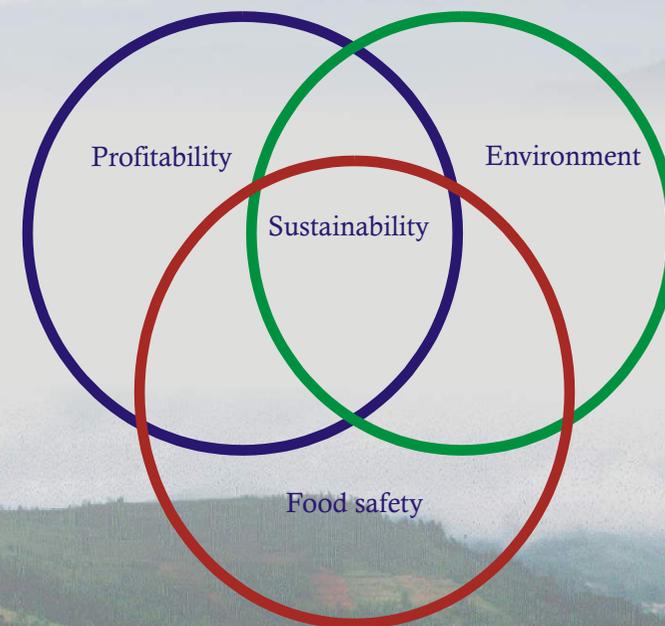


Eco-friendly Approaches for Sustainable Management of Potato Pests



All India Coordinated Research Project on Potato
Central Potato Research Institute
(Indian Council of Agricultural Research)
Shimla-171 001 (HP), India

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Compiled & Edited

by

Khyal C. Thakur and Prakash S. Naik

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Foreword



Potato is an important world food crop. Due to its high production potential per unit area and time, the crop has been recorded for sustaining millions of lives during the times of war and hunger. Native of South America, this crop was introduced into India in early seventeenth century. Organized research efforts in India have transformed this temperate crop to suit prevailing sub-tropical climate of the country. Currently India ranks 3rd for area and 2nd for potato production in the world.

Potato is afflicted by several diseases and insect pests. Viruses and late blight are the most important diseases in India causing huge economic losses. In warm sub-tropical parts of the country the incidence and spread of viruses is rapid due to high populations of virus vectors. Emergence of new late blight races and cultivation of late blight susceptible varieties is changing the incidence pattern of late blight in the country. Other diseases and insect pests although are under control, they pose problems in areas where recommended package of practices are not followed. These are mainly management problems. Indiscriminate use of pesticides to manage these biotic stresses attaches several concerns regarding environmental degradation, emergence of new pests, food safety and increased cost of production.

The bulletin on “Eco-friendly Approaches for Sustainable Management of Potato Pests” is a timely and appropriate effort to educate farming community on eco-friendly management of potato pests. I am sure that description of potato pests, their prevalence in different regions, sustainable measures for their management and chronology of these measures (what to do, when to do, why to do, what not to do and why not to do) described in this bulletin will be highly helpful to the farmers of different regions to reap rich dividends from potato. The bulletin is aimed at making potato farming economically and environmentally sustainable. I congratulate Dr. KC Thakur, Dr. PS Naik and scientists working under All India Coordinated Research Project on Potato for compilation of this valuable information for the benefit of potato farmers in India.

Date: August, 2007

Place: Shimla

A handwritten signature in black ink, appearing to read 'SK Pandey', written over a horizontal line.

(SK Pandey)

Director

Central Potato Research Institute
Shimla (HP)

1. MAJOR POTATO DISEASES IN INDIA

The diseases caused by fungi, bacteria and viruses are complex interactions between host, pathogen and the environment leading to malformed foliage and disfigured tubers eventually having an adverse effect on productivity and quality of the produce. Some of the important diseases afflicting potato in India are described below.

1.1 FUNGAL DISEASES

1.1.1 Late blight

Late blight is the most dreaded disease of potato occurring worldwide. It is caused by the fungus *Phytophthora infestans*. Late blight affects foliage as well as tubers, and severity of damage depends upon the disease incidence and the variety planted. Late blight pathogen survives from one season to another through infected seed tubers serving as the primary source of inoculum. After the initiation of primary infection further spread of pathogen takes place by airborne or waterborne zoosporangia. The disease appears first on the lower leaves touching soil. Symptoms on the leaves appear as pale green, irregular water soaked spots surrounded by white growth of the fungus on the under surface of the leaves. Symptoms start on tips and margins of the leaves and subsequently spread to other parts of the plant. Affected tubers show purple sunken spots and necrosis of the underneath tissues.

Newly formed tubers, which become exposed due to less earthing up or cracks developed in the soil due to bulking of tubers, are infected by the spores washed from the infected leaves into soil either by rains or irrigation water. Temperatures ranging between 10-22 °C; relative humidity > 80% and cloudy/foggy weather with intermittent rains for 2-3 days favour the outbreak of late blight leading to severe yield losses depending on the variety grown and plant protection measures adopted. In hilly regions of the country it appears in epiphytotic form every year causing severe yield losses ranging from 50-80% in the eastern hills, 40-80% in north-western



Late blight on potato foliage



Devastated potato field by late blight



Necrosis in late blight infected tubers

Table 6: Package of practices for managing major diseases and insect pests in potato.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
LATE BLIGHT <i>(Phytophthora infestans)</i>	Use healthy seed of late blight resistant/tolerant varieties.	Selection of varieties and procurement of healthy seed is to be done much before planting.	Procure healthy seed of late blight resistant/ tolerant varieties from a reliable source and obtain receipt. List of late blight resistant varieties is given under 1.1.1.	Incidence of late blight on resistant/tolerant varieties is less. Infected unhealthy seed tubers serve as a source of primary infection.	Do not purchase seed without seed class tag and receipt. Check suitability of varieties in your area.	Seed is likely to be unreliable. Unsuitable varieties yield less.
	Seed treatment.	It is better to purchase potato seed that has been treated before cold storage. If not, treat the seed with suitable fungicide before planting. Consult experts in Agricultural Universities or Krishi Vigyan Kendras of your area.	Treat/spray seed tubers with recommended concentration of the fungicide.	To kill late blight inoculum present in seed tubers.	Do not use over-/under-dose of pesticide. Do not use the same solution for more than three times for dipping seed tubers.	Over-dose is toxic while under-dose is ineffective. Effectiveness of the solution decreases with repeated use.
	Planting at optimum time.	At the time of planting.	Adjust planting date in such a way that potato crop is towards maturity at the time of late blight incidence. This is to be done keeping in view the time of appearance of late blight in your area.	To escape attack of late blight on immature potato crop.	Do not use treated tubers for table purpose. Do not plant potatoes too early or too late.	Treated tubers are toxic and unfit for consumption. Night temperatures during tuberization phase (about 40 days after planting) should be around 20°C otherwise the yields will be low.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	High ridges	At the time of earthing-up.	Ridges are made manually by hoe/spade or by bullock/tractor drawn ridger.	To avoid tuber infection by not exposing growing tubers.	Do not injure plants or roots while earthing-up.	Damage to the plants leads to low yields.
	Judicious irrigation	During crop growth.	Apply only required quantity of water.	To avoid development of congenial conditions for disease appearance through excessive moisture.	Avoid irrigations during overcast conditions.	Excessive humidity favours sporulation and disease development.
	Chemical control	Prophylactic spray as weather conditions become congenial for appearance of late blight (temperature 10-20 °C and relative humidity > 80%).	Spray mancozeb 75% WP or propineb 70% WP or chlorothalonil (@ 2 gm/lit) preferably with power sprayer to wet underneath of foliage. Mix sticker [Triton AE (@ 0.1%)] in the spray solution, if rains are expected.	To check the incidence of late blight.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while spraying and do not spray in opposite wind direction. Do not spray when crop is at maturity.	Over-dose is toxic while under-dose is ineffective. To protect the worker from hazardous compounds of the fungicides. Increase in cost of cultivation and pesticide residues in the produce.
		Protective sprays at an interval of 10 days if late blight can not be controlled by prophylactic spray.	Spray metalaxyl + mancozeb (@ 2.5 gm/ lt) or cymoxanil plus mancozeb (@ 3 gm/lit) preferably with power sprayer to wet	To check spread of late blight and damage to the crop.	Do not use same fungicide in repeated sprays Do not spray with sprinkler irrigation.	This may result in resistance development in pathogen. To economize on quantity of fungicide. Sprink-

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Destroy infected foliage/tubers.	Before harvesting.	underneath of foliage at an interval of 10 days. When the crop is mature or about 90% foliage is infected, cut haulms and burn them.	To destroy inoculum from the field.		ler irrigation also creates congenial conditions for growth and spread of late blight.
		After harvesting.	Sort out infected tubers from the produce before storage and burn/burly them. Collect left over tubers from the field & destroy infected tubers.	To destroy inoculum from the tubers/field.	Do not store infected tubers.	These tubers spread infection to other healthy tubers and infected seed tubers are primary sources of inoculum in the field.
EARLY BLIGHT (<i>Alternaria solani</i>) LEAF SPOTS (mainly <i>Phoma exigua</i> and <i>Phoma sorghina</i>)	Use healthy seed	Healthy seed is to be procured before planting.	Procure healthy seed from reliable source and obtain receipt.	Infected tubers are primary sources of early blight and leaf spots.	Do not purchase seed without seed class tag and receipt.	Seed is likely to be unreliable.
	Optimum fertilization	At the time of planting.	Apply recommended doses of NPK.	Crop grown under low fertilizer conditions is more prone to the disease.	Do not apply excessive fertilizers.	This will increase cost of cultivation and affect soil health.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
		At 40 days after planting.	Spray foliage with 0.1% urea. Repeat the spray after 10 days.	Under low nitrogen conditions (particularly when potato is grown after fertilizer exhaustive crops like rice) there is more incidence of early blight and leaf spots.	Do not use over-dose of urea.	It is toxic to foliage.
	Judicious irrigations	During crop growth particularly after 40 days of planting.	Apply irrigation as and when needed through furrows preferably in the morning.	To keep low moisture in the fields. High humidity is favourable for disease incidence and build up.		
	Chemical control	At 40-50 days after planting or on noticing disease symptoms.	Spray foliage with mancozeb (@ 0.2%) or copper oxychloride (@ 0.3%) using sprayer.	To check spread of the disease.	Wear mask and hand gloves while spraying and do not spray in opposite wind direction.	To protect the worker from hazardous compounds of the fungicides.
					Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose is ineffective.
					Do not spray when crop is at maturity.	Increase in cost of cultivation.
					Do not spray any acidic substances after spray of copper fungicides.	More copper is available to the plant in acidic medium that leads

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do	
BLACK SCURF <i>(Rhizoctonia solani)</i>	Remove and burn/burly haulms from the infected field.	Ten to fifteen days before harvesting.	Cut haulms of mature crop and either deep burry or burn them.	To reduce inoculum of early blight in the field.	Do not spray with sprinkler irrigation.	to chlorosis (yellowing of foliage). To economize on quantity of fungicide. Sprinkler irrigation also creates congenial conditions for growth and spread of the disease.	
	Use healthy seed.	Procurement of healthy seed is to be done before planting.	Procure healthy seed from reliable source and obtain receipt.	Diseased seed is source of inoculum for incidence and spread of black scurf.	Do not purchase seed without seed class tag and receipt.	Seed is likely to be unreliable.	
	Crop rotations with maize and/or green manure (dhaincha, green gram, sun hemp or cowpea).	During preceding season.	Green manuring should be done <i>in situ</i> during monsoon. Other corps can be grown by standard mehods.	Maize and green manure crops reduce inoculum and check disease build up. Green manure crops also fix atmospheric nitrogen in the soil.			
	Hot weather	During summer.	Affected fields should	Deep ploughing exposes	Do not keep the	To create	

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
WART (<i>Synchytrium endobioticum</i>)	cultivation.		be deep ploughed using bullock drawn or tractor mounted plough.	pathogen to high temperatures. This practice reduces inoculum in the field.	field fallow in monsoon.	anaerobic conditions.
	Seed treatment	Before planting.	If you are using untreated seed tubers, treat them with carbendazim 0.2% solution for 30 minutes, dry in shade and plant.	To destroy inoculum on tuber surface. Repeated use of treated tubers of 2-3 seasons is found to check the disease completely.	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose is ineffective.
		After harvesting.	After harvesting the tubers meant to be kept for seed purpose are to be treated with 3% boric acid* (spray or dip treatment for 20-30 minutes) before cold storage.	To kill inoculum on tuber surface. Such treated tubers do not need any chemical treatment at the time of planting in next season.	Do not use the same solution for more than three times to dip seed tubers. However, boric acid solution can be used for 20 dips, if cleaned tubers are used.	Effectiveness of the solution decreases with repeated use.
	Use healthy seed of wart immune varieties.	Selection of varieties and procurement of healthy seed is to be done before planting.	Procure healthy seed of wart immune varieties (see 1.1.4) from a reliable source and obtain receipt.	There is no incidence of wart on immune varieties. Infected/unhealthy seed tubers serve as a source of infection.	Do not use treated tubers for table purpose. Do not purchase seed without seed class tag and receipt. Wart is mainly confined to Darjeeling Hills. Check suitability of varieties in this area.	Treated tubers are toxic and unfit for consumption. Seed is likely to be unreliable. Unsuitable varieties lead to yield loss.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
DRY ROT (<i>Fusarium</i> spp.)	Follow quarantine restrictions.	Do not move out or procure potato tubers from wart infested areas (Darjeeling Hills of West Bengal)				
	Follow 5-6 years crop rotation.	Before planting potato.	Plant potato only once in 5-6 years in a wart infested field. In other years grow other crops.	Potato is the only natural host of the pathogen. Crop rotations with other crops reduce inoculum in the soil.	Do not plant potato every year in the same field.	This will build up inoculum in the soil.
	Rouging	On noticing greenish-yellow tumors (warts) on stems and lower leaves during wet conditions.	Uproot such plants along with roots and tubers and burn them.	This will reduce inoculum of wart in the soil and also check its spread.		
	Proper consumption.	After harvesting	Diseased tubers may be consumed or fed to animals only after properly boiling.	Boiling kills pathogen and checks its spread.	Do not throw peels and warted lumps in open or in manure pit. Burn them.	These can spread the disease.
	Hot weather cultivation.	During summer	Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	Deep ploughing exposes pathogen to high temperatures and reduces soil inoculum.		
	Use healthy seed.	Procurement of healthy seed is to be done before planting.	Procure healthy seed from reliable source and obtain receipt.	Diseased seed is source of inoculum for incidence and spread of dry rot.	Do not purchase seed without seed class tag and receipt.	Seed is likely to be unreliable.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control	Before planting	If you are using untreated seed tubers, treat them with 0.2% mancozeb (for 10 minutes) or spray them with 1200 ppm benomyl (1.2 gm in one litre water) and shade dry before planting.	These chemicals kill pathogens adhering on the tuber surface.	Do not use cut seed.	Cutting of seed spreads the inoculum to healthy seed. In case of cut seed, treat seed pieces with 0.2% mancozeb before planting. Over-dose is toxic to tubers while under-dose is ineffective.
		After harvesting	After harvesting, the tubers meant to be kept for seed purpose are to be treated with 3% boric acid* (spray or dip treatment for 20-30 minutes) before cold storage.	To kill inoculum on tuber surface. Such treated tubers do not need any chemical treatment at the time of planting in next season.	Do not use over-/under-dose of pesticide.	Effectiveness of solution decreases with repeated use.
	Avoid damage to tubers.	At the time of harvesting.	Cut haulms and stop irrigation 10-15 days prior to harvesting. Avoid injury to the tubers during harvesting, handling and storage.	Cutting haulms and stopping irrigation results in maturation of tuber skin. Injured sites on tubers are entry points for the pathogen.	Do not use same solution for more than 3 times to dip seed tubers. However, boric acid solution can be used for 20 dips, if cleaned tubers are used. Do not use treated tubers for table purpose. Avoid storing soiled tubers for seed purpose.	Treated tubers are toxic and unfit for consumption. Adhered soil is a source of inoculum in the field.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
SCLEROTIUM WILT OF POTATO <i>(Sclerotium rolfsii)</i>	Hot weather cultivation.	During summer	Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	Deep ploughing exposes pathogen to high temperatures. This practice reduces inoculum in the field.		
	Use healthy seed.	Healthy seed is to be procured before planting.	Procure healthy seed from reliable source and obtain receipt. Avoid procuring potato seed from areas prone to <i>Sclerotium</i> wilt (mainly plateau region).	Sclerotial wilt incidence is more in seeds procured from unreliable source or from areas known to have the disease.	Do not purchase seed without seed class tag and receipt. Do not use cut tubers for planting. In case of cutting, treat seed pieces for 5 minutes with 0.2% carboxin and shade dry before planting.	Seed is likely to be unreliable. During cutting the disease spreads from diseased tubers to healthy tubers.
	Seed treatment	Before planting	Treat seed tubers with 0.2% carboxin solution for 5 minutes. After shade drying again treat these tubers with 1% <i>Trichoderma harzianum</i> solution for 5-10 minutes. Shade dry the	Carboxin kills inoculum of pathogen present on tuber surface. <i>T. harzianum</i> is a bio-control agent for the disease.	Do not use over-/under-dose of pesticide. Do not use same solution for more than 3 times.	Over-dose is toxic to tubers and <i>T. harzianum</i> while under-dose is ineffective. Effectiveness of solution decreases with repeated use.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Apply FYM and neem cake in the field.	Before planting.	tubers before planting. Apply FYM (@ 10t/ha) and neem cake (@ 300 kg/ha) to the infected field 15 days before planting. Other inorganic fertilizers are to be applied as per recommended doses for the region.	FYM and neem cake promote growth of bio-control agent <i>T. harzianum</i> .	Do not use treated tubers for table purpose.	Treated tubers are toxic and unfit for consumption.
	Follow crop rotations.	After potato crop.	<i>Sclerotium</i> wilt generally occurs in <i>kharif</i> potatoes in plateau region. <i>Rabi</i> sorghum is the best rotational crop after potato.	Non-host rotational crops reduce inoculum of the pathogen in soil.	Do not grow Bengal gram, potato, chilli, cowpea, green gram, brinjal, tobacco, black gram, red gram, peas etc. as rotational crops.	These are alternate hosts for the pathogen and increase/sustain inoculum in the soil.
CHARCOAL ROT (<i>Macrophomina phaseoli</i>)	Use healthy seed.	Healthy seed is to be procured before planting.	Procure healthy seed from reliable source and obtain receipt.	Infected tubers are primary sources of infection.	Do not purchase seed without seed class tag and receipt. Do not use cut tubers for planting.	Seed is likely to be unreliable. During cutting the disease spreads from diseased tubers to healthy tubers.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
BACTERIAL WILT OR BROWN ROT <i>(Ralstonia solanacearum)</i>	Early harvesting of the crop.	February end or beginning of March.	Plant early/medium maturing varieties (table 4) and harvest them before the soil temperature reaches 28 °C by the end of February.	Warm conditions are favourable for incidence and spread of disease in tubers.	Do not keep the field completely dry in February. Check suitability of the variety in your region.	This will raise soil temperature. Unsuitable varieties yield less.
	Seed treatment	After harvesting	After harvesting, the tubers meant to be kept for seed purpose are to be treated with 3% boric acid* (spray or dip treatment for 20-30 minutes) before cold storage.	To kill inoculum on tuber surface. Such treated tubers do not need any chemical treatment at the time of planting in next season.	Do not use such tubers in food.	Treated tubers are toxic and unfit for consumption.
	Cold storage	After harvesting	Sort out damaged/charcoal rot infected tubers and store healthy tubers in cold store. Before doing so, check terms and conditions for losses during cold storage.	At low temperatures of cold store, the disease does not appear.	Do not treat table potatoes with fungicides.	Treated tubers are toxic and unfit for consumption.
	Crop rotation with non-host crops.	Generally 2-3 years' crop rotation should be followed.	Use non-host crops like finger millet, maize, sorghum, wheat, cabbage, cauliflower, onion, garlic, barley etc.	To reduce load of inoculum in the soil.		
Summer/winter ploughing	During hot summer months in sub-tropical plains and cold winter	Deep plough the fields using bullock drawn or tractor mounted plough.	The pathogen survives on undisturbed plant remnants and weeds.			

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
		months in temperate hills.		Ploughing disturbs such remnants and weeds. Ploughing also exposes bacteria to high/cold temperatures.		
	Use healthy seed of early maturing varieties.	Healthy seed is to be procured before planting.	Procure healthy seed from reliable source and get receipt. Avoid procuring potato seed from areas prone to bacterial wilt (mainly mid-hills and plateau region). Refer table 4 for list of early maturing varieties.	Bacterial wilt incidence is more in seeds procured from unreliable source or from areas known to have bacterial wilt.	Do not purchase seed without seed class tag and receipt. Do not use cut tubers for planting.	Seed is likely to be unreliable. During cutting the disease spreads from diseased tubers to healthy tubers.
	Adjust planting time.	At the time of planting.	In north-eastern and – western hills plant potato early in February. In eastern and southern hills plant autumn crop in September. In plateau region plant <i>kharif</i> crop in June.	Early maturing varieties can buffer excessive yield loss due to early bulking. To escape high bacterial wilt incidence during early stages of crop growth. High temperature and high humidity favour disease incidence. In north-eastern and – western hills the incidence is more in July. While in eastern and southern hills it is more	Check suitability of the variety in your region.	Unsuitable varieties yield less.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Chemical control.	At the time of planting.	Apply stable bleaching powder @ 12 kg/ha mixed with fertilizer in furrows at the time of planting.	in November/December. In plateau region incidence of bacterial wilt is more in August. Bleaching powder is known to reduce bacterial wilt incidence to a greater extent.	Do not apply bleaching powder in completely dry soil.	This may affect germination.
	Clean cultivation and minimum tillage.	At planting and during crop growth.	Give full earthing-up at the time of planting. Avoid further earthing-up during crop growth, which causes root injury. Keep the field free from solanaceous weeds. Uproot weeds by hand or use pre-emergence (2,4-D, metribuzin, oxyfluorfan, atrazine, isoproturon etc.)/post-emergence (paraquat) weedicides.	Post-planting tillage during earthing-up and removal of weeds may cause injury to roots, stolons and tubers. These injuries are entry points for the pathogen.	Do not spray post - emergence weedicides on potato plants (weed directed spraying is to be done at 5% potato emergence).	This may kill potato plants also.
	Destroy infected plants/tubers.	Before harvesting. After harvesting.	Uproot plants showing wilting and burn them. Sort out infected tubers from the produce before storage and burn/burly them. Collect left over	To destroy inoculum from the field. To destroy inoculum from the tubers/field.	Do not store infected tubers.	These tubers spread infection to other healthy tubers and infected

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
COMMON SCAB (<i>Streptomyces scabies</i>)			tubers from the field and destroy infected tubers.			seed tubers are sources of inoculum in the field.
	Crop rotation with cereals (wheat, oat, maize, sorghum, bajra, barley etc.). Hot weather cultivation.	In place of potato during <i>rabi</i> season. During summer.	Plant recommended varieties of cereals in <i>rabi</i> season. Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	To reduce <i>S. scabies</i> population in the soil. Deep ploughing exposes pathogen to high temperatures. This practice reduces inoculum in the field.	Do not plant potato in affected field every year. Do not keep the field fallow in monsoon.	Infection gets aggravated. Inoculum builds up in fallow/undisturbed fields.
	Green manuring with dhaincha, green gram and sun hemp.	In monsoon.	Plant green manuring crop in monsoon.	Green manure crops reduce inoculum, check disease build up and also fix atmospheric nitrogen in the soil.		
	Organic amendments.	At the time of planting.	Broadcasting of organic amendments at soil preparation or applying them in furrows at the time of planting.	For increasing the population of saprophytes in soil.	Do not apply diseased organic amendments like straws of diseased crops.	This would add inoculums of other diseases in the soil.
	Seed treatment.	Before planting.	If you are using untreated seed tubers, treat them with 0.2% carbendazim solution for 30 minutes, dry in shade and plant.	To destroy inoculum on tuber surface.	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose is ineffective.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
SOFT ROT (<i>Erwinia carotovora</i> subsp.)		After harvesting	After harvesting, the tubers meant to be kept for seed purpose are to be treated with 3% boric acid* (spray or dip treatment for 20-30 minutes) before cold storage.	To kill inoculum on tuber surface. Such treated tubers do not need any chemical treatment at the time of planting in next season.	Do not use the same solution for more than three times to dip seed tubers. However, boric acid* solution can be used for 20 dips, if cleaned tubers are used.	Effectiveness of the solution decreases with repeated use.
	Narrow down irrigation interval.	During tuber initiation and growth (40-75 days after planting).	Maintain high moisture through frequent irrigations during this period.	To create anaerobic condition in soil, which is unfavourable for development of the disease.	Do not use treated tubers for table purpose.	Treated tubers are toxic and unfit for consumption.
	Hot weather cultivation.	During summer.	Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	Deep ploughing exposes pathogen to high temperatures and reduces soil inoculum.	Do not create water logging conditions.	The crop will be damaged.
	Use healthy seed of early/medium maturing varieties.	Procurement of healthy seed is to be done before planting.	Procure healthy seed of early/medium maturing varieties (table 4) from reliable source and obtain receipt.	Diseased seed is source of inoculum for incidence and spread of soft rot.	Do not purchase seed without seed class tag and receipt. Check suitability of the variety in your region.	Seed is likely to be unreliable. Unsuitable varieties yield less.
Judicious irrigation		During crop growth	Irrigate the crop as and when needed (no over-	Water stagnation provides congenial		

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Early harvesting of the crop.	February end or beginning of March.	/under-irrigation). Provide proper drainage so that water does not stagnate. Harvest potatoes before the soil temperature reaches 28 °C by the end of February.	conditions and promotes incidence and spread of the disease. Warm conditions are favourable for incidence and spread of disease in tubers.	Do not keep the field completely dry in February.	This will raise soil temperature.
	Avoid damage to tubers	At the time of harvesting	Cut haulms to mature tuber skin prior to harvesting. Avoid injury to the tubers during harvesting, handling and storage.	Cutting haulms 10-15 days prior to harvesting results in maturation of tuber skin. Injured sites on tubers are entry points for the pathogen.		
	Seed tuber treatment	After harvesting	After harvesting, the tubers meant to be kept for seed purpose are to be treated with 3% boric acid* (spray or dip treatment for 20-30 minutes) before cold storage.	To kill inoculum on tuber surface. Such treated tubers do not need any chemical treatment at the time of planting in next season.	Do not use such tubers in food.	Treated tubers are toxic and unfit for consumption.
	Cold storage.	After harvesting.	Sort out damaged/soft rot infected tubers and store healthy tubers in cold store. Before doing so, check terms and conditions for losses during cold storage.	At low temperatures of cold store, the disease does not appear.	Do not treat table potatoes with fungicides.	Treated tubers are toxic and unfit for consumption.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
SEED DECAY WHEN USED AS CUT PIECES	Chemical treatment of cut seed pieces.	Before planting.	Mix 5 kg talk powder with 1 kg mancozeb and spread evenly on the cut pieces. Allow the cut pieces to dry and suberise in shade for two days before planting.	To kill pathogens and prevent decay of cut seed pieces in the soil.	Avoid cutting of seed tubers. Instead use small or seed sized whole tubers for planting. Do not use treated pieces in food.	In addition to seed decay, cutting of seed tubers spread other diseases from infected tubers. Treated pieces are toxic and unfit for consumption.
VIRAL DISEASES & SUCKING INSECT PESTS (Potato virus X, Y, A, S, M and Potato leaf roll virus) (Leafhoppers and Aphids)	Use healthy seed Chemical control	Healthy seed is to be procured before planting. At the time of planting Need based application 40 days after planting.	Procure healthy seed from a reliable source and obtain receipt. Apply phorate 10 G (@ 15 kg/ha) in furrows at the time of planting. Spray foliage with methyl demeton 25 EC @ 1.2 ml/lit or dimethoate 30 EC @ 1.0 ml/lit or imidacloprid 17.8 SL @ 0.2 ml/lit at an interval of 15 days if needed after 40 days of planting.	Viral diseases spread from infected tuber originated plants to healthy plants. Systemic pesticides help in protecting the crop from sucking insects and in turn prevent virus transmission.	Do not purchase seed without seed class tag and receipt. Wear mask and hand gloves while applying pesticide. Wear mask and hand gloves while spraying and do not spray in opposite wind direction. Do not use over-/under-dose of pesticide. Do not spray when crop is at maturity.	Seed is likely to be unreliable. To protect the worker from hazardous compounds of the pesticide. To protect the worker from hazardous compounds of the pesticide. Over-dose is toxic while under-dose is ineffective. Increase in cost of cultivation and pesticide residues in the produce.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Follow best cultural practices. Control of aphids is mainly required in seed crop to maintain health standards. For table crop the over riding factors will be yield and profit.	Adjust potato crop during relatively aphid-free period. Keep the field weed-free Roguing in seed crop. Twice during crop growth (at 45 days and 60 days after planting)	Plant potato crop keeping in view build up of aphid population in your area. Weeds are removed manually or using weed specific herbicides. Uproot diseased plants along with tubers and dispose them off.	To escape severe infestation of aphids Many weeds are hosts for aphids. To prevent spread of viral diseases from diseased plants/tubers.	Do not use same pesticide in repeated sprays. Do not spray with sprinkler irrigation.	This may result in resistance development in vectors. To economize on quantity of pesticide.
		Kill haulms in seed crop before aphid population reaches critical level (20 aphids/100 compound leaves).	Kill above ground plant parts using weedicide (paraquat formulation 200g/ltr @ 2.5 ml/ltr) on sunny day.	To prevent exposure of potato foliage to aphids.	In case of table potatoes do not kill haulms before full maturity.	This will result in yield loss.
STEM NECROSIS AND THRIPS (Tospovirus) (<i>Thrips palmi</i>)	Use tolerant varieties. Late planting	Selection of varieties and procurement of healthy seed is to be done before planting. At the time of planting	Plant healthy seed of cvs. Kufri Sutlej, K. Anand, K. Badshah or K. Jawahar. Plant potatoes 10-15 days later than the	Incidence of stem necrosis on these varieties is less. To escape stem necrosis.	Check suitability of these varieties in your area. Do not plant highly	Unsuitable varieties lead to yield loss. Heavy infections

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
			optimum planting time in your area.	Stem necrosis is spread by thrips and their population is more in early part of potato season.	susceptible varieties like Kufri Chandramukhi and K. Bahar. Do not plant late maturing varieties.	of stem necrosis on these varieties. High temperatures during tuberization result in low yield.
	Chemical control	Before planting	Dip seed tubers in solution of imidacloprid 17.8 SL (0.4 ml/lit) for 10 minutes, dry in shade and plant.	Imidacloprid is systemic insecticide. Tuber treatment can protect the crop from thrips for few days after emergence.	Do not use over-/under-dose of pesticide. Do not use the same solution for more than three times to dip seed tubers. Do not use treated tubers for table purpose.	Over-dose is toxic while under-dose is ineffective. Effectiveness of the solution decreases with repeated use. Treated tubers are toxic and unfit for consumption.
		At about 80% emergence.	Spray the crop with imidacloprid 17.8 SL (@ 0.2 ml/lit) using sprayer.	To protect the crop from thrips and in turn from stem necrosis.	Wear mask and hand gloves while spraying and do not spray in opposite wind direction. Do not use over-/under-dose of pesticide. Do not spray with sprinkler irrigation.	To protect the worker from hazardous compounds of the fungicides. Over-dose is toxic while under-dose is ineffective. To economize on quantity of pesticide.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
POTATO APICAL LEAF CURL VIRUS (PALCV) AND WHITEFLIES	Use healthy seed	Healthy seed is to be procured before planting.	Procure healthy seed from reliable source and get receipt. Variety Kufri Bahar is tolerant to PALCV.	Viral diseases spread from infected tuber originated plants to healthy plants.	Do not purchase seed without seed class tag and receipt. Check suitability of the variety in your region.	Seed is likely to be unreliable. Unsuitable variety yields less.
	Delay planting	At the time of planting	Plant potatoes 10-15 days later than the optimum planting time in your area.	Whiteflies are vectors of PALCV. Whitefly population is more in high temperatures in early part of potato season and goes on reducing at low temperatures of later part.	Do not plant late maturing varieties.	The crop will be subjected to high temperatures during tuber growth.
	Chemical control	Seed treatment before planting	Dip seed tubers in solution of imidacloprid 17.8 SL (0.4 ml/lt) for 10 minutes, dry in shade and plant.	Imidacloprid is systemic insecticide. Tuber treatment can protect the crop from whiteflies for few days after emergence.	Do not use over-/under-dose of pesticide. Do not use the same solution for more than three times to dip seed tubers. Do not use treated tubers for table purpose.	Over-dose is toxic while under-dose is ineffective. Effectiveness of the solution decreases with repeated use. Treated tubers are toxic and unfit for consumption.
		At about 80% emergence.	Spray the crop with imidacloprid 17.8 SL (@ 0.2 ml/lt) using sprayer.	To protect the crop from whiteflies and in turn from PALCV.	Wear mask and hand gloves while spraying and do not spray in opposite wind direction.	To protect the worker from hazardous compounds of the pesticides.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
APHIDS AND LEAF- HOPPERS	Roguing in seed crop.	Twice during crop growth (at 45 days and 60 days after planting).	Uproot diseased plants along with tubers and dispose them off.	To prevent spread of PALCV from diseased plants/tubers.	Do not use over-/under-dose of pesticide. Do not spray with sprinkler irrigation.	Over-dose is toxic while under-dose is ineffective. To economize on quantity of pesticides. This will result in yield loss.
	Control measures are described under viral diseases and sucking insect pests.					
MITES [<i>Polyphagotarsonemus latus</i> (= <i>Hemitarsonemus latus</i>)]	Chemical control.	When infestation is observed in the field.	Spray foliage with wettable sulphur @ 3 gm/ltr or kelthane @ 2.5 ml/ltr using sprayer. Repeat the sprays 2-3 times alternatively at an interval of 8-10 days.	To kill mites.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while applying pesticide. Do not spray with sprinkler irrigation. Do not repeat same insecticide.	Over-dose is toxic while under-dose is ineffective. To protect the worker from hazardous compounds of the pesticide. To economize on quantity of pesticide. To avoid resistance development in mites.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do	
WHITE-FLIES (<i>Bemisia tabaci</i>)	Control measures are described under potato apical leaf curl virus (PALCV) and whiteflies.					Do not grow chilli as neighbouring crop.	Chilli is highly susceptible to mites and can serve as source for mite infestation.
THRIPS (<i>Thrips palmi</i>)	Control measures are described under stem necrosis and thrips.						
CUTWORM (<i>Agrotis flammatra</i> / <i>A. spinifer</i>)	Summer ploughing/off-season tillage	During hot summer months.	Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	Deep ploughing exposes larvae to hot temperatures and predatory birds like crow, mynah, starling etc.	Do not allow the field to remain fallow.	Undisturbed field may lead to more population of cutworms in soil	
	Fire accompanied with light during night.	Night hours.	Burning dry twigs/leaves. Also provide some light above the fire.	Cutworm moths get attracted towards light and fall in fire.			
	Chemical control.	At the time of first earthing up (30-35 days after planting). On noticing cutworm damage at stem bases. Presence of cutworm	Apply phorate 10 G granules @ 15 kg/ha near the plant base before earthing-up. Spray chlorpyrifos 20 EC(@ 2.5 ml/lit) on foliage and ridges using sprayer.	To protect the crop from cutworms as well as sucking insects. To kill moths and cutworm larvae.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while spraying and do not spray against	Over-dose is toxic while under-dose is ineffective. To protect the worker from hazardous compounds of the	

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
WHITE GRUB <i>(Lachnosterna longipennis/ Lachnosterna coracea)</i>		can be ascertained by digging below the plant and locating cutworm larvae.	Spraying should usually be done in the evening because cutworm larvae remain in soil during day time		wind direction. Do not spray when crop is at maturity.	pesticide. Increase in cost of cultivation and pesticide residues in the produce. To economize on quantity of pesticide.
	Mechano-chemical killing of beetles.	In late May or early June after pre-monsoon showers.	Downing beetles by shaking shrubs around the field and killing them by spraying chlorpyrifos 20 EC @ 2.5 ml/lt.	After 1 st pre-monsoon shower beetles start appearing. This is followed by mating and increasing population.		
	Summer ploughing/ off-season tillage	During hot summer	Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	Deep ploughing exposes larvae to hot temperatures and predatory birds like crow, mynah, starling etc.	Do not allow the field to remain fallow. Do not use undecomposed FYM.	Undisturbed field may lead to more population of cutworms in soil Undecomposed FYM is source of white grub infestation.
Chemical control	At planting	Apply phorate 10 G @ 15 kg/ha or carbofuran 3G @ 75 kg/ha in furrows at the time of planting.	To kill white grub stages present in the soil and provide systemic control for at least a month.	Do not use over-/ under-dose of pesticide. Wear mask and hand gloves while	Over-dose is toxic while under-dose is ineffective. To protect the worker from	

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
RED ANT <i>(Dorylus orientalis)</i>		Whenever beetles are noticed in the field.	Spray foliage and ridges with chlorpyrifos 20 EC @ 2.5 ml/ltr or endosulfan 35 EC @ 1.5 ml/ltr or carbaryl 50 WP @ 2 gm/ltr using sprayer.	To kill beetles and other developmental stages.	applying pesticide.	hazardous compounds of the pesticide.
	Use of repellent.	At the time of first earthing-up (30-35 days after planting).	Apply mustard oil cake (@ 150 kg/ha) near the plant base before earthing-up.	Mustard oil cake repels red ants.	Do not spray with sprinkler irrigation.	To economize on quantity of pesticide.
	Chemical control.	Whenever infestation of red ants is noticed.	Drench ridges with chlorpyrifos 20 EC (@ 2.5 ml/ltr) using sprayer.	To kill red ants and its developmental stages.	Do not use over-/under-dose of pesticide. Do not spray when crop is at maturity.	Over-dose is toxic while under-dose is ineffective. Increase in cost of cultivation and pesticide residues in the produce.
					Do not spray before evening.	The pest remains in soil during day time.
					Wear mask and hand gloves while	To protect the worker from

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
MOLE CRICKET (<i>Grylotalpa africana</i>)	Flooding	When infestation is observed during tuber formation stage	By furrow irrigation	Red ants do not withstand anaerobic conditions created by flooding.	<p>spraying and do not spray against wind direction. Do not spray with sprinkler irrigation.</p> <p>Should not be practiced in cloudy weather with low temperatures. Should not be practiced in dehaulmed mature crop.</p>	<p>hazardous compounds of the pesticide. To economize on quantity of pesticide.</p> <p>This will invite late blight.</p> <p>Cause tuber rottag.</p>
	Chemical control	When infestation is observed in the field.	Spray foliage with cartap hydrochloride 50 SP @ 1 gm/lit using high pressure power sprayer or knapsack sprayer.	To kill mole cricket and its developmental stages.	<p>Do not use over-/under-dose of pesticide.</p> <p>Wear mask and hand gloves while spraying and do not spray in opposite wind direction. Do not spray when crop is at maturity.</p> <p>Do not spray with sprinkler irrigation.</p>	<p>Over-dose is toxic while under-dose is ineffective.</p> <p>To protect the worker from hazardous compounds of the fungicides. Increase in cost of cultivation and pesticide residues in the produce. To economize on quantity of pesticide.</p>

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
EPILACHNA BEETLES (<i>Henosepilachna ocellata</i>)	This is major pest in higher hills in certain years. The IPMs given for leaf eating caterpillars have also been found effective against epilachna beetles.					
LEAF EATING CATERPILLARS (<i>Heliothis armigera</i> , <i>Psodoptera litura</i> etc.)	Mechanical control.	In initial stages of infestation.	Hand picking and killing of eggs, larvae and pupae. It is also advisable to collect and destroy infested plant parts (mainly leaves).	To check population build up. This is most efficient method to control leaf eating caterpillars when the population is not very high in initial stages.		
	Bio-formulation.	When damage is less than 2%.	Spray bio-formulation Bt @ 10 ⁹ spores/ml using sprayer. The spraying should preferably be done in the evening.	Bt is toxic to these insect pests and can control them when their population is less. There are reports that in bright sun-light Bt gets inactivated.	Do not use under-dose	It is ineffective.
	Chemical control	When damage is more than 5%.	Spray endosulfan 35 EC (1.5 ml/lit) or carbaryl 50 WP (2 gm/lit) or chlorpyrifos 20 EC (2.5 ml/lit) or monocrotophos 40 WSC (1.2 ml/lit) using sprayer.	To kill different stages of these insects.	Do not use over-/under-dose of pesticide.	Over-dose is toxic while under-dose is ineffective.
					Wear mask and hand gloves while spraying and do not spray in opposite	To protect the worker from hazardous compounds of the

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
POTATO TUBER MOTH <i>(Phthorimaea operculella)</i>	Proper earthing up and regular irrigations	Two earthing ups at 30-35 and 50-55 days after planting. Regular irrigations whenever needed.	Manually by hoe/spade or bullock drawn or tractor mounted ridger. Irrigations applied through furrows.	Not to expose growing tubers. To maintain ridges uncracked.	wind direction. Do not spray when crop is at maturity. Do not use same pesticide in repeated sprays. Do not spray with sprinkler irrigation.	fungicides. Increase in cost of cultivation and pesticide residues in the produce. This may result in resistance development in the insect. To economize on quantity of pesticide.
	Chemical control	When infestation is observed in the field.	Spray monocrotophos 40 WSC @ 1.2 ml/ltr on foliage and drench ridges.	To kill moths and larvae.	Do not injure plants or roots. Do not allow ridges to dry and crack.	Damage to the plants leading to low yield. The pest enters soil through cracks and damage tubers.
	Proper storage of tubers.	After harvest	Store potatoes in cold store. Before doing so, check terms and conditions for losses	Potatoes are semi-perishable and need to be stored properly for future use.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while spraying and do not spray in opposite wind direction. Do not use insecticides for treating table potatoes.	Over-dose is toxic while under-dose is ineffective. To protect the worker from hazardous compounds of the pesticide. To avoid pesticide residues in stored potatoes meant for consumption.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
			during storage. In country stores, store potatoes on layer of dried lantana or eucalyptus or neem leaves and also cover potato heap with them. It is always better to spray country store with contact insecticide (monocrotophos 40 WSC @ 1.2 ml/lit) 15 days before storing potatoes			
	Cleaning of fields after harvest.	After harvesting	Sex pheromone capsules on water traps @ 4 traps/ 100 m ³ space can also be placed in country stores. Collect left over tubers from the field and burn left over foliage.	To attract and kill male moths in water traps.		
ROOT-KNOT NEMATODES <i>(Meloidogynae incognita, M. hapla, M. javanica)</i>	Summer ploughing.	During hot summer months.	Affected fields should be deep ploughed using bullock drawn or tractor mounted plough.	Deep ploughing exposes larvae to hot temperatures and are killed.		
	Crop rotation with cereals.	Crop rotation is to be followed as per seasons.	Plant recommended varieties of cereals in infested field. Grow potato only	To reduce nematode population in the soil.	Do not plant potato in affected field every year.	Infection gets aggravated.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
	Use healthy seed.	Healthy seed is to be procured before planting.	once in two years. Procure healthy seed from reliable source and obtain receipt. Do not procure seed originating from nematode infested areas.	Infested tubers are source of infestation.	Do not purchase seed without seed class tag and receipt.	Seed is likely to be unreliable.
	Adjust dates of planting	At the time of planting.	Late planting (by about 15 days) in plains and early planting (by about 15 days) in hills.	The infestation is less in late and early planted crops in plains and hills, respectively.	Do not deviate much from normal planting dates in your area. Do not plant late varieties in late planting.	You are likely to get lower yields. The crop will not get sufficient period for maturation.
	Use of trap crops	At the time of planting	Plant one row of trap crop like <i>Tagetes spp.</i> (marigold) between 2-3 rows of potato.	Exudates from marigold roots attract nematodes and prevent their multiplication in the soil.		
	Chemical control	At planting and earthing up.	Apply carbofuran 3 G (75 kg/ha) in rows in two equal doses, half (37.5 kg/ha) at planting and remaining half (37.5 kg/ha) at the time of earthing up (30-40 days after planting).	To kill different stages of root knot nematodes.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while applying pesticide.	Over-dose is toxic while under-dose is ineffective. To protect the worker from hazardous compounds of the pesticide.
CYST NEMATODES (<i>Globodera</i>)	Use healthy seed of resistant varieties.	Healthy seed is to be procured before planting.	Procure healthy seed of variety Kufri Swarna from reliable source	Incidence of cyst nematodes is less on variety Kufri Swarna.	Do not purchase seed without seed class tag and receipt.	Seed is likely to be unreliable.

Name of the disease/ insect pest	What to do	When to do	How to do	Why to do	What not to do	Why not to do
<i>pallida</i> and <i>Globodera</i> <i>rostochiensis</i>)	Follow crop rotations with non-solanaceous crops.	Cyst nematode is restricted in South Indian hills. Annual crop rotations are to be followed as given in next column.	and obtain receipt. Avoid procuring seed grown in cyst nematode infested fields. Grow potato in summer season and other rotational crops (cabbage, carrot, radish, garlic, beet root, turnip, oat etc.) in other seasons.	Seed grown in nematode infested fields is source for infestation. To reduce cyst nematode population in the soil.	Do not follow mono-cropping with potato continuously.	Mono-cropping with potato will increase the nematode population.
	Chemical control.	At planting.	Apply carbofuran 3 G (75 kg/ha) in rows in at the time of planting.	To kill different stages of cyst nematodes.	Do not use over-/under-dose of pesticide. Wear mask and hand gloves while applying pesticide.	Over-dose is toxic while under-dose is ineffective. To protect the worker from hazardous compounds of the pesticide.

- * **Boric acid is a safe and eco-friendly chemical. Use laboratory grade 99.5% pure boric acid. The most economical method for treating seed tubers is to spread seed tubers in a single layer and spray 3% boric acid (30g in 1 liter water). Another method is dip treatment for 20-30 minutes. In dip treatment same boric acid solution can be used for about 20 times if clean (soil free) tubers are treated.**