CPRI

Technical Bulletin No. 80

Seed and Ware Potato Production Technology for Southern Hills

Central Potato Research Station
(Indian Council of Agricultural Research)
Muthorai, Ooty-644 004

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Printed: January 2007, 500 copies

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Designed & Printed at : Nirmal Vijay Printers
B-62/8, Naraina Industrial Area
Phase-II, New Delhi - 110 028
Phone : 51418526, 25891449, 9811053617

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Foreword

Ever since potato was introduced by Mr. John Sullivan in the Nilgiri hills in the year 1822, the potato production has been gaining new heights. The quantum jump in cultivation of potato in the region lies in the agro climatic conditions which are conducive in taking potato crop around the year. The Central Potato research Station, Ooty was established near Muthorai, Ootaccmund in the year 1957 to boost the potato seed production in the southern region and to reorient its activities following the ban imposed on the export of seed potatoes out of Nilgiris under the Disease and Insect Pests Act 1914. The scientists had no option but to attempt a solution to the problem by developing varieties which are not only resistant to cyst nematode and late blight but also specific agronomic practices suitable to the climatic conditions of the region.

The enormous scientific progress has been made on various aspects of potato research and development leading to enhancement in area under potato and developing package of practices for potato based cropping systems to produce disease free quality seed. This has been possible only with the joint efforts made by the scientists from the Central Potato Research Institute, Shimla and its regional station at Muthorai. The bulletin presents an overall view of the potato production technology over the last five decades. It is likely to serve as a benchmark for the future of scientific data generation for the scientists, extension workers and more important to the farmers engaged in potato cultivation not only in the Nilgiri hills but other parts in the southern India.

The painstaking efforts for compilation of this bulletin taken by the team of scientists consisting of Drs.G. Ravichandran, TA Josheph, R Muthuraj, Sarjeet Singh and EP Vekatasalam and Mrs (Dr) M Monorma and their colleagues from Head Quarter and Central Potato Research Station, Muthorai deserve appreciation. The Nilgiri region is likely to serve as a prime center in meeting the demand of quality seed in Nilgiri's and for supplying fresh tubers for table purposes and catering to the need of processing industries which are coming up in big way.

SK Pandey
Director

1. Introduction

The Central Potato Research Station, Muthorai, Ooty, Tamil Nadu, was established during 2nd five year plan under the Ministry of Agriculture with the cooperation of the Madras Government and started functioning from April 1957. It is working on the basic problems of potato production in the state in addition to the dissemination of the latest improved technologies for improving the crop productivity. The station is located 6 Km away from Ootacamund town on the Ooty-Emerald road near Muthorai village at an altitude of 2130 meters above msl. It has an area of 16.6 hectares out of which about 12 hectares is cultivable. Originally it was to cater to the needs of seed potatoes of the States of Kerala, Madras, Mysore and Andhra Pradesh. However, the occurrence of potato cyst nematodes in 1961 and the late blight in epiphytotic form in the region changed the mandate. Under the Disease and Insect Pest Act 1914, the export of seed potatoes was banned out of Nilgiris. So the station reoriented its activities to develop the management strategies for potato cyst nematodes and late blight disease, suitable agronomic practices for a potato based cropping system and production of disease free quality seeds of existing potato varieties. The station has identified non-availability of quality seed potatoes, late blight and potato cyst nematodes as three foremost important potato production problems and working on them with suitable recommendations.

Potato was introduced in the Nilgiris by Mr.John Sullivan, the founder of present day Udhagamandalam, in 1822. The area under potato in the Nilgiris had been increasing considerably since 1910 due to the demands from Colombo, Bombay, Calcutta and other places. The increase was also due to the Ist and IInd world wars as the import of potato for European countries was banned and it reached a peak of 10,000ha during 1944. With the establishment of Central Potato Research Station in 1957, the potato production in the Nilgiris has gained a new momentum. Though there was a set back in potato area during 1961 due to the attack of late blight, again it started rising with the introduction of new varieties and suitable management practices. At present, potato is cultivated in about 5600ha in Tamil Nadu, out of which 4500ha lies in the Nilgiris, which has been the focal point of potato production in the state. Due to low acreage under potato in Kerala and Andhra Pradesh, a good in house demand of fresh potatoes for table as well as by the processing industries and the Nilgiris region will continue as a viable and prime centre in the south for potato production

2. Topgraphy and climate

Potato is an important vegetable crop of which plays a prominent role in the agricultural economy of Nilgiris. The Nilgiris is unique one with regard to climatic conditions, economy and also land use pattern. It consists of four blocks, namely, Udhagamandalam, Kotagiri, Coonoor and Gudalur (fig. 1). The entire district is in hilly tract with an elevation ranging from 1000m (Gudalur) to 2500m (Thottapetta) above msl. The Udhagamandalam, Kotagiri and Coonoor blocks lie at an altitude of 1500 to 2500m above msl. Udhagamandalam and Coonoor are the more suitable for potato cultivation due to favourable temperature conditions.

2.1 Climate

The climate of the region is humid and sub temperate type and is served both by South-west (50-55% rainfall) and North-east (30-35% rainfall) monsoons with a well distributed mean annual rainfall of 1300mm in 100 rainy days. The months of July, August and September are the wettest and January and February receive almost no rain. The mean maximum and minimum temperatures range between 17.5 to 22.2 and 7.3 to 12.3°C, respectively. On the whole, the climate of the region is suitable for potato cultivation through out the year, but irrigation facilities are required for the crop grown during January to April, as these are dry months.

2.2 Seasons

Due to the equinox climate prevailing in the Nilgiris, potato can be grown through out the year under three distinct seasons namely, summer, autumn and spring. Summer is the main season (April/May to August/September) occupying around 60-65% area followed by autumn (August/September to December/January) occupying 25-30% of the area. During summer and autumn seasons potato crop is grown under rainfed conditions. A meager area of about 5-10% is grown under irrigation during January/February to May/June as spring crop.

2.3 Soils

There are three broad categories of soils in the Nilgiris. They are i) Nanjanad, ii) Udhagamandalam and iii) Kundah series. The physico-chemical properties of these soils are given in the table 1.

Table 1. Physico – chemical properties of Nilgiri soils

Soil series	Clay (%)	Silt (%)	Sand (%)	Organic Carbon	pH	CEC
Nanjanad	40-58	-	24-30	2-3	4.1-4.3	16.3-18.0
Udhagamandalam	38-44	Appreciable	28-34	High	Low pH	-
Kundah	42-56	15 – 24	-	high	4.2-4.4	High

Potato can be grown in all types of soils. Loose and friable soil with low clay content and good in humus is the most suitable soil for potato cultivation.

2.4 Constraints of potato cultivation in Niligiris

There are several constraints in potato cultivation in the Niligiris they are

1. Infestation of soil with cyst nematode
2. Lack of country and cold storage facilities
3. Inadequate participation of state govt. in seed production activities.
4. Restriction of movement potato as seed due to domestic quarantine.
5. Regular appearance of late blight.
6. High cost of seed from out of state sources due to transportation cost.
7. Non availability of suitable site for quality seed production.
8. Lack of awareness to use good quality seed

2.4.1 Infestation of soil with potato cyst nematodes (*Globodera pallida* and *Globodera rostochiensis*)

This is a second important pest of Nilgiris and not seen in any other part of India. The affected plants get stunted with dull and unhealthy foliage and

have a tendency to dry/wilt during the day. In case of heavy infestation plants turn yellow and die prematurely. The control is done by application of Carbofuran (Furadan) 3G @ 2 kg ai ha^{-1} as basal dose at the time of planting and cultural practices.

- Use of resistant cultivar like Kufri Swarna, Kufri Giriraj and Kufri Jyoti also which limits the growth of nematode populations along with nematicide application as the later two varieties do not support fast multiplication of the pathogens.
- Following crop rotation with crops like cabbage, carrot, radish and wheat.
- Use of quality seed from recognized sources.

2.4.2 Lack of country and cold storage facilities

The farmers have small land holding do not have sufficient storage space in their houses and there is no cold store facility (Co-operative/ private) to store the produce for use as seed in the next crop season. Due to this fact and remunerative price the whole produce is disposed off in the market. This practice leads to non availability of seed of right physical age. The farmers generally use either freshly harvested produce after breaking the dormancy or procure potato tubers from the market and use as seed. Hence there is a need of augmentation of suitable/country cold store for seed purposes so that the farmers can use the seed of suitable physiologically age for better yields.

2.4.3 Inadequate participation of state govt. in seed production activities

The seed production activity is a planned programme in which the multiplication of high quality seed into subsequent generations is essential. The state governments does not have adequate network of seed production stations to multiply the seed in different generations to meet the local requirement of seed of Nilgiris hills or there is no co-operative society involved in production of seed in collaboration with the state/ Central Govt. organizations. Hence, the availability of quality seed is not enough in the Nilgiris from the organized sector.

2.4.4 Restriction of movement of potato as seed due to domestic quarantine

The state has the enforcement of domestic quarantine due to infestation of cyst nematode which does not encourage the farmers to be enterprising in seed production activities even for local supply within the Nilgiris and there

is no scope of out let of potato as a seed to other states. However, there is a need of involvement of farmers in seed production activities to provide enough quality seed to the quarantined region of the state.

2.4.5 Regular occurrence of late blight (*Phytopthora infestans*) in epiphytotic form

This is a major and important problem of seed as well as ware potato production in the Nilgiris. The yield loss ranges between 20 to 50% depending upon its severity and adoption of control practices. For a normal seed production plot, to control late blight a prophylactic spray of systemic fungicide is to be given as soon as the climate becomes more congenial i.e. temperature <20° C and relative humidity >90%, followed by contact fungicidal spray (Mancozeb 75% WP @ 2.5 kg ha^{-1}) at 7 days interval from the initial appearance of the disease. The lower surfaces of the foliage are to be covered with fungicidal spray. In case of severe infection, the systemic fungicide spray is repeated twice or thrice. In general, 3 sprays of Cymoxanil (Curzate) a systemic fungicide and 4 to 5 sprays of Mancozeb are recommended, depending upon the weather conditions. However, if resistant variety like Kufri Giriraj is planted, these sprays can be reduced to minimal number (4-5). But, as the farmers are using the seed from general market, for which there is no assurance of quality and have more infected tubers, the disease incidence is more. Hence, warrants more number of sprays at higher doses than the recommended one to control the disease. There are also overlapping crops, which also become the source of infection. This finally leads to increased cost of production and still reduced yields. If the quality seed is used from an assured source, then it is possible to reduce the number of sprays to recommended level and the produce will be free from tuber borne infections in addition to improved yields.

2.4.6 High cost of seed from out of state sources due to transportation cost

The good quality disease free seed is not available the state. It has to be procured from far of states like Punjab and Uttar Pradesh. The transportation cost is very high resulting in very high cost of seed.

2.4.7 Lack of identification of suitable site for quality seed production

In the state potato is being grown in hills in three districts (Nilgiries, Dindogal and Salem) and one district in plains (Krishnagiri). The Nilgiri district soils are well known for their infestation with cyst nematode. However, there is a possibility that certain locations like Palani hills in Dindugal District and Shervarayan hills in Salem district may be free from cyst nematode, bacterial

wilt and brown rot which is purely a conjecture and needs confirmation. The state government/KVK should take intensive survey in collaboration with CPRS, Ooty to identify the suitability of these areas, whether they are free from these disease and pests or not. Adjoining areas of Housur in Krishnagiri district, located in the plains, may have suitable area for production of quality seed in autumn to support the availability of seed to hilly district.

2.4.8 Lack of awareness to use good quality seed

Since the farmers do not get quality seed from the reliable source so they are not able to know the attributes of quality seed in improving the productivity hence they remained unaware about the utility of a disease free seed stocks. The state government should organize more field days demonstration to make the farmers aware about the use of quality seed.

2.5 Remedies

2.5.1 Regularizing the seed circulation system

The main root cause is lack of practice to use good quality seed is lack of systematic seed supply system in the Nilgiris and other potato growing areas.

2.5.2 Demarcation of seed producing areas

The areas which are less infested with cyst nematode and brown rot needs to be demarcated for production of quality seed for the sub-temperate region of southern hills which can produce sufficient quantity of seed and it should be stored properly and supplied to the farmers at a premium cost at appropriate time and place.

2.5.3 Discouragement of breaking dormancy through chemicals

There is a practice of breaking the dormancy with carbon disulphide as a fumigant. The dormancy of freshly harvested tuber is broken but its effect on different size of tubers is variable. Some tuber can overdose of treatment and the plants emerging from such tubers show senescence resulting in less numbers in small size tubers for yield. The treated tubers give rise to a single sprout which only yield 3-4 tubers while the use of seed tubers of right physiological age will give 3-4 multiple sprouts with more number of main stems resulting in more number of tubers in higher yields.

2.5.4 Use of summer seed for spring, autumn seed for summer and spring seed for autumn

This can be overcome by adopting the regularized seed circulation system as mentioned elsewhere, i.e. demarking a small area for early summer crop

planted in March & harvested in June-July or spring crop produced can be used as seed for autumn season either after natural sprouting or by force sprouting through chemical treatment using carbon-di-sulphide @ 30ml/q as fume for 12-15 days in a air tight heap/ container as this chemical is volatile and diffuses in the air slowly. The summer harvested material can be used for irrigated crop in spring in which the dormancy is naturally broken during the period of harvesting & planting. In practice the spring crop produced should be used as seed in autumn but the area is so small in spring that it cannot meet the seed requirement of autumn hence the farmers are to depend on the freshly harvested produce of early summer crop for seed of autumn crop and this situation compels the farmers to resort chemical treatment of the freshly harvested produce for breaking the dormancy. The best practice for seed production and utilization would be that the produce of spring crop is used as seed in autumn and produce of autumn crop is used as seed for main summer crop and produce from main crop is used as seed for spring crop. This is possible if state govt. undertake this job in areas in Ooty block only and the current practice of use of fresh seed after treatment is to be changed. Normally, the harvested tubers require 2-3 months time for breaking their dormancy and natural sprouting in normal conditions depends upon the variety and weather conditions. There is a practice of storing the potato to be used seed on the space/ slab made over the fire place known as Chullah in the kitchen. For natural storing, the seed materials need to be stored in the wooden racks in order to get proper sprouting. Farmers can maintain their own source of seed by adopting the above procedure. However, they need to change their seed once in 3-4 years from an authorized source in order to avoid degeneration.

3. Package of practices of potato production

Potato cultivation in the Nilgiris differs from that of North Indian plains because of climatic conditions but is somewhat similar to the northern hills.

3.1 Crop rotation

The crop rotation is important in management of pests and diseases because continuous cultivation of potato in the same field and that to growing more than one crop in a year increase the population of cyst nematode. This also helps in sustaining the inoculums of late blight pathogen from one season to another due to overlapping of potato growing seasons. Hence, carrot, radish, turnip, cabbage and cauliflower need to be grown after potato crop. It is advisable that at least 2-3 years crop rotation should be followed.

3.2 Land preparation

The land preparation is done either manually or mechanically with power tiller or tractor depending on the size of land holding, topography and its accessibility. The fields are forked to a depth of 25-30 cm and then clods are broken with the help of guddalies. Lastly the fields are cleaned and leveled. Tractor drawn disc plough is run once to cut and turn the soil and then disc harrow followed by tiller or rotovator for pulverizing and leveling the soil. In both the above cases furrows are to be drawn to a depth of 10-15 cm across the slope on the bench terraces.

3.3 Seed preparation

There is a practice to use freshly harvested potato as seed after breaking dormancy. It is not a healthy practice. The well sprouted seed of right physiological age for main summer crop from winter crop and for autumn crop from spring or autum n crop is used then it will give higher yield.

3.4 Spacing

The season to season inter and intra row spacings are different due to variations in rainfall pattern. In summer crop 60x20-30 cm and higher foliage growth spacing between row to row and plant to plant respectively is kept due to plenty of rains while for autumn crop closer spacing of 40-50x20cm is kept due to scanty rain and lesser foliage. For irrigated crop 40-60cm row to row and 15-25cm plant to plant is kept as assured irrigation is available.

3.5 Varieties

The station has so far released four late blight resistant cultivars suitable for Nilgiris. These are, Kufri Neela (1963); Kufri Neelamani (1968); Kufri

Muthu (1971) and Kufri Swarna 1(985). Of these, Kufri Swarna possesses resistance to both late blight and cyst nematodes and is popular among the farmers of the region while the other varieties are not in cultivation. The potato cultivar Kufri Jyoti released in 1968 for North Indian hills is more popular among the growers covering area of 60 percent and 35 percent area is grown with Kufri Swarna while the remaining 5 per cent area is grown with mixtures. Now, a new variety Kufri Giriraj released in 1999 for North Indian hills is getting popular among the Nilgiri farmers as a replacement of Kufri Jyoti because of its high degree of resistance to late blight and higher yield. Recently two more varieties i.e. Kufri Shailja and Kufri Himalini have been released for North India. They may also do well under Nilgiris conditions.

Seasons	Varieties recommended	Features of the variety
Summer	Kufri Swarna, Kufri Jyoti, Kufri Giriraj, Kufri Shailja and Kufri Himalini.	Kufri Swarna resistant to late blight & cyst nematode. Kufri Giriraj tolerant to late blight but does not support high population of cyst nematode, Kufri Shailja and Kufri Himalini newly released for northern hills resistant to late blight.
Autumn	Kufri Jyoti and Kufri Giriraj	Kufri Jyoti is early bulking and tolerant to cyst nematode became susceptible to late blight, Kufri Giriraj high yield and moderately resistant to late blight
Spring	Kufri Jyoti	Kufri Jyoti is early bulking and tolerant to cyst nematode became susceptible to late blight

3.6 Size of seed tubers

A relatively bigger size tubers are used for summer crop as there is low moisture at the time planting as bigger size tubers can sustain the water stress conditions. For autumn crop 30-60g tubers are preferred as there is enough initial moisture for early emergence of tubers. Spring crop is irrigated hence, small to medium size tubers (20-60g) are planted.

3.7 Seed rate

For raising ware potato crop, the required seed rate both during summer and autumn seasons is 2.5 and 3.0 t ha^{-1} respectively. This difference in seed rate during different seasons is due to differences in recommended spacing and also in size of seed tubers. If whole tubers of large size are used then the seed rate will be more than 3.0 t/ha.

3.8 Depth of planting

The optimum depth of planting of potato tubers during summer and autumn seasons is 10 and 5 cm respectively. During summer tubers are placed deeper placement of tubers is done (10cm) because of lesser moisture and during autumn at shallow depth due to enough moisture. In summer crop the tubers are placed 4-6 cm depth

3.9 Organic manures

Organic manures are essential as they improve the water holding capacity of the soils through improved soil texture, besides supplying nutrients. Farmyard manure is recommended @ 15 t ha^{-1} and it may be applied in the furrows just before planting.

3.10 Fertilizers

It is necessary to make the farmers aware with the utility of chemical fertilizers in crop production. The nitrogen, phosphorus and potassium are the major essential nutrients required for plant growth. Nitrogen deficiency causes discoloration of leaves, slow and stunted growth and consequently lower yields. Phosphorus stimulates root development and hastens the maturity. Deficiency of phosphorus results in stunted growth, dull green lusterless leaves with margins turned upward and scorched. The availability of phosphorus is a major problem in the acid soils due to the problem of fixation. In potassium deficiency leaves are dark, bluish green, downward curled, showing silvery colouration at center, cholorotic spots on lamina and margins become scorched. Its deficiency causes reduction in tuber size and so lowers the yield.

3.10.1 Dose of fertilizers

A potato crop yielding 25-35 t of tubers ha^{-1} removes 120-140 kg N, 25-30 kg P and 170-230 kg K. The recommended doses of NPK fertilizers differ from place to place depending upon the soil properties and available nutrient status. In general, the recommended dose is 90 kg N, 135 kg P_20_5 and 90 kg K_2O ha^{-1} the available NPK status is between medium to high.

3.10.2 Form of fertilizers

Nitrogen through ammonium sulphate or urea, phosphorus through single super phosphate and potassium through muriate of potash are the most suitable forms. The unit cost of urea is very cheap than ammonium sulphate and it was found equally effective provided the physical contact of the seed tuber with the fertilizer is avoided. All the three fertilizers (NPK) are to be mixed at the time of planting and then applied in the furrows just before planting. Entire doses of PK and 2/3 dose of N are applied as basal at the time of planting. 1/3 dose of N is applied as top dress at 50-55 days after

planting. The practice of applying of full dose of N at planting leads to more leaching of the nutrient and is not utilized by the plants fully. Similarly top dressing of complex fertilizer is not of much use to plants hence P & K are fixed in the soil and there is a wasteful expenditure.

3.11 Method of planting

Among the farmers there is a practice of flat planting and earthing up after emergence. Which need to be changed to furrow planting and blind earthing up. Depending upon the season, the furrows are to be drawn at recommended spacing, across the slope. The recommended quantities of FYM, fertilizers are applied in the furrows and then to be mixed thoroughly in the soil with the help of "guddalies" (narrow blade spade). Then the recommended dose of 65 kg ha^{-1} Carbofuran (Furadon) 3G (2.0kg a.i.) nematicide is applied in the furrows. The tubers are placed with crown end upward at the recommended spacing. Finally, the tubers are earthed up with soil making 15 cm high ridges above the seed tubers.

3.12 Inter cultural operations

3.12.1 Weed control

The major weeds in the potato crop are *Emillia scabra, Helichrysum bracteatum* and *Setaria glauca.* Application of pendimethalin @ 0.5 kg a.i or fluchloralin @ 0.7kg a.i ha^{-1} as pre planting or methabenzthiazuron @ 1.0 kg a.i. ha^{-1} or Metribuzin @ 0.75-1.0 kg a.i ha^{-1} as pre emergence within 3 to 5 days of planting or paraquat @ 0.4-0.6kg a.i ha^{-1} as post emergence (<5% emergence of potato plants) in 500 l of water gives an effective control of annual and broad leaves weeds.

3.12.2 Hoeing

A light hoeing of soil is recommended after 50-55 days of planting in order to loosen the soil and to control early weeds before earthing up. Under moisture stress conditions this operation can be skipped to save the moisture loss, however, weeds are to be removed.

3.12.3 Earthing up

Earthing up is an important operation in potato cultivation to conserve the soil moisture. It helps in early tuberization. The optimum time of earthing up in the Nilgiris is 50-55 days after planting in summer crop and 35-40 days in autumn and spring crop if the seed of right physiological age is used. In case of the crop is raised from freshly harvested seed tubers after breaking dormancy then the time of earthing up will be same as of summer crop. Proper earthing up is very much essential for better crop yield.

4. Pests and diseases

Following is the account of important pests and diseases and their control/ management.

4.1 Pests

4.1.1 Potato cyst nematodes (*Globodera pallida* and *Globodera rostochinensis*)

a. Infestation: It is a quarantined pest. Hence, the movement of seed material is not allowed out of Nilgiris. Affected plants get stunted with dull and unhealthy foliage and have a tendency to wilt during hot period of the day. In case of heavy infestation, plants die prematurely. The cyst can be observed on roots as golden balls based on which it is called as golden cyst nematode.

b. Control: Application of Carbofuran (Furadon) 3G (2.0 Kg a.i) @ 65 kg ha^{-1} as basal dressing at the time of planting. Use resistant cultivar like Kufri Swarna and adoption of crop rotation with crops like cabbage, carrot, radish and wheat is an integrated method of effective control measure of cyst nematode.

4.1.2 Cut worms (*Agrotis* spp.)

a. Damage: The larvae cut the shoots at the collar region of the plant or the leaves, thereby affecting the plant growth. In the later stages, tubers are damaged by making holes.

b. Control: Spraying the crop and ridges with Chlorpyriphos 20 EC @ 2.5 l ha^{-1} in 1000 l of water. Use of light traps during crop season to attract the adult moths. Exposing of the soil to sunlight destroys the pupae. A combination of these measures provides more effective and economical control.

4.1.3 *Myllocerus* (Ash) weevils

a. Damage: Adult weevils feed on leaflets from the edges. The larvae attack the tubers, the adult feeds the leaves and make shot holes. Continuous dry spells aggravate the incidence.

b. Control: Drenching the plants and ridges with Chloropyriphos 20 EC @ 2.5 l ha^{-1} in 1000 l of water controls these weevils.

4.1.4 Potato tuber moth *(Phthorimaea operculella)*

The crop gets affected by the larvae in the field and it becomes serious in storage damaging the tubers.

a. Damage: In the field, larvae mine into the leaf or bore into petioles, terminal shoots as well as newly formed tubers in the soil. The attacked plants dry off and may die. The tubers in storage are completely damaged and have little value in the market as well as food or seed. Germination of the seed gets affected as the eyes are damaged by the emerging larvae. The incidence in the field becomes more serious during dry periods.

b. Control: Spraying the crop in the field either with Phosphamidon (0.03 per cent a.i) or Quinalphos (0.05 per cent) or Fenitrothion (0.05 per cent a.i) or Carbaryl (Sevin 20EC)0.1 per cent (a.i) or Monocrotophos (Nuvacron 40 WSC) 0.60 kg a.i (0.05% a.i) ha^{-1} is effective for potato tuber moth control. The promising insecticides effective against potato tuber moth in the stores are Malathion50 EC (5 per cent as dust or 0.05 per cent spray), Fenitrothion (Folithion) 5 per cent ha^{-1}, Quinalphos (1.5 per cent dust) and spray of 0.1 per cent Carbaryl (50 WP). Tubers treated with these insecticides become unfit for table purpose because of persistence of residue in the tubers but can be used for seed purpose. The following cultural practices should also be adopted.

1. Use of healthy and clean seeds for planting.
2. Deeper planting and proper earthing up to protect the tubers from exposure and damage.
3. Clean cultivation without leaving the plant and tuber debris especially at harvest is to be practiced.
4. Destroy infested tubers before storage.
5. Avoiding delayed harvest, which may enhance the infestation chances.
6. Stores should be cleaned before storing potatoes after closing the crevices and cracks.
7. Using light traps for collecting adult moths in the field and store.
8. Crop rotation with non-solanaceous crops.

4.1.5 White grubs

a. Damage: Tubers get damaged in the field by eating into the flesh and making large cavities in them.

b. Control: Application of Thimet (Phorate) 10G @ 30 kg ha^{-1} or Quinalphos

5G @ 40 kg ha^{-1} during earthing up, use of light traps and deep ploughing in autumn to expose the grubs.

4.1.6 Rodents

a. Damage: By burrowing the fields, they push out the soil causing damage of plants. They eat tubers in the field as well as store. More damages occur due to transport of tubers into the burrows.

b. Control: Baiting with 5% Zinc phosphide and use of rat traps.

4.2 Diseases

The most common diseases of potatoes in the Nilgiris include late blight, brown rot and common scab. The incidence of viral diseases and their spread is less common due to very low vector activities. Viruses are a problem only if degenerated stocks are used.

4.2.1 Late blight (*Phytophthora infestans*)

The most important problem of potato production in the Nilgiris. The yield loss ranges between 20-50% depending upon severity of the disease and adoption of control practices.

Control: Fungicidal spray with Mancozeb (75%WP) @ 2.5 kg ha^{-1} at 7 days interval from the initial appearance of the disease. The lower surfaces of the foliage are to be covered with fungicidal spray. In case of severe infection systemic fungicide having Mancozeb and Cymoxanil @1.5 liter per ha is to be sprayed twice during the entire crop growth period alternating with Mancozeb. Use of resistant varieties like Kufri Giriraj, Kufri Swarna, Kufri Shailja and Kufri Himalani in combination with fungicidal sprays will provide better control.

4.2.2 Brown rot or bacterial wilt (*Ralstonia solanacearum*)

This disease is of endemic nature and the over all incidence in the Nilgiris is with in 1% in field. Its primary source of inoculum is infested soil, infected plant debris and infected seed tubers. It is a problem only in small patches along drainage channels.

a. Symptoms: The disease affects both above and underground parts of the crop. Infected potato plants show sudden wilting and collapse of one or more branches. The yellowing of lower leaves and stunting of plants.

b. Control: Application of stable bleaching powder @ 12 kg ha^{-1} at the time of planting. Crop rotation with wheat, cabbage, cauliflower, carrot, onion, garlic etc. and use of disease free seed. Dry weather cultivation

Symptoms of cyst nematode

A: Nematode infected field

B: Nematode on the tuber

C: Nematode on the roots

Symptoms of late blight

A: Leaf infection

B: Tuber infection

C: Stem infection

coupled with one or more of the above measures effectively control the disease. *Bacilus subtilis* bared formulation(s) have been found effective in the control of the disease.

4.2.3 Common scab (*Streptomyces* sp)

a. Symptoms: The pathogen is soil and tuber borne. Three types of lesions occur on tubers in general in case of common scab infection. Slight abrasion or rusetting of the skin. Raised (1-3mm) and rough corky scab. Pitted or deep scabs upto 12 mm in diameter and 1-3 mm deep.

b. Control: Seed treatment with boric acid (3%) for 20-30 minutes, sanitation and use of healthy seed. Crop rotation with *Penicum miliare* is highly effective in the control of common scab in the Nilgiris.

4.2.4 Viral and mycoplasmal diseases

Leaf roll, rugose, crinkle, purple top roll and marginal flavascence are the diseases that have been noticed in the Nilgiris. Among them, leaf roll and mosaics are very common when degenerated stocks are used as seed.

Control: Controlling the disease carrying insects (vectors) through systemic insecticides namely Rogor or Metasystox @ 1.0 l ha^{-1} in 1000 lit. of water. Use of healthy seed, roguing of diseased plants, dehaulming of seed crop and isolation of 50 meters between seed and ware crop.

4.3 Harvest

The crop should be harvested at full maturity. Haulm killing either manually or by spraying Paraquat @ 2.5 l ha^{-1} about 15 days prior to full maturity helps in proper skin development of tubers and avoids infilteration of certain viral diseases. Potato can withstand 30 days delayed harvesting after maturity. Under delayed conditions of harvest, to avoid tuber moth infection, the soil can be sprayed with Carbaryl @ 4 kg ha^{-1} ridges 750 l of water.

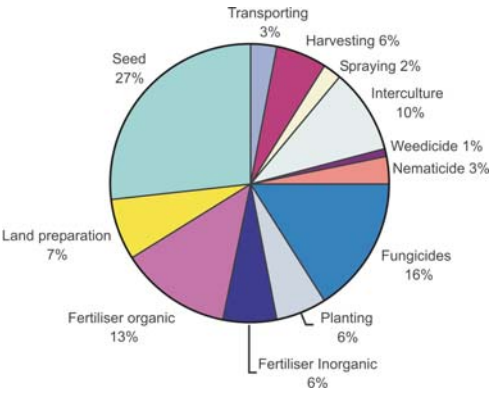
4.4 Storage

The harvested tubers can either be sent to the market directly or they can be stored for certain period depending upon the market prices. The produce can be stored in dark and cool place. A small room built indigenously with locally available bricks, mud, blue gum, wood and asbestos sheets can serve the purpose. If there is a rising trend in the market prices, the produce can be disposed off. Own seed should be covered with dry neem leaves or lantana leaves to manage tuber moth damage or it should be dusted with Melathion dust.

4.5 Crop rotation

Continuous cropping of potato year after year leads to build up of nematodes and other soil borne pests and diseases. It is a heavy feeder of nutrient and requires high doses of chemical fertilizers and pesticides and causes environmental hazards. Hence, crop rotation with other vegetable crops like cabbage, carrot and cauliflower or even wheat can help in controlling pest build up and improving the soil fertility status. Among the different crop rotations, potato-cabbage was found to be the most sustainable rotation for the Nilgiris. By adapting this package of practices, it is possible to obtain good yield of potato crop, which fetches better market price.

5. Seed potato production

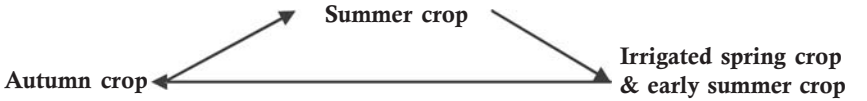


The cost of potato cultivation (Rs.88,885 ha^{-1}) is very high in Nilgiris as compared to the plains. This is mainly because of cost of seed, high labour requirement and expenditure in management of two major problems viz., late blight and potato cyst nematode. Here, the major share of cost among all factors goes to seed followed by plant protection both during main as well as autumn seasons. The cost towards fungicidal spray is little higher during autumn due to more favourable conditions prevailing for spread of late blight disease due to overlapping crop seasons which always serves as source of inoculum for proceeding crop.

5.1 Cost of seed potato production in Nilgiris

In the Nilgiris, potato is grown under three distinct seasons namely, summer, autumn and spring.

The seed requirement of main crop is met from the autumn season harvest and for autumn it is from the freshly harvested summer crop. This is planted after breaking the dormancy with carbon di-sulphide 30ml q^{-1}. The main crop is planted little earlier than the regular summer crop i.e. during mid March. The irrigated crop is grown in a very negligible area which cannot meet the seed requirement of autumn grown crop.



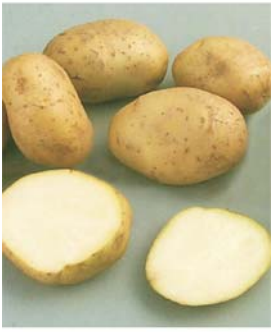
5.2 Points to be considered in quality seed potato production

If the crop is to be grown for quality seed production, the following extra points should be considered in addition to practices taken up for ware potato production.

- Select the fields, which are either free from cyst nematode or have minimum inoculum in the field.
- Go for summer or winter ploughing.
- Apply bleaching powder @ 12 kg/ha and apply Carofuron 3G @ 65 kg/ ha. at the time of land preparation to manage the inoculum of brown rot pathogen and cyst nematode respectively.
- Adjust the planting of seed crop in such a way that early summer crop harvested produce is used as seed for spring crop, the autumn crop produce is used as seed for summer crop and spring crop produce is used as seed for autumn crop.
- Well sprouted, seed sized (50-60g for summer and 30-40g for autumn) tubers of suitable variety need to be planted at 50 x 15 cm, with a recommended dose of fertilizers (90 : 135 : 90 kg NPK ha^{-1}).
- Use recommended plant protection measures against foliar diseases.
- Apply a granular systemic insecticide such as Phorate 10 G @ 20 kg/ ha at the time of planting to prevent the infestation of aphid vectors.
- Spray the crop with lmidacloprid 17.8 EC (Confidor) @ 400 g (0.04%a.i)ha^{-1} or Metasystox 25 EC (Methyl-demeton) @ 1.2 lit./ha in 1000 litres water when the aphid count reaches 2 aphids/ 100 compound leaves in sprayed crop or 20 aphids/ 100 compound leaves in unsprayed crop.
- Repeat the spray at 10-15 days intervals based on the aphid population buildup in the crop and cut the haulms when its population reaches 20 aphids/100 compound leaves when the crop is near to maturity.
- Use of Endosulphan (Thiodan) 35 EC @ 1.25 l/ha against leaf eating insects.
- Inspect the field thrice during crop season, i.e. 40-45 days, 60-65 days and 75 days to remove all off-type and plant showing mottling, mosaic, crinkle, necrosis and leaf rolling symptoms.
- Cut the haulms at the ground level of summer crop in June and autumn crop in January.
- Harvest the summer crop in September-October when the tuber skin is firm and autumn crop in February-March.
- Sort out the infected tubers and grade the produce according to recommended size before storage.
- Seed should be treated with 3% boric acid solution for 30 minutes.
- Store the seed in plastic trays and turn the seed twice or thrice to keep it in good physiological condition and to avoid over sprouting. Store the seeds in well ventilated, dark place preferably racks. Lindane dust may be applied to avoid the superficial infestation of tuber moth.

Kufri Jyoti

Parentage 3069 d (4) x 2814 a (1)



Year of release: 1968

Morphological characteristics

Plant: Plants tall, erect, compact and vigorous. Stems few, thick, colored in patches with moderately developed straight wings.

Foliage: Grey-green. Leaves intermediate, rachis green. Leaflets ovate, smooth glossy with entire margin, terminal leaflet fused.

Flowers: White. Profuse flowering.

Anthers orange-yellow, well developed, high pollen stainability. Stigma round and slightly notched.

Tubers: White, large, oval, smooth skin, fleet eyes, white flesh. Tendency to crack.

Sprouts: Blue-purple.

Agricultural characteristics

Adaptability: North and south Indian hills, parts of Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Uttar Pradesh, and West Bengal.

Maturity: Hills medium-early (110-130 days) ; Plains medium (90-100 days)

Yield potential: Hills -20 t/ha; Plains 30 t/ha

Dormancy: Medium (6-8 week)

Diseases: Moderately resistant to late and early blight. Resistant to wart. Slow rate of degenertion.

Dry matter: Medium

Consumer and processing quality

Easy to cook, texture waxy, mild flavor, occasional discoloration after cooking. Suitable for instant flakes and chips.

Kufri Swarna

Parentage Kufri Jyoti x $(VTn)^2$ 62.33.3

Year of release: 1985

Morphological characteristics

Plant: Plants tall, erect, compact and vigorous. Stems few, thick with prominent wings.

Foliage: Dark green. Leaves open, rachis green. Leaflets ovate, moderately pubescent, entire margin, many folicels.

Flowers: White, profuse flowering. Anthers orange-yellow, well developed, low pollen stainability. Stigma round.

Tubers: White, medium, round oval, smooth shining skin, fleet eyes, white flesh.

Sprouts: Blue-purple.

Agricultural characteristics

Adaptability: South Indian hills.

Maturity: Summer medium (130-135 days); Autumn medium (100-110 days)

Yield potential: 28 t/ha

Dormancy: Medium (4-6 weeks)

Diseases: Highly resistant to both the species of cyst namatodes (*Globodera rostochiensis* and *G. palida*). Resistant to early and late blight.

Dry matter: Medium

Consumer and processing qulaity

Easy to cook, texture floury, free from discoloration after cooking. Suitable for processing.

Kufri Giriraj

Parentage SLB/J-132 x EX/A 680-16

Year of release: 1998

Morphological characteristics

Plant: Plants medium tall, semi-erect, medium compact and vigorous. Stems many, medium thick, colored at base with moderately developed straight wings.

Foliage: Green. Leaves open, rachis green. Leaflets ovate, smooth dull surface with entire margin.

Flowers: Light purple, shy flowering. Anthers yellow, well developed, low pollen stainability. Stigma round.

Tubers: White, medium to large, oval, smooth skin, fleet eyes, white flesh.

Sprouts: Light purple.

Agricultural characteristics

Adaptability: North and South Indian hills.

Maturity: Medium (130-135 days)

Yield potential: 25 t/ha

Dormancy: Medium (8-9 weeks)

Diseases: Field resistant to late blight (both foliage and tubers)

Dry matter: Medium (17-18%)

Consumer and processing quality

Easy to cook, waxy texture, mild flavor, free from discoloration after cooking. Not suitable for processing.

Kufri Shailja

Parentage Kufri Jyoti x EX/A 680-16

Year of release: 2005

Morphological characteristics

Plant: Plants medium tall, semi-erect, semi-compact and vigorous. Stems few, thick with feebly developed straight wings.

Foliage: Leaves structure intermediate, leaflet width narrow, leaflet coalescence absent, rachis and midrib pigmentation absent.

Flowers: Light red-purple, moderate flowering, floral stalk light purple, calyx completely pigmented, anther yellow, stigma round,.

Tubers: White, medium, round oval, smooth skin, shallow eyes, pale yellow flesh.

Sprouts: Red-purple.

Agricultural characteristics

Adaptability: All Indian.

Maturity: Medium (100 days).

Yield potential: 252 q/ha.

Diseases: Resistant to late blight both in foliage and tubers.

Kufri Himalini

Parentage CP 2000 x CP 2132

Year of release: 2005

Morphological characteristics

Plant: Plants medium tall, semi-erect, semi-compact and vigorous.

Foliage: Green, leaves compact, rachis green. Leaflets ovate, moderately pubescent, entire margin, many folicels.

Flowers: Light purple, profuse flowering, calyx green, corolla light purple, anther yellow, stigma round.

Tubers: White, medium, oval-oblong, smooth skin, shallow eyes, pale yellow flesh.

Sprouts: Purple with white to green at apex..

Agricultural characteristics

Adaptability: All India.

Maturity: Medium (110-120 days)

Dormancy: Medium (10-11 weeks)

Diseases: Field resistance to late blight in foliage and moderate resistance in tubers.

6. Monitoring of seed quality

The certification is undertaken visually to control the spread of bacterial, fungal, viral and nematode diseases to ensure the quality of the seed. The health of seed is the basic consideration and the system of seed production varies fundamentally from the grain crop.

6.1 Monitoring quality of stocks

The seed certification methods are a way of ensuring the availability of true to type healthy seed, free from degenerative diseases and varietal mixture. The main objective of seed monitoring is to control the spread of fungal, bacterial, viral and nematode diseases and to maintain the quality of seed. Hence the general approach, which implies to potato, is given below:

1. Seed tubers should not be less than 20 g.
2. Seed stocks should be reasonably clean from black scurf and common scab.
3. Proportion of tuber with cuts, bruises: cracks should not exceed 1% by count.
4. Seed should be free from insect damage, worms, late blight, dry or wet rots, charcoal rot, wart, black heart and freezing injury. The damage caused by above factors should not be more than 1% by count.

In seed monitoring the following aspects are taken into consideration for inspecting a crop:

i) History of the plot about the previous crop, soil-borne pathogen whether it is free from them or not.

ii) Isolation of 15 m between seed and ware crop has been maintained or not.

iii) Roguing of diseased plants has been done or not and plant protection measures have been taken or not.

iv) Variety and source of seed.

Other information on crop rotation, pre-sprouting of seed stocks, cultural practices and timely planting, suitable combination of seed size and spacing will give the idea about the varietal mixture (in hills only) tubers at harvest.

6.2 Methods of inspection for monitoring the quality

The crop should be fully-grown at the time of final inspection and the germination should be uniform. Too early or too late inspection serves no purpose of seed monitoring. Final field inspection for monitoring is carried out provided the following conditions are fulfilled:

i) The previous history of the field, crop operation, manuring and plant protection schedule are made available at the time of inspection.

ii) Final rouging should be done before certification/inspection. At the time of rouging all off type and diseased plants should be removed along with mother and newly born tubers.

A minimum of four counts of 100 plants each are taken randomly on four spots in an area of one hectare. For additional each hectare or part thereof on sample of 100 plants is observed for all visible mosaics other diseases and off types. All relevant observations of each count will be filled in the proforma. The overall appraisal of all the counts, thus inspected, will decide the rejection or selection of the seed crop in a particular field. If the crops meets the tolerance limit of Foundation-I or Foundation-II seed grade or certified seed then it is selected or passed for a particular category of quality seed. If it does not meet the tolerance limit of particular grade then it is either down graded or rejected and recommended for ware use. After the dates of dehaulming are disclosed then the monitoring authority is to ensure that haulms are removed at the ground level on due dates and there is no re-growth of stumps at all. Finally the graded produce is inspected for tuber grades and surface infections.

6.3 Seed monitoring standards

As per the national policy of seed multiplication, the multiplication phases of seed have been grouped into three categories:

i) Breeder's or basic seed which is produced scientifically under the supervision of expert scientists.

ii) Foundation I and II is produced by State Agriculture/ Horticulture departments, NSC and SFCI .

iii) in Nilgiris. quality seed is produced by central Potato Research station Ooty, State Horticulture Department and contract growers.

6.3.1 Field standards for seed crop

The breeder's seed is considered to be pure and disease-free, and no tolerance limit is fixed for it, while for foundation (FS I, and FS II) and certified seed

stocks tolerance limit of viruses, off type, tuber-borne diseases and grades have been fixed by Govt. of India which are as follows. These standards can be observed for quality seed production.

Grade of seed crop/purity% of plants infected with

	Off type	Mild mosaic	Severe mosaic / PLRV/PVT/ Yellows	Total viruses	Brown rot	PSTVd
FS-I	0.05	1.0	0.5	1.0	-	-
FS-II	0.05	2.0	0.75	2.0	3 pl/ha	-
Certified	0.10	3.0	1.0	3.0	-do-	-

6.3.2Seed tuber disease standards

Grade	Common Scab*	Black scurf	Cut/ bruised	LB	Dry rot	Total disease
FS-I	5.0	5.0	1.0	1.0	1.0	5.0
FS-II	5.0	5.0	1.0	1.0	1.0	5.0
Certified	5.0	5.0	5.0	1.0	1.0	5.0

*** Standard and limits approved 1982-83**

6.3.3 Seed size standards

Seed source	Grade	Size	Corresponding weight
Hill Seed	Seed size Large	30-60 mm Above 60 mm	25-150 g Above 150 g
Plains Seed	Seed size Large size	30-55 mm Above 55 mm	25-125 g Above 125 g

NB: in a seed lot, tubers not conforming to specific size of seed should not be more than 5%

6.4 Quality control

The post harvest quality of stocks is checked by grow-out tests. A sample of two tubers from each jute bag of 50 kg is drawn and bulked as one lot based on the seed supplied to the seed – producing agency. Thus the samples of each variety are planted lot-wise separately and observations on disease incidence and varietal mixture are recorded, and the quality is judged. Based on the percentage of viral diseases, the quality of seed is decided whether the tolerance is within the limits of above mentioned standards. A few tubers are also cut to see the bacterial infection in the stock.

7. Calendar of events for potato cultivation in Nilgiris

Month	Week	Southern hills (Summer crop)
March	IV	Remove seed from store and inspect for cut and infected tubers.
April	I	Deep ploughing of field and expose the soil for 3-4 weeks.
	II	Prepare the field by giving 2-3 ploughing with disc and harrow followed by leveling the field with leveler once.
	III	Open the furrows manually. Apply the recommended dose of fertilizers as per soil fertility status in the rows. (Recommendation: FYM: 15-20 t ha^{-1}, N: 90 kg ha^{-1} i.e 450 kg of Ammonium Sulphate, $P_2 0_5$: 135 kg ha^{-1} i.e 844 kg of SSP and $K_2 0$: 90 kg ha^{-1} i.e 150 kg of Muriate of Potash). Apply carbofuran @ 2 kg ai (i.e Furadan @ 65 kg ha^{-1}) as basal in furrows to control cyst nematodes. Plant the seed manually in furrows at 60 x 20 cm spacing.
	IV	Planting can be extended to this week also. No irrigation is required as the crop is generally grown under rainfed conditions.
May	I	Crop starts emerging depending upon the receipt of rainfall.
	II	Pre-emergence application of paraquat @ 0.2%
	IV	Light hoeing with kottu (hand gudli) to loosen the soil.
June	I	Give prophylactic spray of any systemic fungicide like mencozeb+ cymoxanil (e.g. curzate) (1.5 kg ha^{-1}) for Late blightcontrol.
	III	Give Mancozeb (0.2%) spray for the control of Late blight alternating with systemic fungicide depending upon the weather condition and severity of disease, till the crop reaches to its maturity.
July	II	Earth up the crop with the help of kottu.
	III	Continue the late blight control measures depending upon the situation.
	IV	Continue the late blight measures depending upon the situation.
August	I	Continue the late blight measures depending upon the situation.
	II	Continue the late blight measures depending upon the situation.
	III	Cut the haulms and cover the exposed tubers.
	IV	Allow the tuber to cure its skin.
September	I	Allow the tuber to cure its skin.
	II	Harvest the crop and heap the tubers in well ventilated store.
	III	Harvest the crop and heap the tubers in well ventilated store.
	IV	Open the heap, grade the tubers after removing the cut/infected tubers.
October	I	Open the heap, grade the tubers after removing the cut/infected tubers.
	II	Dispose off the produce in the market.

Contd.....

Month	Week	Southern hills (Autumn crop)
July	II	Remove the seed from store, inspect for sprout development, reject cut and infected tubers. Treat seed tubers with Carbon-di-sulphide for chitting of freshly harvested crop.
August	I	Prepare the field by giving 2-3 ploughings with disc and disc harrow followed by leveling the field with leveller once or twice.
	II	Make the furrows manually. Apply the recommended dose of fertilizers (Just like summer crop) Apply Carbofuran @ 2 kg a.i Furadan @ 65 kg/ ha as basal in furrows before planting to control cyst nematodes. Plant the seed manually in furrows at 50 x 20 cm spacing.
	III	Planting can be extended to this week also.
	IV	No irrigation is required as the crop is grown under rainfed conditions. Emergence starts depending on the weather.
September	I	Crop starts emerging depending upon the receipt of rainfall.
	II	Pre-emergence application of Paraquat @ 0.2%
	IV	Light hoeing with kottu (hand godli) to loosen the soil.
October	I	Give prophylactic spray of any systemic fungicide like mencozeb+ cymoxanil (e.g. curzate) 1.5 kg ha^{-1}) for Late blight control.
	III	Give Mencozeb (0.2%) spray for the control of late blight alternating with systemic fungicide depending upon the weather condition and severity of disease, till the crop reaches to its maturity.
November	II	Earth up the crop with the help of kottu.
	III	Continue the late blight control measures depending upon the situation.
	IV	Continue the late blight measures depending upon the situation.
December	I	Continue the late blight measures depending upon the situation.
	II	Cut the haulms and cover the exposed tubers.
	III	Allow the tuber to develop its skin maturity & firm ness.
	IV	Allow the for curing of skin.
January	I	Harvest the crop and heap the tubers in well ventilated store.
	II	Harvest the crop and heap the tubers in well ventilated store.
	III	Open the heap, grade the tubers after removing the cut/infected tubers.
	IV	Dispose off the tubers in the market.

Contd.....

Month	Week	Southern hills (irrigated crop)
December	IV	Remove the seed from store, inspect for sprout development, reject cut and infected tubers.
January	I	Prepare the field by giving 2-3 ploughings with disc and disc harrow followed by leveling the field with leveller once or twice.
	II	open the furrows manually. Apply the recommended dose of fertilizers (Just like summer crop) Apply Carbofuran @ 2 kg a.i Furadan @ 65 kg/ ha as basal in furrows before planting to control cyst nematodes. Plant the seed manually in furrows at 50 x 20 cm spacing.
	III	Planting can be extended to this week also.
	IV	Irrigate the crop (normally with sprinkler) almost three days once.
February	I	Crop starts emerging.
	II	Pre-emergence application of paraquat @ 0.2%
	IV	Light hoeing with kottu (hand godli) to loosen the soil.
March	III	Give Mencozeb (0.2%) spray for the control of late blight depending upon the weather condition and severity of disease, till the crop reaches to its maturity.
April	I	Earth up the crop with the help of kottu.
May	I	Cut the haulms and cover the exposed tubers.
	II	Allow the tubers in the field for maturity of skin.
	III	Allow the tuber in the field for maturity of skin fully
	IV	Harvest the crop and heap the tubers in well ventilated store.
June	II	Open the heap, grade the tubers after removing the cut/infected tubers.
	III	Dispose off the tubers in the market.