capable of moving from the

decaying seed piece into the vascular system of the plant causing wilt and blackleg.

Treat the seed with a recommended seed piece treatment. There are many seed treatments available - experience and the results of professional evaluations by the Iraqi MOA should guide you to which one to use.

Seed treatments can be made before potatoes are placed in storage or at cutting time, this will depend on the individual operation and the particular need for disease control. The usual application time is immediately after seed cutting. Consult the product label to determine best timing of the seed treatment.

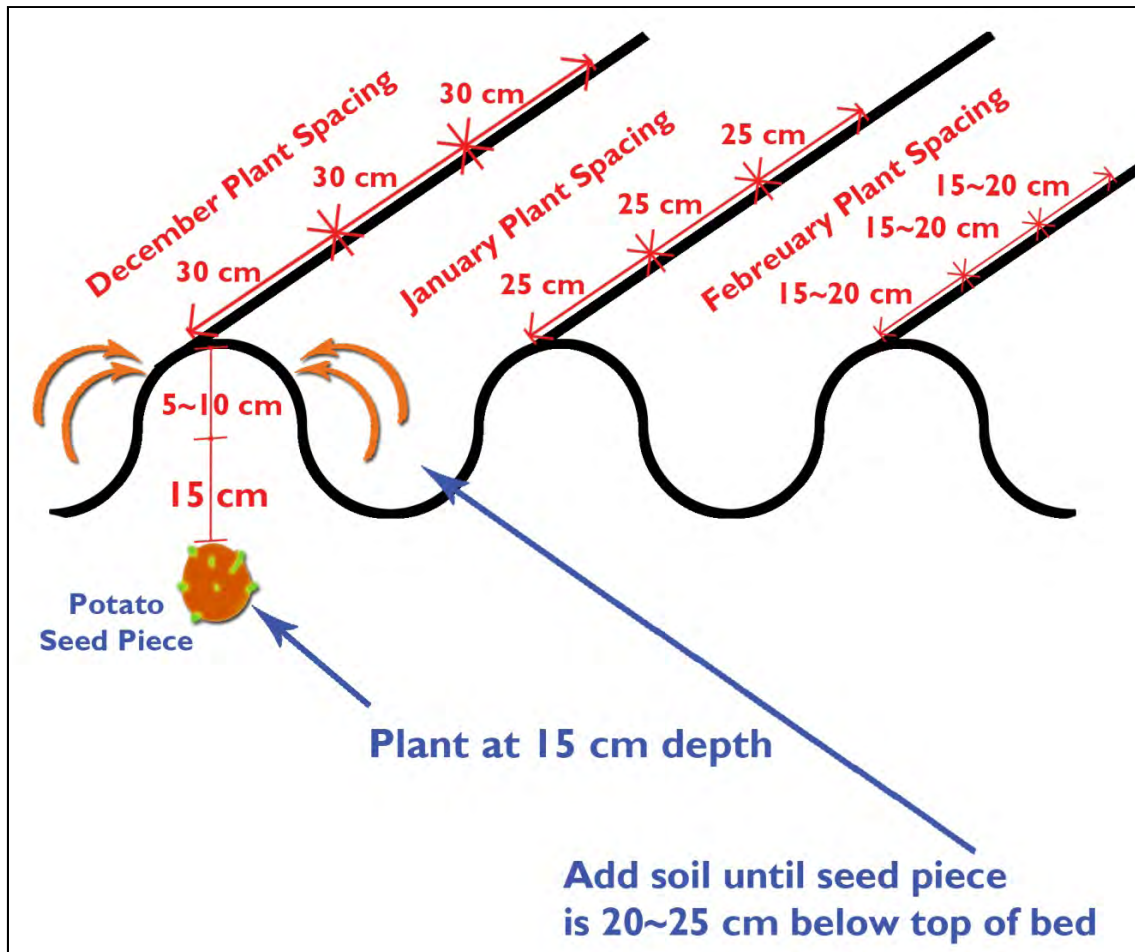
If the seed has been in cold storage warm the seed to the ambient temperature, plant in warm soil, and plant shallow to encourage rapid emergence and establishment. These practices will help avoid seed piece decay problems.





## **Seed Spacing & Depth**

USAID-*Inma* recommends a 30 cm spacing between seed pieces for December planting and gradually decreasing the spacing to 25 cm in January and 15 to 20 cm for February plantings. This spacing may need to be adjusted for varieties which may show a tendency for either very high or low tuber sets. Varieties with a tendency for hollow heart should use the closest spacing.



The seed should be planted into moist, but not overly wet soil at a depth of at least 15 cm. As the plant develops, the beds should be increased in height until the seed piece is 20 to 25 cm below the top of the bed.

## Fertilization

A planter with a fertilizer attachment, which allows the placement of two bands of fertilizer 5 cm to each side of the seed piece and

5 cm below the seed piece is recommended. The second option is broadcasting the initial fertilizer application onto the soil surface ahead of the planter. This allows the fertilizer to be mixed into the bed during the planting process. This planting time application of fertilizer will supply the season's requirements for phosphorus and potassium, and a portion of the nitrogen requirements. The amount and type of fertilizer applied should be based on soil tests and experience in the area. It is expected that added nitrogen will be applied during the growing season.

## **Stage Three: Post Planting Operations**

### **Cultivation**

The purpose of post planting cultivation is twofold;

- Kill germinating weeds

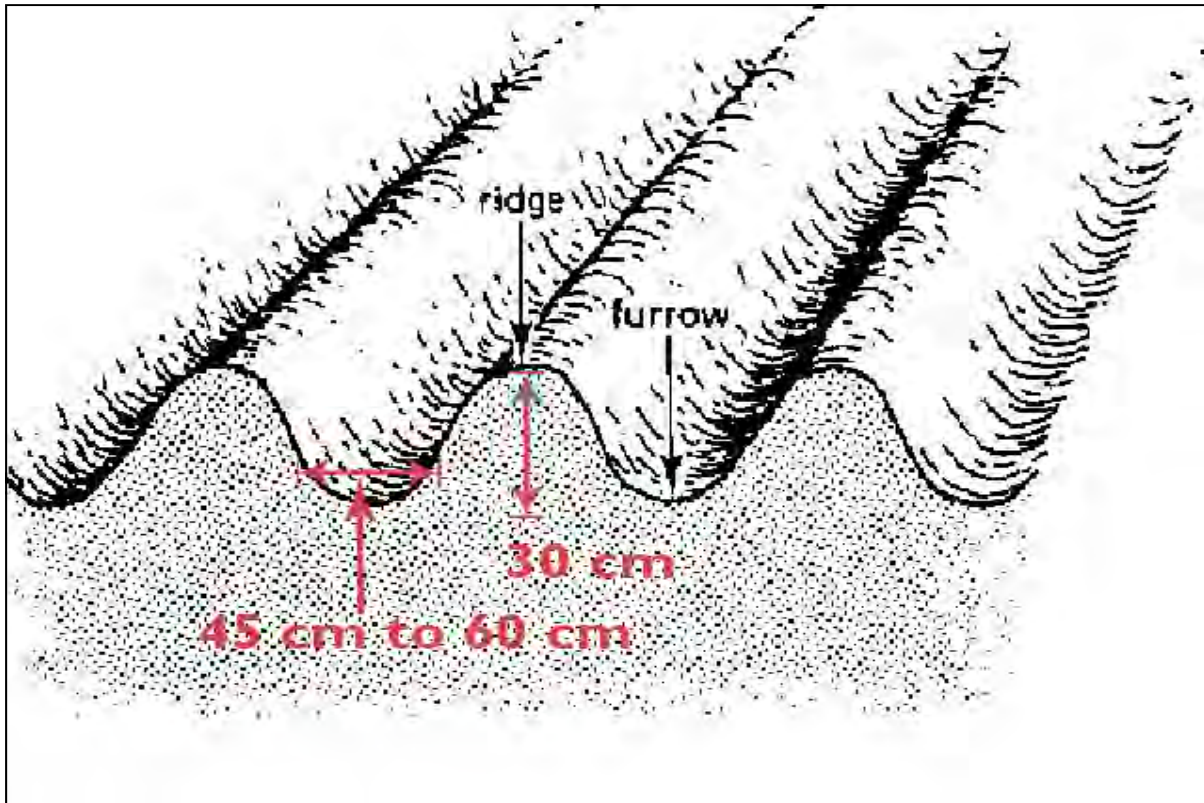
- Build the large bed needed to ensure that there is room for development of the potato crop.

If potatoes are planted on beds that are too narrow such as 75 cm beds then the potatoes tend to grow near the soil surface and eventually become green from exposure to sunlight. An 80 cm or 85 cm bed spacing allows more room in the bed for the developing crop.

**Farmers need to maximize the width of the bed and minimize the width of the furrow.**

Weed control can be accomplished best with herbicides, but can also be done mechanically. Weed control by herbicides should be based on recommendations of the Iraq MOA. If weed control is done by hand or mechanically the farmer should inspect the growth of the shoots frequently. When the shoots are within 5 cm to 8 cm of reaching the surface, the bed surface should be cultivated to kill all

germinating weeds. Then the soil should be thrown back up onto the bed, making the bed larger and higher than the original bed.



This process may need to be repeated several times with the final bed covering the seed with 20 cm to 25 cm of soil. The important point being to reform the final bed so that it is at least 30 cm high when measured from the furrow bottom and at least 45 cm to 60 cm wide at the base.

A simple alternative cultivating method, if manufactured cultivators are not available, would be to drag a length of chain, chain link or a pipe behind a tractor adjusted so that it will knock the bed down a bit, being careful not to take it down more than 5 cm. Follow this operation by rebuilding the beds by hand to the 30 cm height.

## **Post-Planting Irrigation**

The potatoes should be planted into a field with sufficient moisture to maintain growth of the growing shoots for several weeks. Ideally, the next irrigation should not be necessary until the young potato plants have broken through the soil of the final beds.

Potatoes have no tolerance for water stress. To optimize yields the total available soil water should not be depleted by more than 30% to 50%.

Depletion of the total available soil water during growing period of more than 50% results in decreased yields. Irrigation scheduling should be based on avoiding water deficit during the periods of stolonization, tuber initiations and bulking (yield formation).

## **Stage Four: Post Emergence Cultural Care**

### **Post Emergence Weed control**

Weeds are a problem because they can take nutrients, water and sunlight away from the potato crop. Some weeds such as dodder and nutsedge can physically damage the plant or the tubers. However, potatoes are very fast growing, competitive plants that can be successfully grown without herbicides in some situations. Fields with fast growing, vigorous stands can shade out most weeds. Adverse growing conditions or pest problems can lead to slow growing plants, which will allow the weeds to become established.



**A gang of Lilliston cultivators used in double passes to manage weeds early in a potato crop.**

Crop rotation and cultivation are two cultural methods used to control weeds. Crop rotation allows other methods of cultivation and herbicides to be used before potatoes are planted in the field again. This permits the control of weeds that escape the potato weed control system to be controlled in an alternative weed control system of the rotation crop. Potato growers usually cultivate before planting, and after planting, but well before sprout emergence.



Further cultivation on the top of the bed or ridge should be avoided when the sprout approaches emergence. This will prevent breaking the main sprout. Broken sprouts will reduce vigor and yield and make the plant more susceptible to pathogens.

During this phase throwing more soil on top of the bed, even covering the emerged plants, will create more underground internodes, thus allowing more stolon formation and more opportunity for tuber set. Bed building should be completed before the plants are very large to minimize root pruning. Potato plants are usually able to shade out any weeds that emerge after canopy closure. (*Canopy closure refers to the plants growing to the point where they fill the entire furrow space*)

There are a number of herbicides available for potato weed control. Farmers should check with the Ministry of Agriculture specialists or their chemical dealer to determine which are available and recommended in Iraq.

## **Post Emergence Fertilization**

Fertilization programs ideally should be based on the results of soil and tissue sample tests and adjusted based on experience with the particular soil. As a general rule, all required phosphorus and potassium should be applied pre-plant or at planting. Nitrogen applications should be split with at least one third of nitrogen applied during the growing season.

In areas where  $\text{NH}_3$  (Ammonia) gas or liquid nitrogen solutions are available they are frequently added to the irrigation water for application to the growing crop.

$\text{NH}_3$  should only be used in drip or furrow irrigation applications, as there would be large losses of N to the atmosphere if applied through sprinklers. In Iraq, the common method of adding additional nitrogen is scattering urea in the furrow, so that it will dissolve and move with the water into the root zone. This is not very efficient.

The use of an injection system or a drip system to apply urea would permit more uniform application of the nitrogen than furrow irrigation.

Total nitrogen applications of 50 to 55 kg per donum of actual N are frequently used in desert production areas. Assuming that all of the nitrogen came from urea, this would be approximately 110 to 120 kg of urea per donum.

Do not to apply excess nitrogen. Excess nitrogen will cause delayed maturity, can create growth abnormalities and is a waste of money. The potato vine will become yellow as the crop approaches maturity and harvest. Excess nitrogen will run off with water draining from the field and is harmful to the environment.

Some growers use foliar applications to correct trace or minor element deficiencies. This is only cost effective if a trace or minor element deficiency has been identified.

To optimize yields the total available soil water should not be depleted by more than 50% during the growing period or decreased yields will result.

The vast majority of Iraqi potatoes are furrow irrigated. Many production areas, outside of Iraq, with similar growing conditions have evolved into the use of more advanced and efficient irrigation systems such as overhead irrigation with either center pivots or solid set sprinklers. The most advanced system now available for potato production is drip irrigation, which reduces water use, nutrient leaching, erosion and deep percolation.

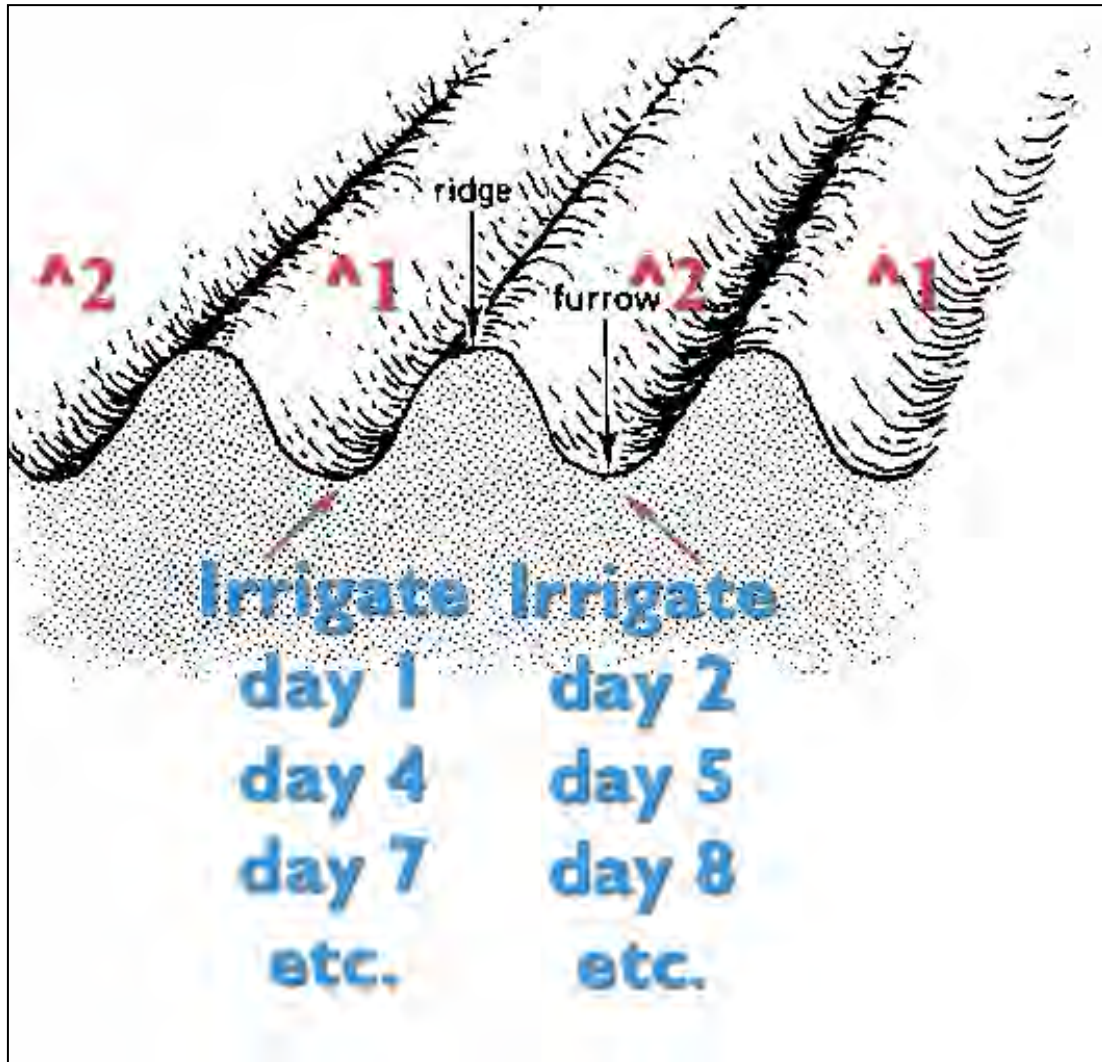
## **Furrow Irrigation**

Furrow irrigation can be used successfully in a desert climate, such as Iraq, with frequent light irrigations. The rule for irrigating potatoes after row closure to vine kill is to **irrigate every other furrow, every second day**. This means only water one side of the bed each time, with a dry day in between.

## **Drip Irrigation Time Charts**

Drip irrigation time charts in which the operational time of the drip system as well as the irrigation frequency are shown is a useful tool. The information contained in this chart is adjusted with the soil moisture monitoring devices. For potatoes irrigated with drip irrigation on loamy soils, growth development is optimal if plants are irrigated when the soil moisture tension in soil moisture monitoring devices at the root depth reaches 30 centibars.

This should be adjusted for weather extremes, but is a very good guideline.



Furrow irrigation efficiencies can also be improved using gated pipe systems which reduce evaporation losses and allow more accurate water application in each furrow.



## **Sprinkler Irrigation**

For potatoes, the leading irrigation method is sprinkler irrigation.



An efficient sprinkler system is the result of good system design, proper irrigation scheduling, careful operation, and timely maintenance. Properly designed sprinkler systems make adequate, uniform water applications that cool the potato plants and soil and reach the roots concentrated in the upper 45 cm.

Good design considers such factors as pressure; nozzle size and spacing; wind; air temperature; humidity; soil intake rate; crop rooting depth and water use rates. There are two relevant parameters that always need to be taken into account in the design of a sprinkler system:

a) **Precipitation rate** - the rate at which water is delivered from the nozzle in mm/hour, over the area covered by one nozzle. When designing a sprinkler system, the precipitation rate must be less than the infiltration rate, otherwise, water will run off

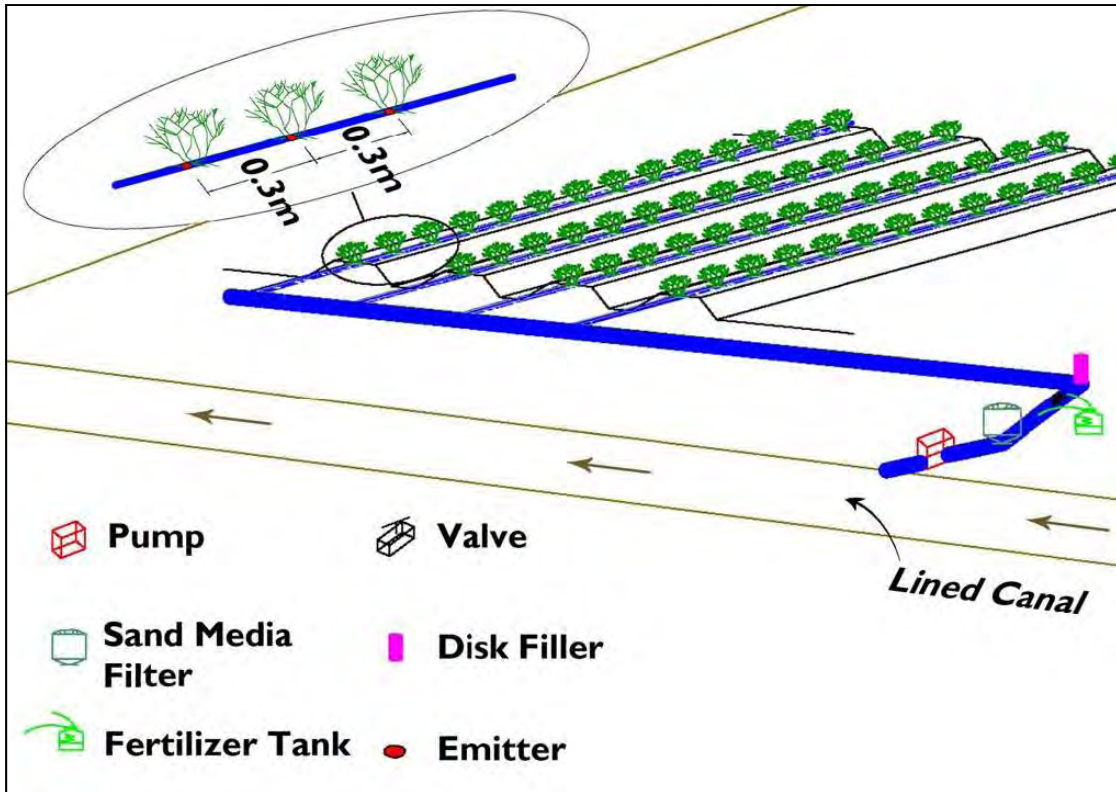
b) **Uniformity of application** - which is generally low where there is a range of pressure difference. Wind plays an important



role in uniform application. For that reason, irrigation has to be programmed during times of the day when wind velocity is low and stable.

## **Drip Irrigation**

Drip irrigation in potatoes apart for increasing tuber yields, prevents tuber cracking and malformation. Drip technology also allows significant savings in water, labor and energy required for pumping the water. The most important feature of drip systems is the capacity to improve fertilizer use efficiency. This may be the principal reason for yield increases under drip irrigation. Continuous small applications of soluble nutrients save labor, result in the fertilizer being placed around the plant roots uniformly, and allow for rapid uptake of nutrients by the plant.



	<b>March</b>	April	May
(Hour , Minute)	2,15	3,50	4,00

Irrigation  
Daily

### Sample Drip Irrigation Time Chart

**Fallujah**

**Soil Type – Clay Loam**

## Salinity

Potato is moderately sensitive to soil salinity as well as salinity in the irrigation water, with yield decreases at the following levels of soil and water electrical conductivity

### Effects of Salinity on Yield

<b>% De-crease Yield</b>	<b>ECe (dS/m) Soil</b>	<b>ECw (dS/m) Water</b>
0	1.7	1.1
10%	2.5	1.7
25%	3.8	2.5
50%	5.9	3.9
100%	10	6.7

*FAO, Water Quality for Agriculture, 1976, Drainage Paper N°29*

Since generally in the central and the south of Iraq water salinity levels are higher than the threshold values, it is necessary to apply an extra amount of water to keep the salts out of the root zone. This is the “leaching requirement” which actually constitutes the predominant criteria in determining water needs.

## **Disease & Pest Control**

### **Diseases**

Potato disease control practices are generally preventative in nature as opposed to curative. Seed and the growing plant are treated to prevent or minimize diseases. There are not many curative treatments to apply once the disease is present. Many potato diseases are fungal diseases, which flourish under certain temperature and humidity conditions.

Other diseases such as viruses may be spread by aphids or other insects or be seed borne.

Examples of viral diseases are:

- . Potato leaf roll virus
- . Y potato virus
- . X potato virus
- . S potato virus
- . A potato virus
- . Cucumber Mosaic
- . Alfalfa Mosaic

Thus sourcing certified seed from a reliable supplier of clean seed and controlling insects, especially aphids, are the best disease preventatives.

A partial list of common potato diseases follows. The following website can be used to identify other potato diseases and find more complete Integrated Pest Management (IPM) information.

[www.ipm.ucdavis.edu/PMG/crops-agriculture.html](http://www.ipm.ucdavis.edu/PMG/crops-agriculture.html)

## **Pre-Emergence Diseases**

Manage soil moisture to minimize:

*Fusarium seed piece decay*

*Bacterial soft rot and blackleg*

Excessive moisture will create ideal conditions for these diseases. Generally it is much better to pre-irrigate and plant into sufficient moisture to carry the sprout to emergence without irrigation.

## **Emergence to Maturity Diseases**

### **Early Blight *Alternaria solani***



## **Symptoms**

Early blight is primarily a disease of stressed or ageing plants. Symptoms appear first on the oldest foliage. Affected leaves develop circular to angular dark brown lesions 3–4 mm in diameter. Concentric rings often form in lesions to produce a characteristic “target” effect. Severely infected leaves turn yellow and drop. Infected tubers show a brown, corky dry rot.

## **Comments on the Disease**

Between crops, the early blight fungus can survive on potato refuse in the field, in soil, on tubers, and on other solanaceous plants. Infection occurs when spores of the fungus come in contact with susceptible leaves and when sufficient moisture is present. Spore germination and infection are favored by warm weather and wet conditions from dew, rain, or sprinkler irrigation. Alternating wet and dry periods with relatively dry, windy conditions favor spore dispersal and disease

spread. Tubers can be infected as they are lifted through the soil at harvest. If sufficient moisture is present, spores germinate and infect the tubers.

## **Management**

Early blight can be minimized by maintaining optimum growing conditions, including proper fertilization, irrigation, and management of other pests. To avoid early blight grow later maturing, longer season varieties. Fungicide application is justified only when the disease is initiated early enough to cause economic loss. Watch for disease symptoms during routine monitoring, and keep records of your results. When justified, apply fungicides as soon as symptoms appear; continued protection requires application at 7 to 10 day intervals. Contact the MOA extension specialist in your area before applying fungicides to learn proper rates and safety requirements.



## Late Blight *Phytophthora infestans*



### Late Blight Damage

## Symptoms

Late blight lesions can occur on all above-ground plant parts. On leaves, lesions typically first appear as small pale to dark green water-soaked spots that are irregular in shape and surrounded by a zone of yellowish tissue. Under conducive conditions, lesions expand rapidly and become brown to purplish black as tissue is killed. Under sufficient humidity white sporulation of the fungus can be observed at the edge of lesions, principally on the underside of leaves. On stems and petioles lesions are brown to black and may also support sporulation of the fungus.

Infected tubers develop a firm brown decay that starts on the outside and may later extend to include the outer 3–12 mm of tissue.

## **Comments on the Disease**

Occurrence of late blight is sporadic, depending on the presence of the pathogen and cool, damp weather conditions. Inoculum of *Phytophthora infestans* can originate from seed tubers, cull piles, volunteer potatoes, closely related weed hosts such as nightshade, and adjacent plantings of potatoes or tomatoes that are affected. Late blight can develop and spread rapidly if inoculum is present and conditions are conducive. High humidity, above 90%, and average temperatures in the range of 10° to 25°C favor the disease.

## **Management**

Late blight is controlled by eliminating cull piles and volunteer potatoes, using proper harvesting and storage practices and applying fungicides when necessary. Air drainage to facilitate the drying of foliage each day is

important. Day time, overhead sprinkler irrigation can favor late blight development, but night time irrigation does not.

Plant certified seed potatoes to limit this disease.

When late blight has developed on foliage and tubers are at risk of infection, make sure that vines are completely dead for 2 to 3 weeks before harvesting. *Phytophthora Infestans* does not survive very long in dead foliage.

In districts that are commonly subjected to outbreaks of late blight, preventive applications of fungicides are advised when environmental conditions are favorable for the disease. Continue fungicide applications at 7 to 10 day intervals as conditions require. Consult the MOA extension specialist for information of fungicide applications. Shorter intervals may be needed under cool, rainy conditions. Interior districts where late blight oc-

curs sporadically should watch for disease symptoms during routine field monitoring and record results. Apply fungicides when late blight lesions appear in the field or in nearby plantings.

Strains of *Phytophthora infestans* have developed resistance to mefenoxam (Ridomil Gold).

## **Bacterial Soft Rot and Blackleg**

**Soft Rot: *Pectobacterium carotovorum* var. *carotovora*, *P. chrysanthemi***

**Blackleg: *Pectobacterium carotovorum* var. *atrosepticum***



**Bacterial Soft Rot Lesions**



**Plant showing symptoms of Black Leg**

## **Symptoms**

**Soft rot:** Symptoms of soft rot include rotted tissue that is wet, cream to tan in color, and soft. Rot begins on the tuber surface and progresses inward. Infected tissue is sharply delineated from healthy tissue by dark brown or black margins. Shallow necrotic (dead) spots on the tubers result from infections through lenticels. Rotting tissue is usually odorless in the early stages of decay, but

develops a foul odor as secondary organisms invade infected tissue. Soft rot can also infect wounded stems and roots.

**Blackleg:** Plants with blackleg are stunted and have a stiff, erect growth habit. Foliage becomes chlorotic (yellow) and the leaflets tend to roll upward at the margins. Plants may wilt. Stems of infected plants exhibit an inky black decay. The base of the stem is often completely rotted. In relatively dry soil, only the pith may show blackening. Tuber symptoms for blackleg are similar to those of soft rot. The soft rot *Pectobacterium* spp. may cause wilting, but affected plants lack the characteristic inky black stem decay of black leg.

## **Comments on the Diseases**

Soft rot: Bacteria are present on all tubers and are associated with many kinds of plants. Infections in the field are favored by high soil moisture and high temperatures. Other factors include extremely wet, tight soil

conditions that limit respiration, enlarged lenticels, and invasion by other pathogens. Bacteria enter lenticels, growth cracks, or any injury. During and after harvest, soft rot is favored by immature tubers, pulp temperatures above 21°C, mechanical damage, and water on tuber surfaces.

**Blackleg:** Blackleg inoculum comes primarily from infected seed tubers, but it may also be spread in infected soil, contaminated irrigation water, and by insects. Blackleg is favored by cool, wet conditions at planting followed by high temperatures after emergence.

## **Management**

The pathogens that cause these diseases occur wherever potatoes are grown. Severity of the disease depends on seed-handling techniques; soil moisture and temperature at planting; environmental conditions; cultivar; amount of infection in the seed used; and

external sources of the bacteria such as irrigation water and cull piles.

### ***Cultural Control***

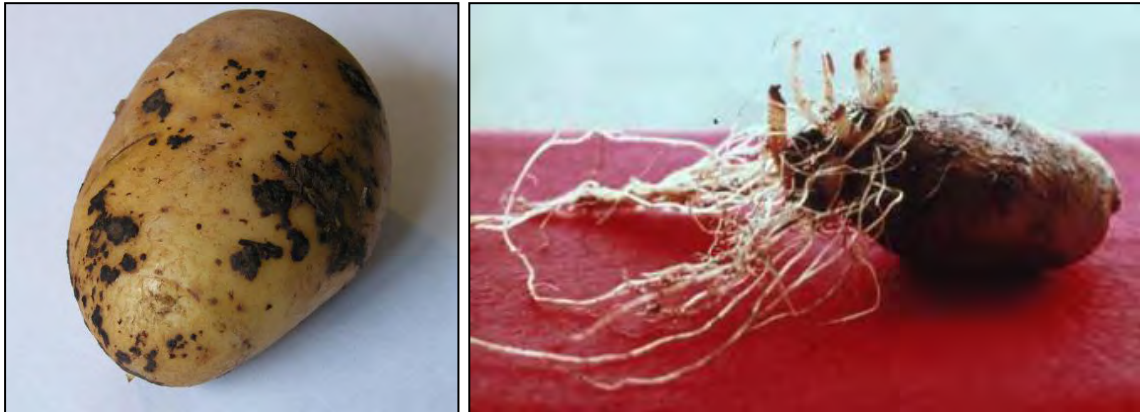
**Soft rot:** Use high quality seed. Split applications of water soluble calcium applied at 30-60 kg/ donum during bulking have been shown to reduce infection and severity of soft rot. Harvest mature tubers with well-set skins and avoid mechanical injury. Avoid excessive soil moisture before harvest to reduce lenticel infection; use clean water to wash potatoes and avoid water films on tuber surfaces during storage. Postharvest curing and storage temperatures can be a critical component of soft rot management. Specific temperature recommendations vary depending on the level of decay evident at packing and the market destiny of the potatoes.

**Blackleg:** Use pathogen-free tubers for seed. Warm seed tubers to about 13°C before planting. Provide good drainage and do not over irrigate. Eliminate cull piles and



potato volunteers in rotation crops and adjacent fields.

## **Black Scurf *Rhizoctonia Solani***



### **Symptoms**

Black Scurf is a fungal disease which is usually found as irregular, black, scab-like marks on the skin of the tubers. They are easily scraped off with a fingernail releasing a distinctive 'fungal' smell. The black masses are the resting phase of the organism. They do not spoil the flesh of the tubers and are made up of compacted mycelia, called sclerotia. The sclerotia do not become any larger during storage. The disease can damage young shoots causing them to become distorted

and weak, usually new shoots develop, but the crop can be reduced. In a bad attack the early sprouts become blackened at the tips and die, then secondary or tertiary ones emerge, but the seed tuber may not have enough stored energy for them to grow to any size, leaving bare patches in the crop. Developing tubers can become distorted and cankers may form.

## **Life cycle**

The lifecycle begins when the white mycelium grows from the sclerotia on "volunteer" tubers left in the ground from a previous crop or from sclerotia in the soil. The mycelium coats the stems of the potato shoots releasing spores to spread the infection. The roots and tuber-bearing stolons can also be attacked at any time during the growing season causing reddish-brown lesions which develop into cankers. If these girdle the stems water and nutrient uptake is reduced and small, green aerial tubers may develop above ground on the stems.

## **Management**

It is important to use certified seed tubers that are free from sclerotia as this is the main cause of the disease. Planting into warm soil means the new shoots develop quicker and are less likely to be badly affected. The closer the seed is to the surface also speeds establishment.

After die-back of the top growth, harvesting should be carried out as soon as possible as sclerotia development increases the longer the tubers are left in the ground, but the skin should be allowed set first to minimize bruising. All dead material should be removed from the field to reduce carryover to future crops. A good crop rotation cycle should be followed.

## **Treatment Decisions**

Fungicides do not directly affect these bacterial pathogens, but seed piece treatments with fungicides can reduce invasion by other fungi and therefore reduce opportunistic infections. Watch for disease symptoms during

routine monitoring, and keep records of results.

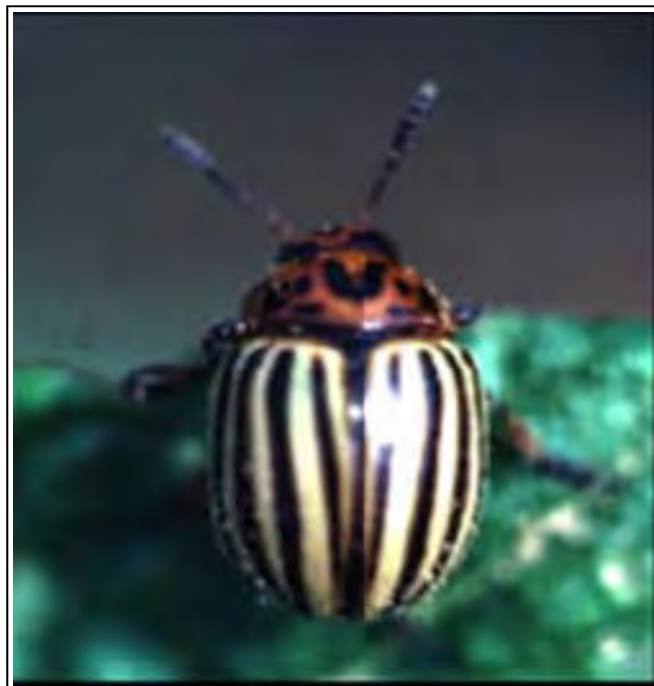
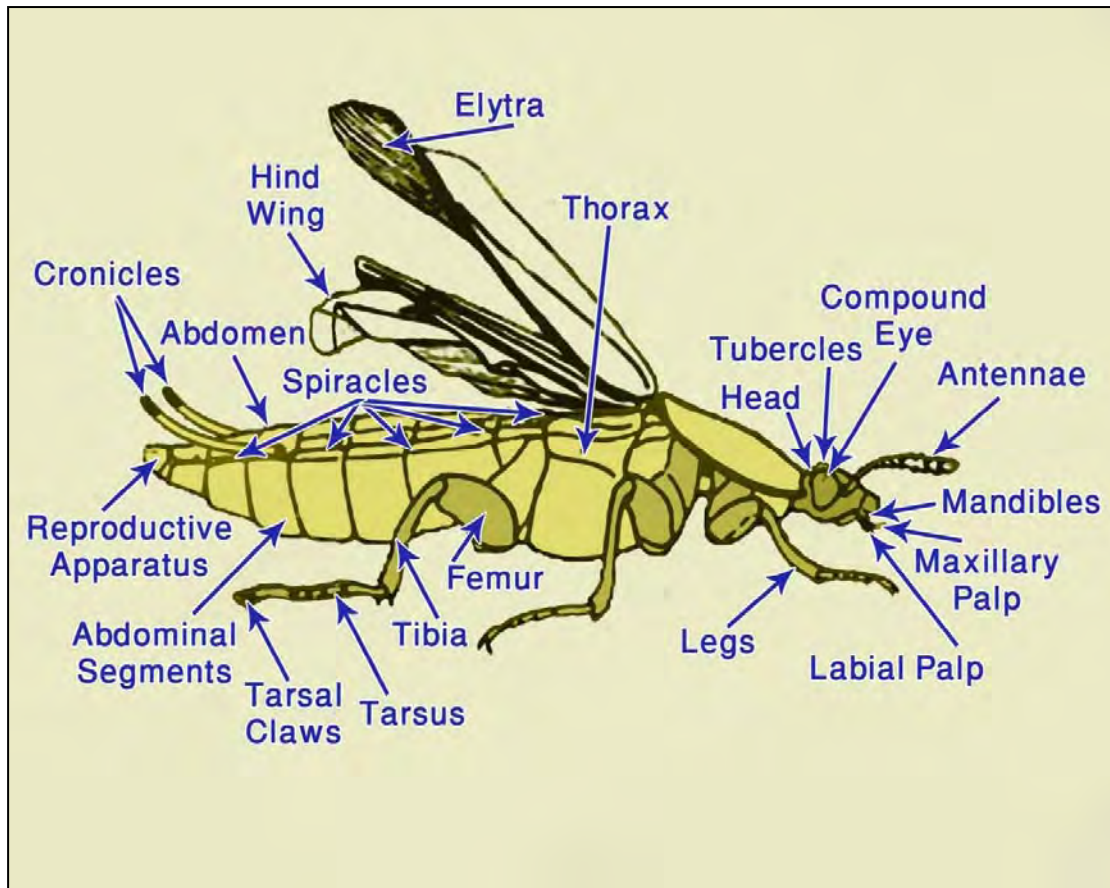
## **Row Closure to Maturity Diseases**

The primary disease problems anticipated during this period will be Early and Late Blight as covered above.

## **Insect Pests**

Insect pests in potatoes can change over time as new pests are introduced and other pests become more controlled. Thus potato farmers must always be vigilant to spot changing pest conditions in the crop. The following illustration of an insect will assist in insect identification. The insect list included in this manual is not all inclusive and the following website can be used to identify other insect pests and find more complete crop IPM information.

[www.ipm.ucdavis.edu/PMG/cropsagriculture.html](http://www.ipm.ucdavis.edu/PMG/cropsagriculture.html)



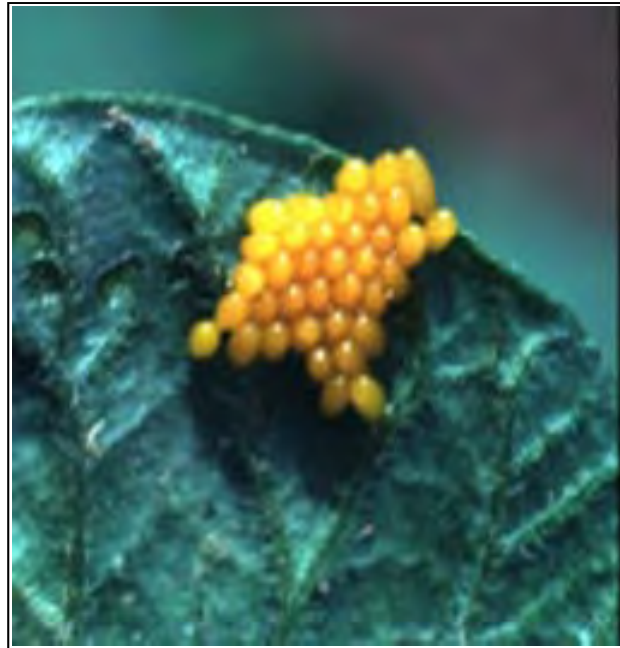
**Colorado potato beetle**  
*Leptinotarsa-decemlineata(Say)*

## Description

Worldwide the Colorado potato beetle is a major pest. Colorado potato beetles are dome-shaped and measure just less than 1 cm long. Adults are yellow with 10 narrow black lines running longitudinally along their elytra (wing cover).



Larvae look similar to other beetle larvae, are soft-bodied, with two rows of black dots along the sides. Colorado potato beetle larvae are brick red with black heads in the earliest instars.



Eggs are yellow-orange and laid in clusters on the undersides of leaves.

## **Life cycle**

Adult Colorado potato beetles overwinter in the soil, emerging in spring. Females lay eggs on the foliage of early crops of solanaceous plants, especially potatoes. First generation larvae feed for 10-30 days, dependant on temperatures. Fourth instar larvae drop to the ground and pupate in the soil, emerging as adults within 2 weeks. These adults will feed, mate, and lay eggs as well. The second generation of adults feeds until

fall, when they burrow into the soil for winter.

## **Crops Damaged**

The Colorado potato beetle feeds on potatoes, tomatoes, peppers and eggplant. Both adults and larvae feed on foliage, stems, flowers, buds, and fruit of affected crops.

## ***Signs and Symptoms***

If left unchecked, Colorado potato beetles can completely defoliate potato plants and other hosts. If you see signs of defoliation, check for beetle larvae. Late instar larvae cause the most damage to plants. Look at the undersides of leaves for clusters of yellow eggs.

## **Control Measures**

For additional information on pest or disease control check with the MOA extension specialist or the Plant Protection Institute for Iraqi recommendations. One Environmentally friendly method of control is to Apply *Bacillus*



*thuringiensis* var. *tenebrionis* when larvae are young (first and second instars).

## **Aphids**

**Green peach aphid: *Myzus persicae***

**Potato aphid: *Macrosiphum euphorbiae***

There are several species of aphids which can cause damage on potatoes. USAID-*Inma* includes the two species above as an example.

## **Description**

The two most common aphids on potatoes are the green peach aphid and the potato aphid. The green peach aphid is usually the most common and abundant species; infestations typically begin on the bottom most leaves of the plant.



**Peach Aphid**

Winged adults of the green peach aphid are pale or bright green and black, with a large, dusky blotch on the dorsum of the abdomen. The immature forms are yellow, pinkish, or pale green. The mature, wingless forms are pale or bright green.



**Potato Aphid**

Potato aphid infestations are generally scattered over the plant. Pink and green forms of the potato aphid are larger than the green peach aphid with longer cornicles and legs. Potato aphid colonies are made up of adults with offspring closely clustered together. The two species can be most reliably distinguished by looking at the tubercles between

the bases of the antennae. The tubercles of the potato aphid slope outward and those of the green peach aphid converge.

## **Damage**

Aphids damage potatoes primarily by spreading plant diseases. Occasionally, aphids become so abundant that their feeding weakens the plants.

**Potato leafroll virus** is spread by both aphids, but green peach aphid is by far the more effective vector. Early season leafroll infection stunts the plant.



**Potato Leafroll Virus**

Plants grown from Leafroll infected seed potatoes will not produce marketable potatoes. An infected Russet Burbank potato often has phloem net necrosis, a brown discoloration inside the potato that reduces quality. The brown discoloration is most intense at the stem end but may extend well into the tuber.



**Phloem Net Necrosis**

White and red-skinned varieties do not develop net necrosis. Other viruses spread by aphids include cucumber mosaic and alfalfa mosaic (calico).

## **Management**

Management of green peach aphid and potato aphid involves an integrated program of reducing overwintering populations by controlling weeds in and around the field.

## **Cultural Control**

Weeds along ditch banks, roads, in farm yards, and other non-cultivated areas contribute directly to the aphid problem. Mustards (*Brassica* spp.) serve as early season host plants where aphid populations increase before spreading to commercial potato fields. It is also important to control nightshades and volunteer potatoes because these plants are reservoirs for potato leafroll virus. Rogue (identify, dig out and remove) infected potato plants to reduce the incidence of infection and spread of the disease within a field. For maximum effectiveness remove the diseased plant, the three plants on each side of the diseased plant in the same row, and the three closest plants in

adjacent rows. Rogueing (removing infected plants) is most important in seed fields. Plant disease-free seed to reduce the incidence of potato leafroll virus.

## **Monitoring and Treatment Decisions**

Inspect fields weekly. Aphids are first found on those plants along the edge of the field toward the prevailing wind, usually the north or west edge of the field. If aphids are found on the edge, sample 100 leaves, taking 50 bottom leaves on a line from one corner of the field to the center of the field and another 50 bottom leaves on a line to the other corner of the field (example: 50 leaves from northwest corner to center; 50 leaves from center to northeast corner). Record your results. For recommendations on aphid control check with the MOA extension specialist or the Plant Protection Institute.

## Potato Tuberworm

*Phthorimaea operculella*



**Black tunnels caused by potato tuberworm**



**Potato tuberworm leaf damage**

## Identification tip

Grayish caterpillars with brown heads; feed inside leaf mines, in stems, or at stem tips forming brown leaflets into shelters.



Tuberworm moth



Tuberworm caterpillar

## Description

The potato tuber worm can be a minor to serious pest depending upon the area and year. The adult is a small moth with a wing expanse of 1.2 cm. When at rest, the wings are held close to the body giving the moth a slender appearance. The general color is gray with darker gray-brown or black markings. The eggs are very small, oval, and range from



white to yellow. Full grown larvae are caterpillars that vary in color from white, dirty white to gray, pink, or greenish when feeding in stems or leaves. They are 1 cm in length with a brown head and dark prothoracic shield.

## **Damage**

Though severe damage to young plants is rare, high numbers of worms in very young plants may result in stand reduction or stunted plants as a result of leaf and stem mining. The typical damage results from larvae mining in the tubers. Small larvae usually enter the tuber at the lenticels. Small deposits of frass can be seen in webbing around a lenticel where a larva has begun to tunnel. Frequently, the larvae feed just below the surface of the potato leaving a dark tunnel. Occasionally they bore deep into the tuber. In either case, the tunnel is filled with excrement and can be described as a dirty tunnel compared to the clean tunnels made by wireworms. Tubers that are exposed as a result

of shallow setting or cracks in the soil are most frequently infested. The longer the tubers remain in the ground after vines are killed, the more damage that can be expected.

## **Management**

Any practice that reduces the exposure of tubers to egg-laying female moths will reduce tuberworm damage. Sanitation is also important for preventing infestations. Moths can be monitored with pheromone traps to determine the need to treat. Consult the MOE extension specialist for approved treatment methods.

## **Cultural Control**

Shallow setting varieties are generally more susceptible to tuberworm than varieties that set tubers deep. Prevention of soil cracking in the beds will reduce tuberworm damage. Cracking of the soil is less severe under sprinkler irrigation than with furrow irrigation. Thus, furrow-irrigated fields have a much greater potential to become infested

than sprinkler-irrigated fields. Prompt, thorough harvest and cleaning the field is essential. Destroy cull piles and volunteer potatoes. Piles of cull potatoes provide a year-round breeding site for tuberworm. Volunteer plants provide a site for early season increase of the population.

## **Monitoring and Treatment Decisions**

Watch for damage during routine field monitoring and record your results. Pheromone traps can detect potato tuberworm moth activity and aid in the timing of insecticide applications for control. One option is to use water pan traps fixed with a protective lid from which the pheromone bait is suspended. Fill pans with soapy water; the soap helps break the surface tension of the water, which increases trap efficiency. Place the traps on the top of the bed, one trap in each corner of the field, but well into the field. Check the traps at least once a week; record sampling results. Another option is to place the pheromone in a sticky trap. The advantages of sticky traps

are that they do not dry out like water pan traps, but they can become dusty and no longer catch moths.

Recommendations for treatment should be obtained from the local MOA

Extension specialist or from the Plant Protection Institute.



**Silverleaf Whitefly**

## Description

The most common species of whitefly infesting potato is the silverleaf whitefly. Adults are 1.5 mm long, yellowish with white wings. Silverleaf whiteflies hold their wings roof-like, over the body; the wings do not meet over the back but have a small space separating them. Other species of whitefly have been observed in potatoes; they tend to be localized within the field and do not cause damage.

Populations of silverleaf whitefly can be found relatively uniformly throughout the field in fall plantings.



Whiteflies are found mostly on the undersides of leaves. They fly readily when plants are disturbed. The tiny, oval eggs hatch into a first larval stage that has legs and antennae and is mobile.



**Silverleaf Whitefly larva**

Both legs and antennae are lost after the first molt and subsequent stages remain fixed to the leaf surface. The last nymphal stage, often called the "pupa" or the red-eye nymph, is the stage that is easiest to identify.



**Silverleaf Whitefly red-eye nymph**

Mature nymphs of silverleaf whitefly are oval, whitish, soft, and have few to no long waxy filaments.

## **Damage**

Silverleaf whitefly damages leaves by feeding, which causes leaves to yellow and curl, and by the production of honeydew, which causes leaves to appear shiny or blackened from sooty mold growing on the honeydew. Damage is similar to that caused by aphid feeding, they debilitate the plants. Whiteflies cause the most damage to summer and fall planted - winter harvested potatoes in warmer climates. Fields near defoliated cotton can be severely infested.

## **Management**

Whitefly populations are often held in check by beneficial insects. If populations do reach high levels, it may be necessary to treat in fall.

## **Cultural Control**

When possible, plant potatoes at least one-half mile upwind from key silverleaf whitefly hosts such as melons, cole crops, and cotton. Maintain good sanitation in areas of winter/spring host crops and weeds by destroying and removing all crop residues as soon as possible. Control weeds in non-crop areas including hedge rows and fallow fields and harvest alfalfa on as short a schedule as possible. In addition, allow the maximum time between whitefly host crops and produce vegetables and melons in the shortest season possible.

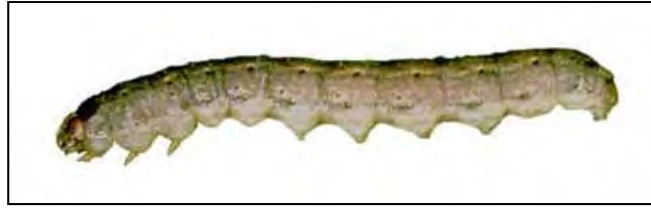
For information on Silverleaf whitefly control consult the MOA extension specialist or the Plant Protection Institute.

## ***Cutworms***

*Black cutworm: Agrotis ipsilon*

*Variiegated cutworm: Peridroma saucia*





**Black cutworm**

## **Description**

The most common species encountered are the black cutworm and the variegated cutworm. Adults are dull colored brown to grayish moths.



**Cutworm Moth**

Larvae are usually earthen colored with various stripes or spotted color patterns.

They are smooth-bodied worms that may be 2 inches in length when mature. Many species curl into a C-shape when disturbed.

## Damage

Cutworms may cut off the stems of young plants during stand establishment. Later in the season they feed on foliage. Tubers that are exposed by cracks, or are set very shallow may be damaged. Cutworm damage to tubers appears as a gouged out cavity.



**Cutworm damage to young plant**



**Cutworm tuber damage**

## **Management**

Weed control in and around the field before planting will reduce cutworm problems through reduction of early season host plants. Monitor the field to detect cut plants and leaf feeding early in the season. Later in the season, inspect plants for leaf damage. Shake the plants over a cloth placed in the row and inspect the beds and furrows for larvae. Inspect shallow set and exposed tubers for damage. Keep records of your monitoring results. Treatment is necessary where worms are abundant and before the tubers are damaged.

For more information on cutworm control consult the MOA extension specialist or the Plant Protection Institute.

## Potato Nematodes

**Northern root knot nematode:** *Meloidogyne hapla*

**Columbia root knot nematode:**  
*M. chitwoodi* (Race 1 & 2)

**Southern root knot nematode:**  
*M. incognita*

**Lesion nematode:**

*Pratylenchus penetrans* and *P. neglectus*

**Stubby root nematode:**  
*Paratrichodrus* sp.



**Nematode Root Knot**

## Description

Parasitic nematodes are microscopic roundworms that feed on plant roots. They live in soil and plant tissues, and more than one species may occur in a field. They have a wide host range, and vary in their environmental requirements and in the symptoms they cause.

## Damage

Root knot nematode larvae invade roots or tubers, establish feeding sites, and develop into the adult stage. Adult females lay eggs in a gelatinous matrix on or just below the root surface. These eggs hatch and larvae invade other roots and tubers. Root knot nematode feeding reduces the vigor of plants and causes blemishes on tubers. Lesion nematodes damage roots by feeding and moving through cortical tissues. In addition, *Pratylenchus penetrans* increases the susceptibility of potato plants to *Verticillium wilt* and blemishes tubers. Stubby root nema-

todes feed on root surfaces, resulting in formation of numerous stubby roots. The major problem caused by this nematode species is transmission of *tobacco rattle virus*, which causes *corky ringspot disease* on developing tubers.

## Symptoms

The symptoms described below are indicative of a nematode problem, but could result from other causes as well. Aboveground symptoms include stunted, yellowed, chlorotic, and dead plants. Infected plants are likely to wilt earlier under temperature or moisture stress. Infestations may occur without causing any aboveground symptoms.

All three species of *Meloidogyne* and *Pratylenchus penetrans* cause bumps or warts on the surface of infected tubers. Brown spots develop inside tubers, mostly in the outer 6 mm, which are visible when a thin layer of tuber is peeled off. Lesion nematodes cause reddish brown lesions on the roots that turn black later.

## Prevention

The following measures will help prevent spread of nematodes to uninfested fields:

- Plant certified seed potatoes
- Clean soil from equipment before moving between fields
- Keep irrigation water in a holding pond so that any nematodes present can settle out and pump water from near the surface of the pond
- Prevent animal movement from infested to uninfested fields
- Compost manure to kill any nematodes that might be present before applying it to fields.

## Crop Rotation

Crop rotation can be useful in reducing nematode populations. Alfalfa is not a host of *M. chitwoodi*, Race I; cereals are non-hosts of *M. hapla*; and there are several nematode resistant tomato varieties that can be used if *M. incognita* is a problem. Cover crops of

rapeseed, mustard, oilseed radish, or sudan-grass reduce populations of root knot nematodes when incorporated as green manure. Currently there are no nematode resistant potato varieties available.

## **Cultural Control**

Fields that are left fallow and kept weed-free usually have an 80 to 90% per year reduction in root knot populations. Infested tubers left in the field after harvest can be a source of inoculum. Destroy volunteer potato plants that subsequently emerge from these tubers to restrict nematode reproduction. Avoid storage of tubers infected by *M. chitwoodi* as blemishes can increase during storage.

## **Cultural Management**

### **Row Closure through Maturity**

### **Irrigation**

It is very important to maintain uniform



moisture during the period of stolonization, tuber initiation and sizing. Major variations in moisture during this time frame will cause growth cracks, malformed potatoes, and reduced yield. Maintain the irrigation schedule provided by the USAID-*Inma* irrigation specialist.

## **IPM - Integrated Pest Management**

Continue regular field inspections to identify developing insect or disease problems. If the problem cannot be identified from the material in this manual, bring a sample of the insect or plant part infected to your local MOA extension specialist or the Plant Protection Institute for identification.

Apply preventative fungicide sprays if weather conditions indicate a potential problem. Treat any insect or disease problem as recommended by the MOA extension specialist or the Plant Protection Institute.

## **Stage Five Harvest**

### **Harvest Timing**

Inspect growing vines for number of tubers set, size, shape, and skin set on a regular basis. As harvest time approaches the grower must determine the ideal time to harvest. Many factors have to be considered when making the decision to stop irrigation to induce maturity.

### **Condition of the vines**

Ideally the vines will begin to run out of nitrogen as the tubers pull energy out of the vine as they size. This will be apparent if the vines begin to yellow and break down. Too much vine vigor late in the season can stimulate knobs and rough growth in the tubers, as well as hinder skin set. If this condition exists, the grower may consider stopping irrigation and even mechanical destruction of the vines to slow and eventually stop tuber growth.

## **Estimated size of the crop**

An estimate can be made from the average number of tubers set per vine and their size. Potatoes will continue to size after irrigation has been stopped until they have depleted the energy and moisture stored in the vines.

## **Market conditions**

Market trends may influence the timing of harvest. When the price is high and is expected to drop, a grower may wish to harvest sooner to take advantage of the better price, but only if he believes it will more than compensate him for a lower yield from the early harvest. When the reverse is true and the price is very low, the grower may wish to keep the potatoes in the field in the hope that the price will improve.

The farmer may have a contractual tie with a potato packer, which mandates delivery to a packing house during a particular time period. In this case he will work with the field man from the packing house to mutually deter-

mine the appropriate time to stop irrigation and induce maturity. A contract with a packing house would usually mean that the crop is planted and harvested on a schedule determined by the packing house, so that the various fields contracted would mature on a pre-determined schedule to allow for orderly harvest and marketing.

Another option is harvest and storage. This is complicated in Iraq and other early season production areas, as many early spring potato varieties have a relatively short storage life.

## **Inducing Maturity**

When, after considering all the above factors, the decision is made to induce tuber maturity - skin set and prepare for harvest, there are alternatives to consider:

## **Stopping Irrigation**

Naturally allowing the field to dry will cause the potatoes to mature and their skin to set in 7-14 days, depending upon temperature.

## Mechanical Vine Killing

Flail mowing and rolling are the prominent mechanical methods used to kill potato vines and are frequently combined with stopping irrigation in desert areas. Rolling will also seal soil cracks and help prevent insects attacking exposed potatoes. Flail mowing should only be used when you want to stop sizing immediately. Care should be taken when using mechanical methods to avoid disturbing the soil so that tubers are not sunburned or mechanically damaged.

## Chemical Vine Killing

Chemical vine killing methods consist of applying agricultural chemicals to desiccate the potato vines. Application of chemical vine desiccants should not be made during cool and damp or hot and dry weather. To insure adequate vine desiccation and tuber safety, labels should be read thoroughly prior to applying any agricultural chemical. ***The chemical method is not recommended by USAID-Inma for Iraqi conditions.***



**Combine (harvester) of potatoes**



# Photo Credits

## V ripper

<http://www.deere.com/servlet/ProdCatProduct?pNbr=0913XP&tM=FR>

## Chisel

<http://www.buctraco.com/Online%20Catalog%20-%20Gallery/Model4720gallery.htm>

## Homemade drag for behind a disc harrow

<http://www.tractorbynet.com/forums/attachments/customization/107785d1218056730-disc-harrow-drags-need-ideas-fencedrag.jpg>

## IPM Information and Photos from UC Davis

[www.IPM.ucdavis.edu/PMG/crops-agriculture.html](http://www.IPM.ucdavis.edu/PMG/crops-agriculture.html)

## Other photos

Late blight damage: [http://www.longislandhort.cornell.edu/vegpath/photos/lateblight\\_potato.htm](http://www.longislandhort.cornell.edu/vegpath/photos/lateblight_potato.htm)

## Colorado potato beetle

<http://www.maine potato ipm.com/ipmfactsheets/cpb.pdf>

## Potato aphid

<http://www.ento.okstate.edu/ddd/insects/potatoaphid.htm>

## Potato Leaf Roll

<http://utahpests.usu.edu/ipm/htm/advisories/small-fruit-and-vegetable-advisory/articleID=10007>

## phloem net necrosis

[http://vegetablemdonline.ppath.cornell.edu/factsheets/Potato\\_Detection.htm](http://vegetablemdonline.ppath.cornell.edu/factsheets/Potato_Detection.htm)

## **Potato tuberworm**

[http://potatoes.wsu.edu/survey/PIPSsummary2010\\_2.html](http://potatoes.wsu.edu/survey/PIPSsummary2010_2.html)

[http://mtvernon.wsu.edu/path\\_team/potato.htm](http://mtvernon.wsu.edu/path_team/potato.htm)

## **Silverleaf Whitefly**

[http://cirs.ucr.edu/silverleaf\\_whitefly.html](http://cirs.ucr.edu/silverleaf_whitefly.html)

<http://agspsrv34.agric.wa.gov.au/ento/pestweb/images/silverleafwfly3.jpg>

<http://www.forestryimages.org/browse/detail.cfm?imgnum=5194042>

## **Cutworm**

<http://www.extension.umn.edu/distribution/horticulture/ml225.html>

<http://www.dowagro.com/uk/potato/cutworm.htm>

## **Rhizoctoni Wilt**

<http://www.ecoport.org>

## **Nematode Root knot**

<http://www.arc.agric.za/home.asp?pid=1798>



# Glossary of terms

**Anaerobic Conditions** - The absence of oxygen, preventing normal life for organisms that depend on oxygen

**Bulking**- Tuber bulking occurs during the fourth phase, when the plant begins investing the majority of its resources in its newly formed tubers.

**Chlorotic**- The yellowing or whitening of normally green plant tissue because of a decreased amount of chlorophyll, often as a result of disease or nutrient deficiency.

**Cornicle** is one of a pair of small upright backward-pointing tubes found on the dorsal side of the last segment of the bodies of aphids.

**Dorsum** - The back or posterior side of the insect

**EC** - The electrical conductivity of a material is the ability of that material to transmit an electrical current expressed in milliSiemens per meter. EC of soils varies depending on the amount of moisture held by soil particles. Sand- low conductivity, silt-medium conductivity, clay- high conductivity

**Elytra** - is a modified, hardened forewing of beetles, primarily serve as protection for the hind-wings underneath, which are used for flying. To fly, a beetle typically opens the elytra and then extends the hind-wings, flying while still holding the elytra open.

**Foliar application**- sprayed on the leaves of a plant

**Lenticels** - small, corky pores or narrow lines on the surface of potatoes that allow the interchange of gases between the interior tissue and the surrounding air

**Inoculum** -a substance (a virus, toxin, spores, or immune serum)

that is deposited onto a plant or seed and produces a disease, or under controlled conditions may produce or increase immunity to a particular disease

**Instars** - is a developmental stage of insects, between each molt until sexual maturity is reached. For most insect species the term is used to denote the developmental stage of the larval or nymphal forms of complete metamorphosis or incomplete metamorphosis, but the term can be used to describe any developmental stage including pupa.

**Internode** - on the above ground stem of a potato the nodes hold buds which grow into one or more leaves, flowers other stems. On the below ground stem the nodes produce new potatoes. The internodes are the stem space from one node to another.

**N**- Nitrogen

**NH<sub>3</sub>**- Ammonia

**Necrotic**- is the premature death of cells and living tissue.

**Pathogen** - an **infectious agent**, or more commonly **germ**, is a biological agent such as a virus, bacteria, prion, or fungus that causes disease to its host

**Phloem net necrosis** - A dark brown to black netting of dead tissue visible in the potato when it is sliced in half often caused by Potato Leaf Roll Virus spread by aphids.

**Pith** - the soft, sponge like, central cylinder of the stems of most flowering plants

**Prothoracic shield**- Dorsal portion or plate of the first thoracic segment, behind the head, often distinctly colored in caterpillars

**Pupate** – to go into the immobile non-feeding stage of development between larva and adult, when many internal changes occur

**Senescing plants-** ageing, past maturity

**Solanaceous plants-** tomato, pepper, chili, potato, eggplant, etc.

**Sporulation-** the formation of spores; especially division into many small spores

**Tubercles-** A small rounded projection or protuberance, esp. on a bone or on the surface of an animal or plant.

**Vector-** A carrier that transmits a disease from one party to another.

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