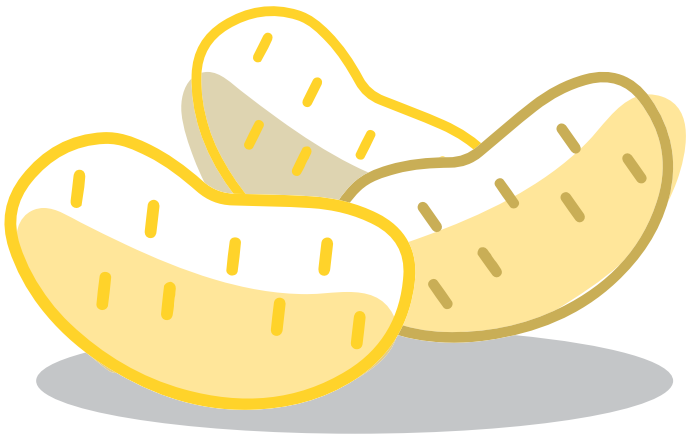
CABI in partnership with WAGENINGEN UNIVERSITY & RESEARCH

Capacity Building of Small-Scale Potato Growers

IN PUNJAB, PAKISTAN

POTATO MANUAL FOR MASTER TRAINERS



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Foreward

This manual is developed under project titled 'Capacity building for improved potato production in Punjab, Pakistan' (2020- 2023). The aim of this intervention is to improve potato production technology including use of certified seed, optimization of use of inputs, disease control, safe use of pesticides and improved storage with due attention to the role of gender. I congratulate the whole management team, technical experts from Wageningen University & Research (WUR), Netherlands and CABI Master Trainers of the project especially who have contributed significantly to this task. I believe that this manual will serve as a basis to make and implement plans for potato value chain. I hope you will enjoy reading this manual and it can help you in preparing training materials for farmers and the stakeholders.

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Acknowledgement

It is not possible to mention the names of all those who collaborated with us in completing this manual, but my foremost gratitude goes to numerous authors and stakeholder who generously shared the information about potato production, safe use of pesticides, storage and role of gender. Without their support, this manual would not have reached to the level of present quality. My sincere thanks go to Rijksdienst voor Ondernemend Nederland (RVO) for this initiative and especially financial assistance to complete the project activities. Here I am especially thankful to Dr. Hafiz Mahmood ur Rehman, Dr. Kauser Khan, Mr. Yasar Saleem Khan and Ms. Maila Al Saba Shah for successful coordinating the project activities and preparation of this manual. I am also grateful to Mr. Yeray Saavedra Gonzales, Mr. Sicko de Vries and Ms. Likoko Eunice of the Wageningen University & Research (WUR), Netherlands for the information shared for this task and offering outstanding cooperation, support and advice during all the stages of this project.

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Acronyms

CM	Centimeter
CO_2	Carbon dioxide
COS	Community Organizations
DAP	Di Ammonium Phosphate
FAO	Food And Agricultural Organization
FYM	Farm Yard Manure
IPM	Integrated Pest Management
KG	Kilogram
M	Meter
MI	Milliliter
MM	Millimeter
MOP	Muriate Of Potash
NGOS	Non-Governmental Organizations
NPK	Nitrogen Phosphorus Potassium
O_2	Oxygen
PLRV	Potato Leaf Curl Virus
PPAF	Pakistan Poverty Alleviation Fund
PPM	Parts Per Million
RH	Relative Humidity
SOP	Sulfate Of Potash Or Potassium Sulphate
T/HA	Tonnes Per Hectare
TSP	Trisodium Phosphate
UC	Union Council
VSA	Visual Soil Assessment
ZTBL	Zarai Taraqiati Bank Limited

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About this Manual

Potato is an important cash crop of Pakistan. Pakistan ranked 25th in the world in production. The average potato production per acre in Pakistan is 265 million while in potato production some progressive farmers are getting me than 12-16 tons per acre. Our country has ample scope to increase the average yield per acre of potato and the yield per acre can be increased by using better production technology. Netherlands government in the country is helping small scale potato farmers in Punjab and imparting the advance production technology. Being partner Centre for Agriculture and Biosciences International (CABI) is enthusiastic in transferring information shared with us by the Wageningen University & Research, Netherlands team. The Potato manual aims to provide standard recommendations for Master trainers who will train small scale farmers of Punjab, Pakistan to enhance their productivity. Our stakeholders i.e., Ayub Agriculture Research Institute, Okara, University of Faisalabad and Punjab Agriculture Department has also shared information which has been included and indigenously validated this manual as well. Their feedback has also been incorporated. Wageningen University & Research, Netherlands team has also reviewed this manual.

This manual is presented in eight easy to read chapters on: introduction, land preparation, seed sowing, fertilization and irrigation management, pest and disease management, safe use of pesticides, harvesting and post-harvest handling, role of gender in potato value chain and communication. Each of the topics covered can be designed in the form of modules, with topics and sessions covering production to marketing of potato depending on the stage of the crop growth and the needs of the trainees. A separate manual on potato production will be produced targeting the small-scale farmers with an interest to participate in the training sessions.

1

Introduction

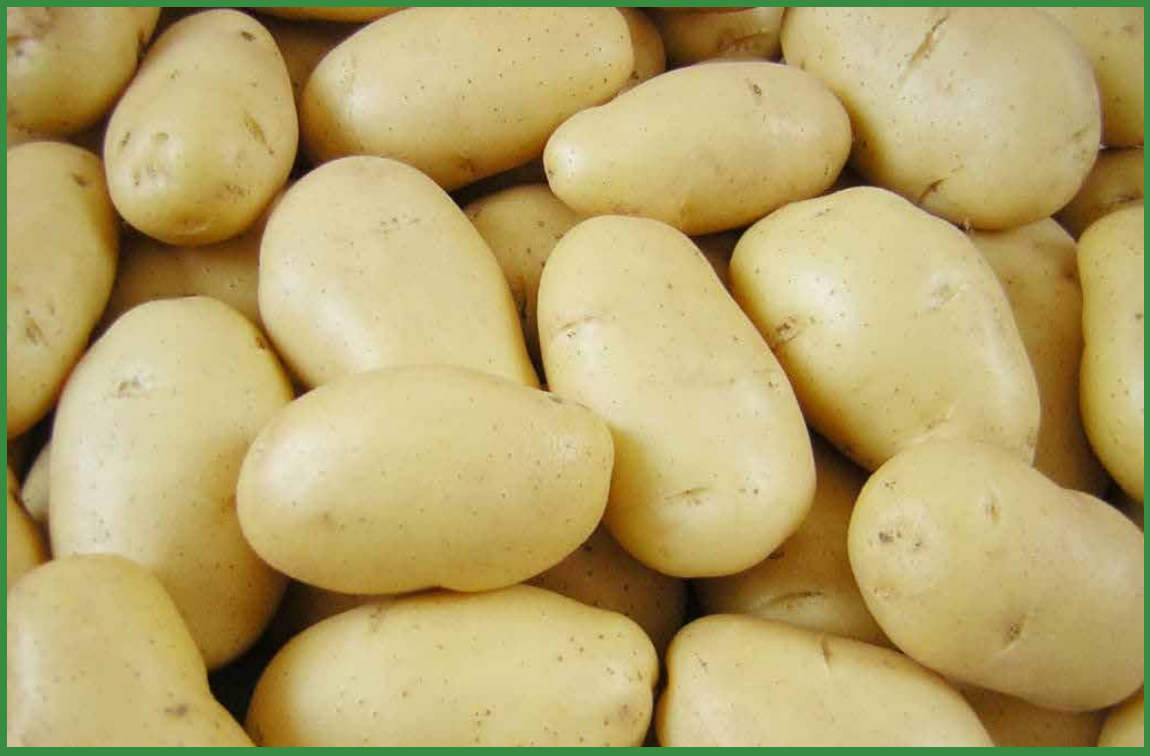

Figure 1: Harvested potatoes (Source: Potato Exporters Pakistan)

Potato *(Solanum tuberosum L.)* is a world food crop, can be grown from sea level to 3,000 m altitude. Potato is a highly nutritious crop containing vitamins, potassium, copper, manganese, phosphorus, fiber and antioxidants. In Pakistan, potato is grown on an area of 1,95,537 hectares with the total production of 48,68,098 tons. Sri Lanka, Afghanistan, and Malaysia are the major markets of Pakistani potato.

The major potato growing districts in Pakistan are:

- Balochistan: Kalat, Pishin and Killa
- KPK: Dir, Nowshehra and Mansehra
- Punjab: Okara, Sahiwal, Kasur, Sialkot, Sheikhupura, Jhang, Lahore, Narowal, Pak pattan, Gujranwala
  T.T. Singh and Khanewal
- Gilgit Baltistan: Nalter, Ghanche, Shiger, Khaploo, Astore, Gilgit and Hunza
- Sindh: Sukkur, Naushahro Feroze, Shikarpur, Khairpur and Dadu

Table no. 1: Area and production of potato crop in Punjab, Pakistan.

Districts	Area (Hectares)	Production (tonnes)
Okara	58,678	15,55,427
Sahiwal	25,637	7,07,740
Pakpattan	24,928	6,85,096
Kasur	19,105	4,87,762

Almost 95 % of the country production is grown in Punjab in an area of 1,82,855 ha with production of 46,90,999 tons in Punjab. The capacity building of the small- scale potato farmers project is targeting the major potato production districts i.e., Okara, Sahiwal, Pakpattan and Kasur. The share of Okara is 38.44 % and 36.66 % in total potato production of Punjab and Pakistan respectively which shows that Okara is contributing remarkably in aggregate potato production in Punjab and Pakistan.

1.1 Project scope

The overall aim of the project is to increase productivity and sustainability of the potato smallholder sector in Punjab with due attention given to supporting the role of women and the safe use of pesticides. The project will deliver improved productivity and sustainability of potato production by 950 smallholder farmers including 100 female farmers in 4 core potato districts of Punjab through an intensive 2.5 years potato training and extension program. Seventeen (17) demonstration plots will be established. One of these demonstration plots has been established in Okara where Netherlands' production techniques are being followed and these techniques will also be repeated in the demonstration plots of other districts.

2

Land Preparation and Management

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Land preparation is one of those important practices in potato production. The practice should be done early enough in the dry season to allow for proper control of weeds, diseases, and burrowing pests. The weed seeds, burrowing pests, and disease pathogens are exposed to predators and desiccation by the heat from the sun during plowing leading to early control.

2.1 Land selection

It is important to select appropriate plot in the potato production method. The following is intended to assist in field selection by identifying and quantifying the major soil physical characteristics that influence crop performance.

2.2.1 Suitable agro-ecology

Okara, Sahiwal, Kasur and Pakpattan districts are very famous for potato cultivation due to suitable and favorable climatic conditions. The climate of Okara is usually warm, dry and annual average rainfall is approximately 509 mm. These climatic conditions and soil made this area suitable for potato production. The climate of the Sahiwal district is warm and average rainfall is about 349 mm. The soil of the district is very fertile due to this potato is the grown as the main crop in autumn. Kasur has a semi-arid climate. Soil type of all these districts is sandy, clayey, silt loam which is suitable for potato production. Mild climate with air temperature of 20 °C to 25 °C and earth temperature of 15 °C to 18 °C is best for potato growing. The project area has warm climate hence suitable for production.

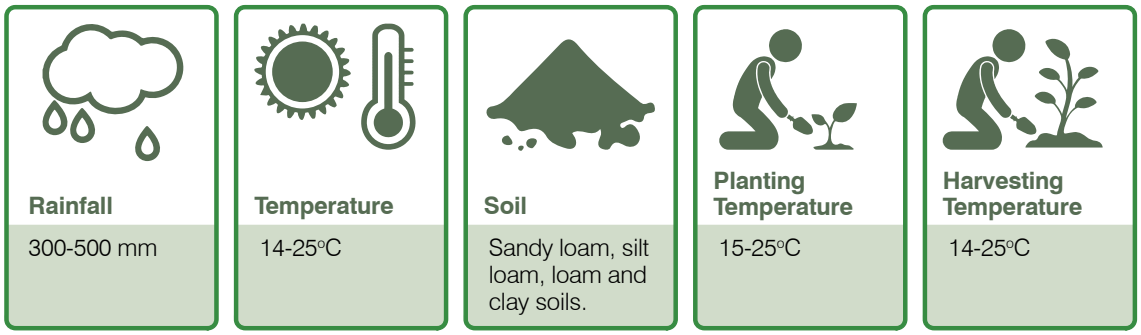


Figure 2: Optimum conditions for the potato production

2.1.2 Compatibility to the Cropping System:

Potato is an integral part of the cropping system of the central Punjab. Okara, Sahiwal, Kasur and Pakpattan are among the highest potato producer districts in Punjab. Potato is mainly grown as main crop during the main Rabi season. These districts are irrigated plains so adequate water is available for the potato crop. The crop rotation is common with maize, cotton and sugarcane. Thus, potato is part and parcel of the cropping system of the project area.

2.2 On-site Soil visual assessment

The principle of visual soil assessment (VSA) is the evaluation of visible soil properties mainly physical and biological as well as partly chemical. The important purposes of the assessment are:

- Soil survey
- Soil quality assessment
- Soil state assessment

2.3 Soil analysis in laboratory

Soil testing is fundamental to any effective nutrient management program is a reliable soil analysis and soil test interpretation. Samples should be representative of the area to be fertilized and should be taken in the top 15- 20 cm. The soil test will help to determine whether lime or nutrients are needed and if so, what rate should be applied. Typical soil analysis for potatoes should include pH, organic matter, P, K, Ca, Mg and Zn. Soil nitrate tests can be done but are most accurate when used in dry climates on finer-textured soils and when taken to a depth of 60 cm. Other nutrients such as S, Mn, Fe, and Cu can be determined if a problem is suspected.

Table no. 2: Fertility status of the soils in Punjab, Pakistan.

District	Soil parameter	Range (Min.- Max.)	Average value	Fertility Status/Class
Okara	pH	7.1-9.2	8.2	Neutral
	Electrical Conductivity	0.1-4.9	0.4	Normal
	Organic matter (%)	0.2-1.8	0.92	Marginal
	Available phosphorus (ppm)	3-20	5.3	Low
	Extractable potassium (ppm)	40-400	137	Marginal
Pakpattan	pH	7.2-9.3	8.2	Neutral
	Electrical Conductivity	0.1-8.2	0.4	Normal
	Organic matter (%)	0.3-1.8	0.9	Marginal
	Available phosphorus (ppm)	3-15	5.4	Low
	Extractable potassium (ppm)	50-375	152	Adequate
Sahiwal	pH	7.5-10.4	8.2	Neutral
	Electrical Conductivity	0.1-7.4	0.5	Normal
	Organic matter (%)	0.1-2.6	0.8	Marginal
	Available phosphorus (ppm)	3-18	5.1	Low
	Extractable potassium (ppm)	30-400	138	Marginal
Kasur	pH	7.1-10.9	8.1	Neutral
	Electrical Conductivity	0.1-20.5	0.8	Slightly saline
	Organic matter (%)	0.1-2.9	0.8	Low
	Available phosphorus (ppm)	1-52	8.0	Marginal
	Extractable potassium (ppm)	25-400	150	Adequate

2.3.1 Sampling in fields

If soils are uniform, an area up to 10 acres can be sampled as a unit. In case of variation, field can be subdivided into uniform sampling units and each sampled separately in the form of composite sample. As potatoes are grown in fertile soil and root remain in furrow slice. So, the depth of 0-15, and 15-30 cm is sufficient for soil fertility evaluation.

2.3.2 Precautions for soil sample collection

Samples should not be taken:

1. Along the water channel, roadside, pathway and boundaries
2. Under the tree shade.
3. Close to the heaps (manure).
4. Areas where plant population is not uniform.
5. Areas where domestic refuse are thrown.
6. Places in the field where organic matter, fertilizers or plant residues are dumped.

For salinity evaluation, if salt crust on the surface is present it should be removed before soil sample collection or it should be sampled separately.

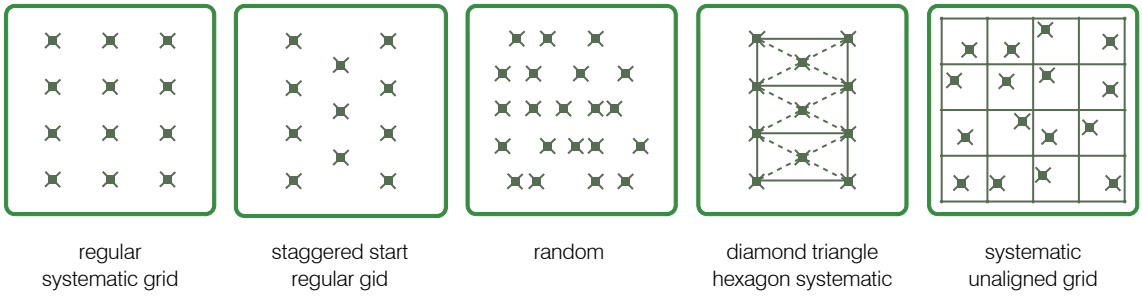


Figure 3: Field sample methods

2.3.3 Soil Sampling procedure

1. Take first sample of the soil with the Augar or shovel/spade at the depth of 0 to 15 cm.
2. Take second sample at the depth of 15 to 30 cm. Similarly, further samples will be taken from the selected area in the field.
3. Put the samples of soil in the bucket depth wise. Mix the soil thoroughly in the bucket
4. Dry the samples at optimum sun shine.
5. Take at least 500 g of composite soil samples and pack them in the polythene plastic bags and note soil depth with the help of marker on the bag.
6. Now store the sample for further analysis.

2.3.4 Soil condition and pH

The potato can be grown almost on any type of soil except highly alkaline, saline and sodic soils. Naturally loose soils which offer the least resistance to enlargement of the tubers are preferred and loamy and sandy loam soils that are rich in organic matter with good drainage and aeration is most suitable. A soil having a deep profile is favorable as it provides deep rooting zone for production. Soil with a pH range of 5.2-6.4 is considered ideal.

The structure of the soil may be evaluated either be Good or Bad. And of course, there are many grey areas in between. Nevertheless, by comparing we understand the importance of soil structure for crop production. A bad soil structure will provide less favorable conditions for the crop development such as a compacted soil, therefore, containing less pores therefore a poorer aeration, more difficult conditions for root development or favoring water logging. Erosion, runoff or crusting can also be a consequence of a poor soil structure meaning a poor infiltration of water or drainage. Less oxygen, a more limited availability of nutrients, a poor root respiration, a limited root penetration and development lead to a reduction of crop yields.

2.4 Land Preparation

In Punjab, most of the potato producers should plough once with deep plough, use rotavator 2 to 3 time and followed by planking. When remains of a previous crop have to be destroyed, disc ploughs are often used. The result is usually a fine textured seed bed with a depth of only 10 to 15 cm. Clod crumbling equipment such as chisel plough should also be considered where hard clods are prevalent. This can achieve with implements of the horizontal or vertical rotation type. If powerful tractors (50-75 Hp) are available, the number of operations can be further reduced by using tandem equipment.

Figure 4: Land preparation for potato production

The planting bed must consist of a loose layer of at least 8 to 10 cm of soil to enable a sufficiently large ridge to be made. The loose layer must not contain any ‘false’ clods larger than 35 mm as they will end up with the potatoes during the lifting process. Prevent the soil compacting and puddling where possible. Both soil structure problems (clods & compacting) will hamper the drainage and will prevent the roots of the crop from growing down to deeper layers of the soil thus reducing the amount of moisture available for the crop. During periods of drought this may result in yield losses, second growth and tuber deformation. A nice seedbed will quicken the emergence of the crop providing for extra growing days.

3

Seed Treatments and Sowing Techniques

KNOWLEDGE FOR LIFE

The seed borne diseases spread quickly, and cannot be controlled using chemicals as well. Use of healthy and disease free seed tuber following crop rotation with proper field inspection can help to minimize the seed borne diseases.

3.1 Characteristics of quality potato seed

Following physical quality attributes to be considered when selecting tuber seeds for planting:

3.1.1 Origin and mother plant

Seeds should be obtained from pest and disease-free mother. To achieve this, farmers should always select, and store seeds harvested from healthy mother plants or buy seeds from certified seed producers and vendors.

3.1.2 Shape and physiques

Egg-shaped or round tuber seeds with an average weight of 40-50 g are preferred for planting the seeds should also be without holes, cracks, and signs of pest and disease attacks. Farmers should completely reject the seed lots with more than 1-2 % tubers with soft spots that ooze with fluids when pressed since this could be a sign of Bacterial wilt attack.

3.1.3 The skin appearance

Fresh and unwrinkled seeds are preferred. A wrinkled tuber is a sign of dehydration and a possible reduction in vigor, germination viability and old age (senescence). For planting purposes, even the greened tubers can be used.

3.1.4 Seed size and weight

Suitable seed size is 35 to 45 mm weighing about 40 to 50 g should be selected for planting. It will produce roughly 3-4 stems per seed tuber depending on variety and planting distance producing 6-12 tubers per seed tuber. It has been found that small to medium seeds produce few but large tubers with high market value compared to large to very large seeds.

3.1.5 Number of eyes and sprouts

Each planting material should have 2-3 eyes/buds these are areas where shoots emerge. These buds should be distributed spirally around tuber surfaces. If the top sprouts only emerge early then lateral buds, it may result in apical dominance. Also, apical dominance will be broken released by the removal of the top sprout when they are 3-4 mm long, the sprouts will grow faster and more stems will grow out from one seed tuber. De-sprouting of

relatively young seed tubers may contribute to the development of new sprouts and more sprouts with a higher rate of sprout growth than without de-sprouting. In the case of chitted tubers, the sprouts should be uniform in lengths and color.

3.1.6 Physiological age of seed

The physiological age of seed is an important factor in choosing potato seed. Factors affecting the physiological age of tubers include growing season stress, storage temperature and time. The physiological age of seed potatoes at the moment the awaken from dormant stage, strongly affects:

- The quickness of emergence: Older seed emerge earlier than the young seed (freshly harvested tubers).
- Number of stems per plant: More stems are produced to a senile (old) seed then young seed
- Tuber size distribution: Young seed has even distribution and more irregular with older seed.

The optimal stage of the seed is normal sprouting. In areas with double cropping wet and dry season cropping, it can be difficult to obtain seeds in the optimal stage. Sometimes it might be best to delay planting date in order to obtain better results when the seed tuber is too young to plant as it delays emergence.

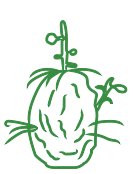
Physiological age	Young ---------- Old					
Tuber characteristics						
Physiological stage	Dormancy	Apical dominance	Normal sprouting	Normal sprouting	Senility	Incubation
Sprouting	No sprouts	Apical sprouts only	Few sprouts	Multiple, branched sprouts	- Excessive sprouting - Excessive branching - Hair sprouts - Some little tubers	No sprouts, direct formation of daughter tubers on seed tuber
Crop condition	No or delayed emergence	Single-stemmed plants	Few vigorous stems per plant	Many stems per plant	Weak, multi-stemmed plants	No plants
Yielding ability in short season	None	Low	Moderately High	High	Hardly any	None
Yielding ability in long season	Very low	Relatively low	Very high	Relatively high	Hardly any	None

Figure 5: Physiological stages of seed maturity

3.1.7 Seed size and impact on time of planting

For the main autumn planting (September 25 to October 10) the farmers in the Punjab use medium size seed, usually around 30 to 45 mm. Small tubers ("goolies" of 20 to 30 mm) do have a high degree of sprouting failure under hot weather. Small tubers from the previous autumn crop should be planted between October 8 – 20.

There are less limitations in the size of the seed tubers used for planting the spring crop. Large seed can produce more sprouts per tuber than the small seed, but small seed produces more sprouts per ton than the large seed; the larger tubers will produce more vigorous early growth. Tubers larger than 60 mm should not be used for seed. Due to high weight and these cannot be favored for whole tuber planting. The cutting of large seed into pieces; the cut pieces are more likely to rot than whole seed.

Figure 6: Potato seed tubers sorting and grading

3.2 Variety selection

The choice of the variety will depend on the time of planting, skin color in demand, resistance biotic and abiotic stresses. In Punjab, two types of seeds varieties are available for planting i.e., indigenous and imported` varieties. Some general recommendations concerning the varieties available in Punjab are given below:

Table no. 3: List of some famous local and imported varieties.

	Variety Name	Salient Features
1	Sahiwal Red	Local variety, high yielding, red skinned and tolerant to frost and diseases
2	Sahiwal White	Local variety, high yielding, white skinned, climate resilient & tolerant to frost and diseases
3	Sialkot Red	Local variety, high yielding, red skinned, climate resilient and tolerant to frost and diseases
4	Sadaf	Local variety, high yielding, white skinned, climate resilient, tolerant to frost and diseases and suitable for processing industry
5	Ruby	Local variety, high yielding, red skinned, late maturing, tolerant to frost and diseases and suitable for processing industry
6	PRI-Red	Local variety, High yielding, red skinned, late maturing, and tolerant to frost and diseases.
7	SH-5	Local variety, high yielding, red skinned, late maturing, and tolerant to frost and diseases
8	Cardinal	Imported variety, high yielding, red skinned, drought tolerant, resistant to common scab.
9	Diamant	Imported variety, high yielding, yellow skinned, heat tolerant, resistant to viral diseases, late blight resistant and high drought resistance.
10	Desiree	Imported variety, high yields and early bulking, red skinned, high resistance to drought, potato viruses and powdery scab. Susceptible to potato cyst nematode.
11	Lady Rossetta	Imported variety, early crop maturity, moderate to high yields, industry good all-round disease resistance, susceptible to Powdery scab and suitable for processing.
12	Laal-e-Faisal	Imported variety, red skinned, tolerance to late blight, scab, and frost, resistant to viral diseases and suitable for processing industry
13	Rosi	Imported variety, good yield, red skinned, high dry matter, tolerance to common scab and powdery scab.
14	Sante	Imported variety, high yield, yellow skinned, tolerance to common scab and powdery scab, resistant to viral diseases and Fusarium.
15	Asterix	Imported variety, high yield, red skinned, suitable for processing, resistant to blackleg, bruising, splitting and dry rot.

3.3 Seed handling

3.3.1 Pre-sprouting

At planting, seed potatoes should be dry, kept at ambient temperature and should have started sprouting. Pre-sprouted seed tubers are better but not essential for the autumn crop planting. In the Punjab, sprouted tubers may not gain any advantage under the prevailing pre-planting handling practice. The main limitations are the:

- Poor soil preparation,
- Poor cold store management,
- Ridging with soil compacting equipment

Growing tubers and freshly harvested mature potato tubers do not sprout, even when environmental conditions are favorable. It in particular occurs when seed is to be used soon as seed after they have been harvested, say within a period of 3 to 4 months. Dormant or semi dormant tubers will not germinate readily in the ground, when it takes too long, they even might start rotting. As a result, the emergence is delayed and often erratic, normal emergence would be 10 to 14 days after planting.

So, the crop is uneven and will not come to its maximum potential and the "reading" of the crop on diseases and fertilization will become difficult when you want to make decisions on certain application, the amount to be given and how to determine the success of a particular treatment. This dormancy of the apical bud of the tuber is necessary to be broken. The physiological readiness to grow after planting is an important factor determining the production potential of the crop. For sprouting of tubers, better germination and early maturity.

Several methods are available for breaking dormancy and can be used singly or in combination.

1. Tubers are kept at 28 ^{o}C until sprouting occurs.
2. Moisture in the sense of free water like condensation will break dormancy.
3. In a well-insulated and air tide storage it is seen that with high levels of CO_2 and low O_2 dormancy is broken.
4. Tubers can be placed at temperature below 28-30 ^{o}C for two to three days.
5. A well know farmer practice is the handling of potatoes (transferring from one bag/box in another) will help to break dormancy.
6. The tubers are dipped in 1% thiourea solution for 1 hour before planting. After treating with thiourea store them with at about 25 ^{o}C.
7. The white dots indicate that the sprouting has started.

3.3.2 Seed treatment

Seed Treatment is very important to protect plants from diseases i.e. Rhizoctonia solani or any other;

- Seeds could be treated with the Fludioxonil (Celest) 100 FS at the rate of 4 ml/ kg seed to protect against Rhizoctonia solani and Fusarium spp.
- Flutolanil (Moncut) 400SC @ 5ml per 400 ml water for the effective control of Rhizoctonia (Black Scurf)

Figure 7: Seed potato treatment

10. Mancozeb (Dithane) WSP at the rate of 566 g per 189 liters of water to protect from common scab and Fusarium spp.

3.3.3 Seed warming up

It is recommended to take the seed out of the cold chambers should be kept in thin layers so they pick up temperature more rapidly when put in the store at 15 °C for 5 to 10 days before planting. During this time, the seed should be placed in a pre-cooling chamber of the store under ambient temperature or under permanent shade of any kind. Potatoes kept at shaded place allows the sorting out of cracked, diseased, rotted or un-sprouted tubers prior to planting. Shocks at handling may be caused by:

1. Too fast coolings
2. Cooling below 3 °C
3. Over-storing more than 3 to 5 months at changing temperatures (higher than 7 °C)
4. Overheating at temperature more than 21 °C
5. Too fast heating up for less than 48 – 72 hours.
6. Long transportation under very hot or very cold temperatures (optimal temperature 17 °C)
7. Rough loading, unloading or poor stacking practice

3.3.4 Transportation of tubers for planting

After warming up, drying and sorting, the seed should be transported to the planting site in crates or baskets, to minimize damage through crushing. Re-bagging of sprouting seed should be avoided if possible. If bagging is unavoidable, smaller bags (30 to 50 kg) than the usual ones of 100 kg should be used. Long transportation from the store to the field is detrimental to cold-stored seed potatoes without warming up and maintaining optimal transport temperature especially is the seed is transported in bags.

3.4 Seed sowing techniques

Four types of planting techniques are being used in the Punjab:

- Manual or hand planting with drawn ridger
- Fully automatic planting

3.4.1 Manual planting with tractor drawn ridger

About 5-10 cm deep furrows are produced with the potato ridger and the seed potatoes are then placed in these small furrows by hand at the desired distance. The potatoes are then covered by the same ridger. The method is labour intensive but not too expensive. Sufficient labour (8 labour/ acre) should be available

Figure 8: Manual seed sowing in ridges

to carry out planting in a short of time. With trained labour, very precise planting can be carried out with this method.

Currently the main problems observed are:

- Too narrow and/or too small ridges are made in shallow plants beds,
- No provision for drainage of excess water is made

3.4.2 Automatic planting

The equipment so far available in Pakistan is only suitable for planting whole, perfectly graded potato tubers within certain band-width (28-35 mm, 35-45 mm and 45-55 mm). Most machines can be equipped with different sized (small - normal - big) cups to plant according to different grades of potatoes and/or systems to overcome double or missing seed tubers. Some farmers in the Punjab are using this equipment. The gaps in the seed flow caused by bad grading are usually filled by two laborers uncomfortably sitting on the machine and placing missing seed tubers in the chain cups. Convex, soil compacting ridges as currently in use in Pakistan are inadequate for seed potato multiplication as well as ware crop. They pass the ridges into shape, causing ridge compaction. This results in large clods hampering the harvest operation.

3.4.3 Seed sowing methods

Potato tubers can be planted either in the furrows or on the ridges, on flat beds; however, ridge sowing is the most preferred method. Ridges are 25 cm high and 60 cm wide. Ridges are marked at 75- 76.2 cm apart and the seed tubers are kept 30-35 cm for ware potatoes and 15-20 cm for seed potatoes, the ridges are made using a tractor drawn ridger to cover the seed with soil. Soil is ridged over the row by throwing soil to the plants during early cultivation, so that about 18 cm of soil cover the seed tuber when tuber formation occurs.

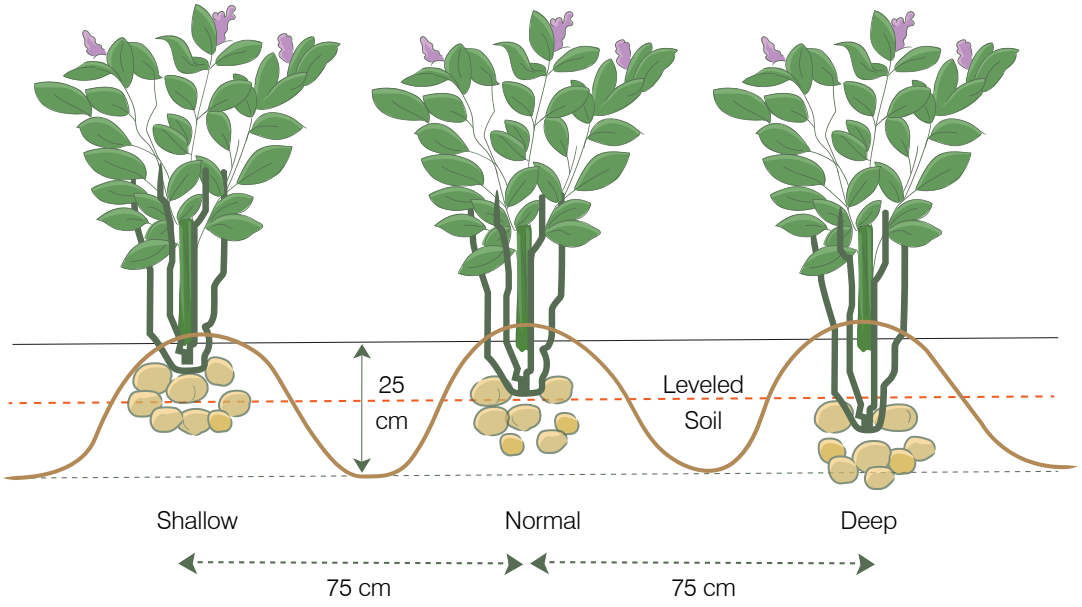


Figure 9: Seed sowing depth

3.4.4 Planting density

As most advanced potato varieties are selected for optimum performance at row to row distance of 75- 76.2 cm. The recommended crop density for the potato cultivation is for ware potatoes 10-15 and seed potatoes 20-30 stems per m^2. The recommended seed size is 35-55 mm and weight 40-50 g.

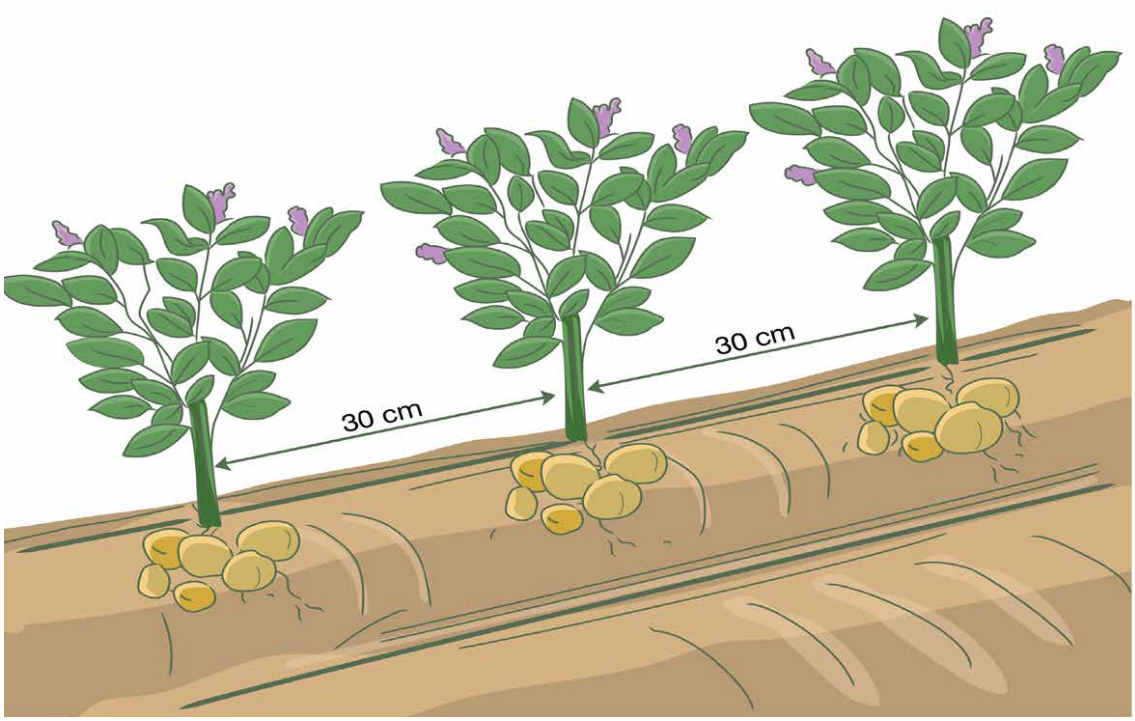


Figure 10: Potato plants planted at interplant spacing of 30 cm

For ware crops seed rate for 10-15 stems/m^2

Diameter seed (mm)	Seed tuber weight (g)	Stems per seed	No. of plants per ha	Kg per ha
28- 35	25	2.5	60,000	1,500
35- 45	50	4.0	38,000	1,900
45-55	90	4.0	30,000	2,700

For seed crops seed rate for 20-30 stems/m^2

Diameter seed (mm)	Seed tuber weight (g)	Stems per seed	No. of plants per ha	Kg per ha
28- 35	25	2.5	120,000	3,000
35- 45	50	4.0	76,000	3,800
45-55	90	4.0	60,000	5,400

3.4.5 Planting time

The autumn seed crop should be planted immediately after the main autumn ware crop planting, generally around 5th to 10th October. Planting of the seed crop should be carried out as fast as possible. Heat tolerant but frost susceptible varieties such as Lal-e-Faisal and Desiree can be planted earlier (3rd to 8th October). The planting dates should therefore

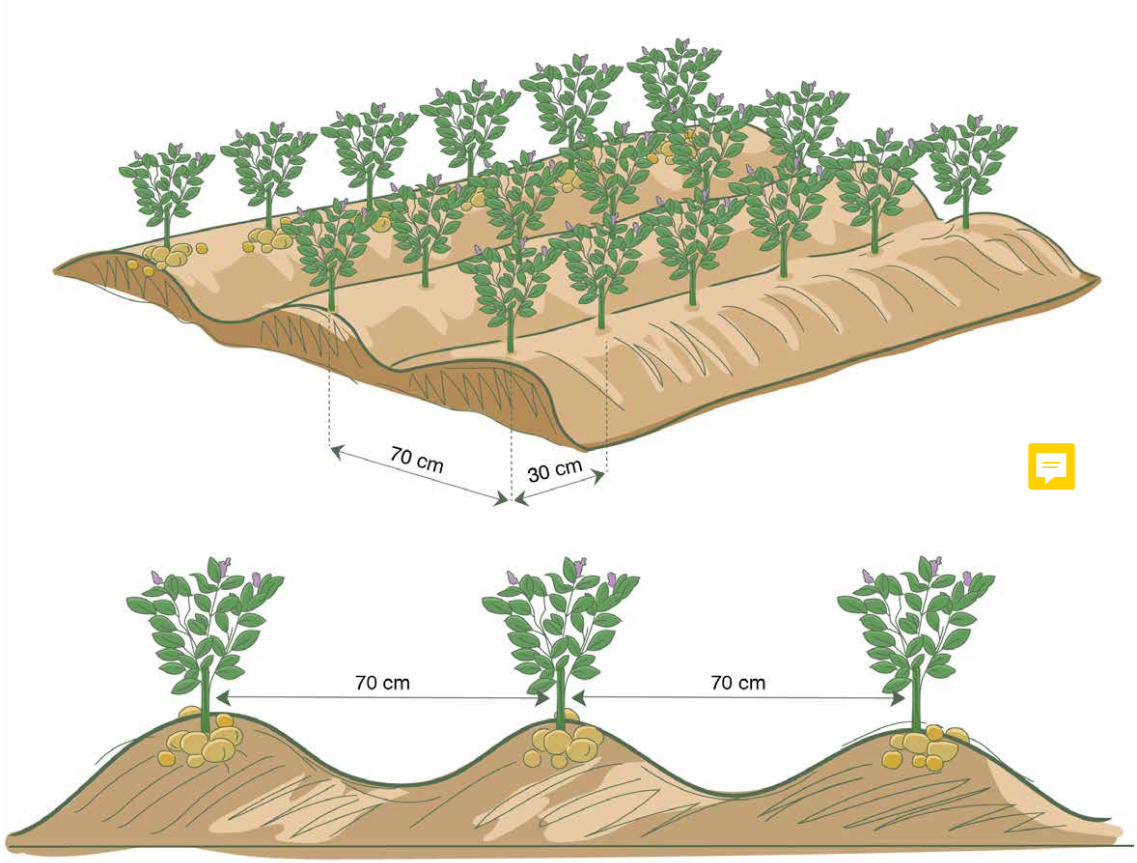


Figure 11: Potato plants planted at interplant spacing of 30 cm

be kept flexible. The spring seed crop is usually planted around 15th January. Planting as late as 15th February has been recorded but planting after 1st February should be avoided due to hot and dry climatic conditions. Seasonal crop production shares in the total potato production in Pakistan are;

Crop	Planting	Harvesting	Production share
Spring	Jan-Feb	April- May	07.10%
Hilly areas	March- May	August-Oct	15-20%
Autumn	Sep- Oct	Jan-Feb	70-75%

4

Fertilizer and Irrigation Management

KNOWLEDGE FOR LIFE

Nutrient uptake rates are often slow early in the season, increase rapidly during the tuber bulking phase, and then slow as the plant matures.

4.1 Macro-nutrient requirements of the potato seed crop

The most important macronutrients are nitrogen (N), phosphorus (P) and potassium (K). Sulphur (S), calcium (Ca) and magnesium (Mg) are called secondary macronutrients because they required in volumes than the first three macro nutrients but are needed in higher volumes than micro nutrients.

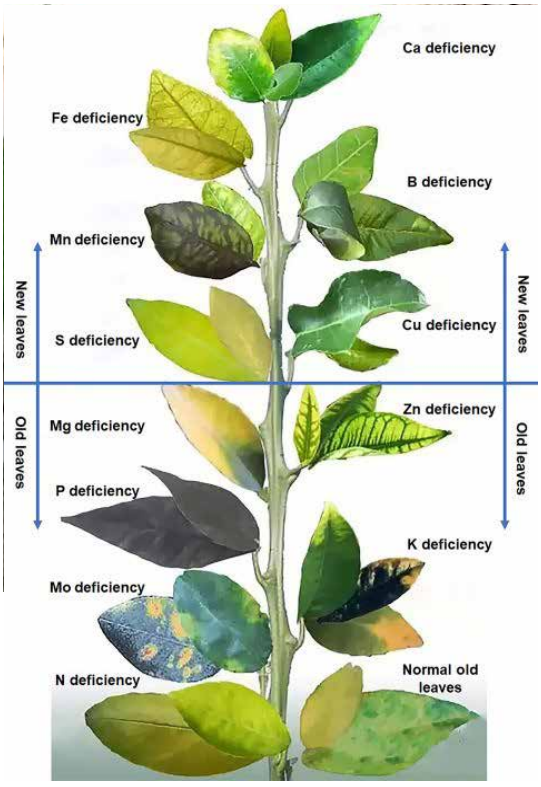


Figure 12: Visual diagnosis of nutrient deficiencies

4.1.1 Nitrogen

Nitrogen plays a key role in the growth of leaves and stems. It enhances the production of chlorophyll which improve the photosynthesis and crop productivity. Nitrogen level affects tuber yield, grading, dry matter content, storage and processing quality of the potato crop. Nitrogen deficiency leads to lower production and early maturation of the crop. Excess of nitrogen makes crop more susceptible to late blight, growth cracks, grey discoloration after cooking or frying.

In the Punjab autumn crop, the leaching is low but in October (hot weather) losses due to denitrification are high. The crop uptake of N is moderate and yield expectations in the 90 days crop are also moderate. The nitrogen is recommended to apply in split doses. Recommended application of fertilizer is

- 60% at planting
- 20% at tuberinitiation
- 20% 3 to 4 weeks later

Nitrogen should be introduced in the soil during the of land preparation, then at the time of tuber formation and the last/final split application on Nitrogen to be before 70 days after plantation.

4.1.2 Phosphorus

Phosphorus is essential in stimulating root development, number of tubers, health and disease resistance. The requirements of the seed potato crop are about 10% less than of the ware potato crop. A full dose of P should be applied for the varieties with late maturity. Full skin maturity is reached earlier under a higher dosage of P which is very desirable in seed potato multiplication. The lack of phosphorus results in slower initial crop development, decrease tubers and reduce yield.

It is necessary that the Phosphorus is applied on the basis of plant nutrient uptake available content in the soil. Phosphorus should be introduced in the soil during the of land preparation preferably close to the plant before planting and ridging, 5 % of the requirements can be applied by spraying the crop with soluble fertilizer before the start of bulking (two sprays before and just after earthing up).

4.1.3 Potash

Potassium involved in several plant metabolic reactions, transport of carbohydrates, water regulation and plant strength. It is important for yield and the potato quality. Potassium recommendation depending on soil fertility, quality requirements of potatoes. Extra high K rate decreases dry matter content and susceptibility of the tubers to black.

Potatoes requires the highest uptake of potash and is stored in the tubers. It is therefore recommended to at least replace the potash removed with the harvested tubers, increased by a factor for leaching. If potash is applied just before planting, jointly with N and P, it is recommended applying only sulphate of Potash. The potash will have to be applied to the soil 2-3 weeks before planting and before the “rouni” irrigation, to avoid the toxic effect of active chlorine on the potato roots and sprouts.

Potatoes are particularly sensitive to chloride and salt. Continued application of potassium sources with a high chloride content or salt index can have a toxic effect, building up in the soil and contributing to lower yields, lower quality and lost income. Therefore, apply potassium sulfate (SOP) in place of potassium chloride (MOP).

4.1.4 Sulphur

Sulphur along with nitrogen is a key element in the amino acids, cysteine and methionine, two essential protein building blocks. S is essential in the formation of chlorophyll as it is a major component of an enzyme responsible for the synthesis of chlorophyll. Sulfur is immobile in plants and does not readily translocated from older leaves to young leaves. Therefore, sulfur deficiency first appears on younger leaves. An adequate supply of sulphur is very important, not only for crops with high sulfur requirements and also crops with high nitrogen requirement which without sulphur cannot optimize their utilization of nitrogen.

It helps to reduce incidences of common scab and improves tuber dry matter content. Soil having ample Sulphur benefits tubers, as it aids with the production of starches. The S requirements of the potato crop can often be provided through the breakdown of soil organic matter. When additional S is required it can be provided by the application of either ammonium sulfate or potassium sulfate. Avoid excess application rates as sulphate can further reduce the soil pH in already acidic soils.

4.2 Micro-nutrient requirements of the potato seed crop

Micronutrients are required in very small amounts nonetheless they are still essential for crop growth to progress. They include:

- Iron (Fe)
- Boron (Bo)
- Zinc (Zn)
- Manganese (Mn)
- Copper (Cu)
- Molybdenum (Mo)
- Chlorine (Cl) and
- Nickel (Ni)

4.2.1 Zinc

Zinc is an important micro-nutrient needed for good growth and performance of potato. The symptoms of zinc deficiency in potato appear as a chlorosis in the interveinal areas of new leaves producing a banding or striping appearance. Leaf and plant growth become stunted with increasing severity of the deficiency; leaves eventually die and fall of the plant. Brown necrotic tissues are also seen, within which the whitish spots develop. Symptoms may also start on older leaves.

The demand of the potato crop for Zn is relatively high and sprayed on the crop. Zinc compounds are relatively cheap and yields can be increased up to 20% with Zn applications to the crop, as a side dressing after earthing up. Zinc Sulphate is applied as a side dressing to the plants before earthing up. Zn can also be applied as a spray if the crop is to be sprayed with micronutrients anyway. The application can first applications to start roughly 3-4 weeks after emergence (shortly after earthing up) but should start well before tuber setting. Zinc deficiency can be avoided by the addition of Zinc Sulphate Monohydrate (27%) (Sona Zinc) available in the 3 Kg packing.

4.2.2 Boron

Boron (B) plays an important role in cell wall synthesis, sugar transport, cell division, cell development, auxin metabolism, good pollination, synthesis of proteins and regulation of carbohydrate metabolism. Main deficiency symptoms are the death of the growing points and growth of lateral buds. Branching occurs due to loss of apical dominance. Leaves may exhibit leaf roll like symptoms. Roots are short or stunted, and thick. Tubers are small with surface cracking. Potato is not a sensitive crop for Boron.

Soils having low organic matter content and high soil pH levels. Potatoes require high amount after 45 days of crop emergence and remain high till crop maturity. B should be applied before planting, at the time of ridging, hilling and tuber initiation. Di-Sodium Tetra Borate Decahydrate (Sona Boron) is also locally available in 3 kg packaging to prevent boron deficiency in the potato crop. No unnecessary or too high B rate: too much B is toxic.

4.3 Fertilization scheme for potato crop

As fertilization directly effects the yield of the potato crop, keeping in view this objective we carefully develop a fertilization strategy based on the soil fertility.

1. Fertilizer application should be done in three spit doses.

No. of Split	Time of application	Dosage
1st Split (Basal dose)	Planting	60%
2nd Split	Tuber formation	20%
3rd Split	Four weeks after tuber formation	20%

2. For expected yield 12 Mt/acre the amount of required fertilizer is

Soil Condition	Fertilizer Recommendation (Kg/acre)		
	N	P_2O_5	K_2O
Poor	123	69	50
Medium	100	50	50
Fertile	67	46	37

3. Name of fertilizers and their amout for fertile soils are:

Name of the fertilizer	Amount of fertilizer in bags per acre		
	Planting	Tuber formation	Four weeks a tuber formation
Urea	2	1/2	1/2
Triple superphosphate (TSP)	3	—	—
Muriate of Potash (MOP)	1/3	1/3	1/3
or			
DAP	2	—	—
Urea	1	3/4	3/4
Sulphate of Potash (SOP)	1/2	1/2	1/2
or			
Nitrophos (NP)	4 1/2	—	—
Urea	—	1/2	1
Muriate of Potash (MOP)	1/3	1/3	1/3
or			
Urea	2	1/2	1/2
Single supSerphosphate (SSP)	5	—	—
Sulphate of Potash (SOP)	1	—	—
Muriate of Potash (MOP)	—	1/4	1/4

For medium fertile soil increase 0.5 bag for each nutrient and for poor soil increase a bag to increase the fertility of soil for potato crop.

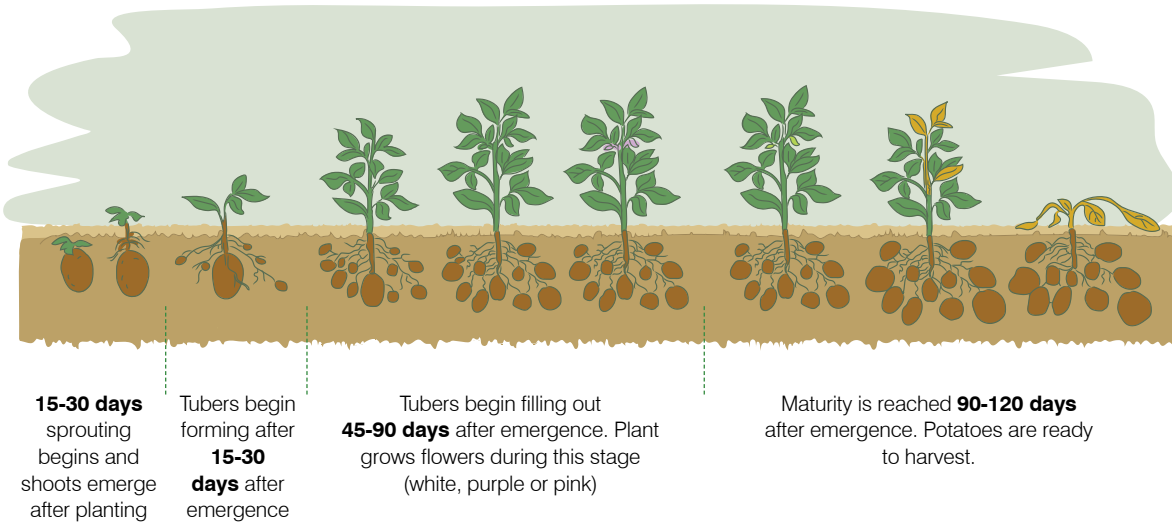


Figure 13: Developmental stages of potato plant

4.4 Irrigation management

There are only a few areas of Pakistan where potatoes are grown without artificial water supply. In the plains, all the potato crops are irrigated. As there are no serious water limitations so far and the labour is relatively cheap, most of the plain areas are irrigated by gravity.

Figure 14 Furrow Irrigation in the potato field (Source: Howard F. Schwartz, Colorado State University, Bugwood.org)

4.4.1 Pre-irrigations

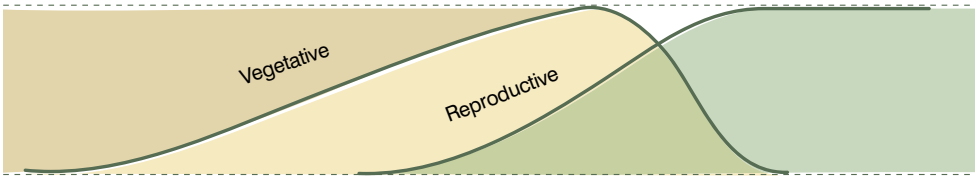
Before planting the Punjab autumn crop, two “rouni” pre-irrigations may be required. The first one is required about 15 to 20 days before planting. Soil preparation should resume some 7-10 days after the first pre-irrigation.

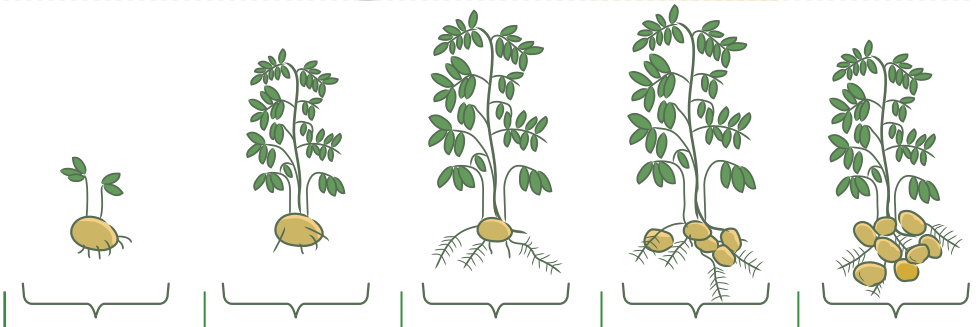
The second pre-irrigation should be applied about 3 days before planting. Again, this is only required if there are no rains during this time. It will help the germination of the tubers and reduce the risk of rotting, especially under hot weather conditions.

Pre-irrigated soils help to achieve homogeneous germinations. It the soil is bone-dry at planting and there are slight leveling errors in the field, some of the seed tubers will not get sufficient moisture until several days (up to 10) after planting.

4.4.2 After planting irrigations

The soil should be kept uniformly moist until tubers have reached full size. The effective rooting depth of potatoes is two feet. The soil should not be allowed to dry below 65% of field capacity. On extremely sandy soils it is nearly impossible to prevent the soil from drying below 65% of field capacity due to the low water holding capacity. Potato is irrigated 5 – 7 days after planting or even earlier and the subsequent irrigations are applied depending on the soil, crop and environmental conditions by several intervals.





	Establishment (15-20 days)	**Stolon initiation** (15-20 days)	**Tuber initiation** (15-20 days)	**Tuber filling** (45-55 days)	**Maturity** (20-25 days)
Impact of water deficit	- Delayed emergence - Restrict root establishment - Restrict plant development - Presence of fewer stalks/stem	- Restrict plant development - Limited stolon initiation - Limited number of stolon - Restrict root growth - Restricts uptake and response to nutrients	- Limited foliage and plant development - Limited tuber initiating - Limited number of tubers	- Limited plant and tuber development - Restricts tuber size - Promotes distorted tuber shape - Faster senescence	- Limited relative tuber density - Limited tuber size

Figure 15. Critical Stages for irrigation and impact of water deficit in potato (Source: Hamlyn Glones)

4.4.3. Irrigation management schedule for potato

Apply irrigation immediately after planting which leads to proper germination of the crop in general. It is recommended to irrigate the crop at a soil moisture of about at 15 cm soil depth which comes to nearly 63 % available water and has found to be optimum for better crop yields.

The potato is very sensitive to oxygen deficiency in the soil. As a result, roots may die and root activity may decrease. Moreover, tubers may rot in the soil. For this reason, it is very important when furrow irrigation is used, never to allow the water to fill the furrow completely. It is wiser to apply the water in smaller quantities but more frequent (shorter interval).

- During autumn the crop in Punjab must be irrigated immediately after planting.
- The decision to irrigate should be made by inspecting the crop every day around 10 am.
- The potato crop should be irrigated after every 5 to 8 days.
- Towards the first week of November, the irrigation intervals can be extended by 1-3 days.
- The last irrigation should be applied 10-15 days before harvest (included haulm killing prior to harvest) to allow the tubers to harden their skin before harvesting/digging of potato.

5

Intercultural Practices and Integrated Pest Management

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Intercultural practices are the operations of soil cultivation performed in standing crop. It facilitates good aeration and better development of root system as well as insect pest's management. These practices include weeding, earthing up, gap filling, thinning and propping are required as part of inter cultivation operations.

5.1 Earthing up

Earthing up is the raising of loose soil from the inter row space and placing on the ridges along the rows where the potato plants are growing. It is common for potato tubers to be exposed to the surface mostly if planting was done on ridges and/or during high intensity rainfall. In the potato crop, earthing up is to incorporation of the nutrients into the soil and destruction of perennial weeds. Covering additional stem nodes with soil before the main stem development, thus increasing the number of tubers per hill. The time of ridging is as follow:

- After planting covered the potato at same day with 8-10 cm of soil your first hilling.
- 2nd hilling after 25-30 days
- 3rd hilling after 40-50 days after planting.

The dimensions for ideal potato ridges with row distances of 75 cm

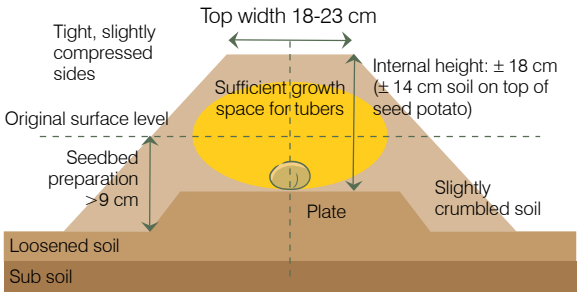


Figure 16a: The dimension of the ideal potato ridge

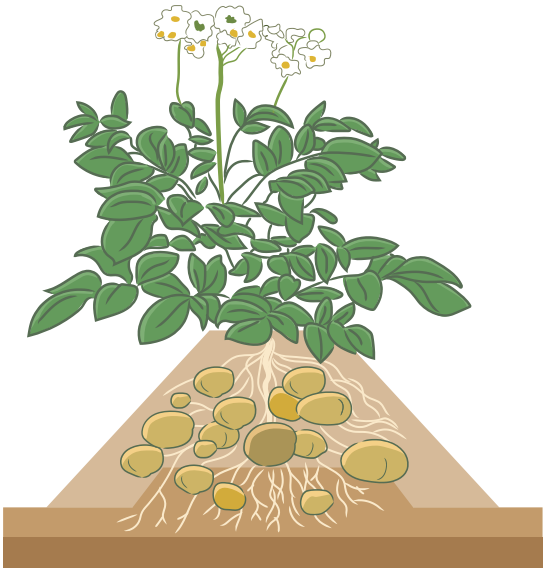


Figure 16b: Earthing up of tubers Improve the color of picture as well.

It is therefore recommended to:

- Often only a shallow ridge is made at planting. A larger final ridge is either made soon after planting, at the start of crop emergence or at the crop stage where plants reach 15-20 cm height.
- Before earthing up, loosen the soil between the ridges by hoeing with three-pronged spring tines,
- Preferably use the concave double-mould board ridgers or concave disc ridgers for the earthing up operation.
- Early ridging is done when the temperature after planting is expected to be relatively high and it is expected to be dry.

5.2 Rouging

This is the technique used to eliminate all diseased, off-type plants in a standing seed potato crop. The precondition for a successful rouging operation is at least 80% of the plants have emerged from the ground and not more than 5% of the plants are diseased or off-types. The top foliage is undisturbed form frost, herbicide burn, fertilizer burn, insect pest and disease damage etc.

The diseases can be reduced considerably by the rouging techniques. Ideally, rouging must be done at

- First rouging should be done 25 days after planting to remove all virus affected plants
- The best timing for rouging is in the early morning hours and preferably in cloudy and/or overcast weather, virus diseases are most easily recognized under such conditions.
- About 50-60 days after panting when earthing up has been completed. The second rouging is made to remove all the off-types, severe PVY, part of PLRV and Fusarium tuber rot.
- About 10 days before haulm destruction. At this stage, all virus affected plants and off-type plants, if any, along with their tubers have to be very carefully removed, so that no such plants are left in the field.
- Rogue aphid free crop and carry out a spray against aphids if necessary.
- Ideally the rouging supervisors should be trained.

5.3 Crop rotation

Proper crop rotations enhance soil fertility, maintain soil structure, reduce the “building-up” of certain pest problems (nematodes, bacteria, insects pests), increase soil organic matter, and conserve soil moisture. Generally, most useful rotations for potato fields are maize, cotton, vegetables (melons), oil seed (sunflower), legume crop and forage crops. Crop rotation is useful for control of soil-inhabiting pathogens that have limited host ranges and require host plant residues for survival.

In case of autumn planting at least a “3 crops” rotations should be considered. The best

results so far have been achieved with spring maize followed by green manure. After potato, the next crop can be spring maize, sunflower, cotton, watermelon, musk melon, mung beans or some other deep rooting crop which will make use of the residual fertilizer left in the soil. For spring planting, the rotation should be as maize, vegetable and wheat.

5.4 Integrated Pest Management

An Integrated Pest Management (IPM) program integrates control tactics including cultural practices, variety selection, biological control and insecticides to manage insect pest populations so that economic damage and harmful environmental side effects are minimized. Insecticides should only be used on an as-needed basis; therefore, insect scouting must be conducted regularly throughout the season to determine if an insecticide application is warranted.

5.5 Weeds

Weeds also affect the potato crop mainly by competing for light and nutrients and therefore reduce yields. Weeds are serious threat to potato crop and may cause 20- 30 percent losses of the crop. Many farmers in the Punjab leave their potato plots fallow over most of the summer months and control annual weeds with broad spectrum pre-emergence herbicides. This has favored the development of high populations of perennial weeds such as Purple nutsedge (Deela), Bermudagrass (Khabal ghas), Cogongrass. and Johnson grass (Baru).

In order to control the annual and perennial weeds by pre-irrigation, hoeing, earthing up and crop rotation. Application of following systemic herbicides has been proven effective against weeds include:

1. Metribuzin (Locker 70% WP and Retard 70% WP) at the rate of 250 gm per acre at the pre-emergence stage.
2. Pendimethaline (Stomp) 455 GL/ CS at the rate of 750 ml per acre at the pre-emergence stage.
3. Haloxyfop-p-ethyl (Spider) 10.8% EC at the rate of 350 ml per acre at the post emergence stage.

5.6 Monitoring

Systematic monitoring of pest populations, weather conditions, plant health and disease symptoms are critical components of an IPM program. Crop damage caused by pests and diseases can be prevented by growing the crop in times of low pest populations. Pests should only be controlled when they are likely to cause economic losses.

5.6.1 Crop Scouting tools/resources

The following is a list of useful crop scouting tools:

- A clipboard or tablet
- Pen, paper, cameras, smartphones, or other mobile devices.
- A hand lens or mobile digital microscope
- Sample collection bags, vials, or a cooler
- A pocket knife
- A trowel or spade
- A sweep net to collect insect samples.
- A soil probe and soil sample bag
- Measuring tape
- Personal protective gears

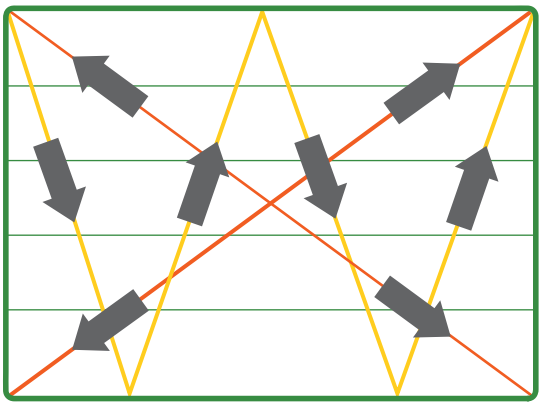


Figure 17: Crop scouting scheme

5.6.2 Scouting procedure

- Monitor at least once a week and preferably twice a week during critical stages.
- Monitor at approximately the same time each day and keep the light behind you.
- Start with an overview of the field looking for any unusual patterns or odd areas that may require a closer investigation.
- Walk through the field in a pattern whether that be a “V”, “Z” or “W” pattern, or a diamond pattern to get a good observation.
- Change up the route you take through the field each time.

Figure 18: Field inspection of potato crop

- As you walk through the field, stop several different points along your route and take a closer look at the plant level.
- Take a closer look at 10-15 plants per acre.
- Stand back and look for patterns, such as patches or areas of poor plant growth or where color is off.
- Getting down onto your hands and knees and observing the crop and soil. Examine the underside of the leaves and inside the canopy etc. to find hidden insects pests.
- Scout the edges of the field and interior of the field separately.
- Give special attention to border areas.
- Inspect plants in several areas across the field to get an accurate idea of pest pressure.

For sample collection, look away from the plant when you take samples of leaves and tubers, etc., otherwise you will tend to choose damaged leaves or fruit and bias the sample.

5.7 Insects pests of potato crop

5.7.1 Armyworm *(Spodoptera litura)*

Figure 19. Mature larvae of army worm (Source: K. Kiritani, Bugwood.org)

Armyworm are a common pest of the potato crop in the Punjab. The larva is the size of your small finger and has bright yellow lines on the back and sides of the body. On touching, the larva curls at once and drops. Eggs are laid on the underside of leaves. To begin with, the eggs are greenish and turn black later on. After larvae have fed on the leaves, it appears as if large chunks of the leaves are missing. If the attack is severe, all of the green part of the leaf is missing and only veins are left behind.

To control armyworm, it is recommended to:

1. Monitor the presence of the pest in patches in the field
2. Keep the potato crop free of weeds likely to attract egg laying and to nurture young larvae.
3. Wash all gardening tools and equipment to reduce the spread of the fall armyworm infestation.
4. Physically remove worms from their hosts.
5. Remove the affected plants and destroy them.
6. For the chemical control of the armyworm, application of insecticides like:

- Flubendiamide (Belt) 48% SC at the rate of 20-25 ml per acre.
- Profenofos + Lambda cyhalothrin (Border) 61.5% EC at the rate of 500 ml per acre.
- Deltamethrin + Triazophos (Combo) 36% EC at the rate of 600 ml per acre.

5.7.2 Aphids *(Myzus persicae)*

Figure 20. Peach potato aphid *Myzus persicae* adult (Source: Koppert biological sysytem)

The aphids, likely to transmit virus diseases or to cause direct damage to the potato crop. Heavy infestation of aphid can cause considerable damage to the potato crop by severely dwarfing and curling the leaflets, and by dwarfing and spindling the tops. *M. persicae* dominates during February-March. Occasionally, high populations appear in some places in December-January. They can transmit virus diseases to the autumn seed crop.

The control strategy of aphid should be:

1. Using many parasites and predators attack aphids like Lady beetles and their laryae, lacewing larvae, and syrphid fly larvae.
2. Check plants for aphids to catch infestations early in the growing season. Look for aphids on the undersides of leaves and new growth. When plants are growing rapidly, check at least twice a week.
3. Rogue infected potato plants to reduce the incidence of infection and spread of the disease within a field.
4. Plant disease-free seed to reduce the incidence of potato leafroll virus.
5. A preventive program using insecticide applications at 2-3 weeks interval.
6. Thiacloprid (Talent) 48% SC at rate of 50 ml/acre.
7. Buprofezin+ Fenpropathrin (Sweep) 250 EC at rate of 750 ml/acre.
8. Acephate + Imidacloprid (Lancer Gold) 51.8% SP at rate of 500 g/acre.

Rotate insecticides with a different mode-of-action group number, and do not use products with the same mode-of-action group number more than twice per season to help prevent the development of resistance.

5.7.3 Whitefly *(Bemisia tabaci)*

Whitefly is a sap feeder. Adults are very small flies with white powdery wings. Females lay eggs directly on the undersides of plant leaves. The eggs hatch into tiny nymphs that develop into pupae before emerging as winged adults. As a sap feeder whitefly reduces overall vigor of potato plants. In severe infestation, plants lose leaves prematurely. They also produce sugary sticky (honeydew) material which attracts and facilitate fungal colonization. Along with all other damages, whiteflies are vectors that transmit many plant viruses.

Figure 21. Adult whitefly *(Bemisia tabaci)* (Source: Central Science Laboratory, Harpenden , British Crown, Bugwood. org)

The measures to control the whitefly attack are as follow:

1. Remove weeds and crop residues to avoid infestation
2. Mulch the soil with straw
3. Spraying soap solution with sticker-spreader can reduce whitefly population
4. Conserve natural enemies (green lacewing, minute pirate bug, ladybug, parasitic wasp)
5. Spray insecticides when the whitefly population is high (seen as many flying adults). Few recommended insecticides are:
    - Betacyfluthrin + Triazophos (Capital Plus) 41.7% EC @250 ml per acre.
    - Spirotetramat + Imidacloprid (Movento Energy) 480 SC at the rate of 150 ml + 250 ml adjuvant per acre.
    - Bifenthrin (Tender) 10% EC @250 ml per acre.
    - Profenofos + Lambda cyhalothrin (Border) 61.5% @ 250ml per acre
    - Deltamethrin + buprofezin (Dream) 50 EC at the rate of 500 ml per acre.

5.8 Diseases of potato crop

Diseases may affect potato at any stage of crop growth or even during storage. They may affect foliage, tubers or both. Environment favoring pathogens can ruin the crop. Diseases transmitted through the seed tubers to the next crop have to be given special attention. Potato diseases affecting the potato crop in Pakistan are treated in some more detail hereunder.

5.8.1 Early blight *(Alternaria solani)*

Figure 22. Early blight lessions on older (lower) leaves (Source: 2021 DPIRD)

The disease affects leaves, stems and tubers and can reduce yield, tuber size, storability of tubers, quality of fresh-market and processing tubers and marketability of the crop. Several spots appear on the leaves. They are irregular, brown to dark brown in colour, and with concentric lines inside the spots. In severe cases the entire foliage is blighted. Alternaria conidia (spores) or mycelium survive in infected plant debris, on seeds, tubers etc. Conidia (spores) are dispersed by rain splashes in the field and to some extent also through the air. Conidia (spores) need free moisture to infect. Higher temperatures and change from wet to dry conditions are ideal for Alternaria.

The integrated management of Early blight should include following measures:

1. Use certified seed of the resistant varieties and from healthy seed source.
2. Avoid irrigation in cool cloudy weather and time irrigation to allow plants time to dry before nightfall.
3. Allow tubers to mature before digging, dig when vines are dry, not wet, and avoid excessive wounding of potatoes during harvesting and handling. And avoid replanting potatoes (and tomatoes or eggplants) in the affected fields for at least 2 years if severe outbreaks have been experienced.
4. Vigorous plants are less susceptible for infection and plants under stress are more susceptible.
5. Discarded tubers and crop debris of the diseased plants.
6. Remove the volunteers plants from the potato field.
7. Application of following systemic fungicides has been proven effective against this disease:

    - Tebuconazole + Trifoxystrobin (Nativo) 200-300 ml/acre
    - Mandipropamid (Revus) 050 EC 140 ml/acre
    - Pyriclostrobin+Dimethomorph (P Vit) 18.7 WG @ 250 g/acre
    - Mencozeb+Carbendazim (Saaf) 75 WP @ 500 g/acre
    - Diafenaconazole (Score) 250 EC @ 120 ml/acre
    - Tebaconazole+Flutriafol (Topguard) 30 SC 200 ml/acre

5.8.2 Late blight *(Phytophthora infestans)*

Figure 23. Late blight (Source: Potato news)

Late blight by is a serious disease in the Punjab. Exceptionally heavy attack occurs in January and the humid weather persists, the date of haulm destruction should be advanced by up to one week. First spray is roughly at a level of 75-80% emergence with an interval of 7 to 10 days (depending on the weather) during the whole crop cycle. In total a protective scheme will behold 8 to 12 sprays. If rains in spring are prolonged preventive treatment against late blight must be applied weekly. When plants have become infected, lesions (round or irregularly shaped areas that range in color from dark green to purplish black and resemble frost injury) appear on the leaves, petioles, and stems.

The integrated management of Late blight should include following measures:

1. The seed material should be obtained from a disease-free area. And should be examined carefully before planting and also make sure to pre-treat by dipping in 1 per cent Bordeaux mixture or other fungicides.
2. Eliminating cull piles and volunteer potatoes, using proper harvesting and storage practices. High humidity and low temperature and leaf wetness favour the spread of the disease
3. When there are low temperatures and high humidity, apply a preventive and curative spray on the crop, e.g.

    - Fluazinam+metalaxyl (Flumax 60 EC) at 150ml /100 litre of water per acre
    - Pyriclostrobin+metiram (Cabrio Top) 60 WDG at the rate of 300-500 g/acre
    - Fluopicolide + Propamocarb Hydrochloride (Infinito) SC at 600 ml per acre with 7-day interval.

5.8.3 Bacterial wilt *(Ralstonia solanacearum)*

Figure 24. Bacterial wilt of potato (Source: Plantwise)

Bacterial wilt is spread by infected seed tubers, crop residues, contaminated irrigation water, soil adhering on shoes and tools as long as machinery. Infected plant wilt when the soil has sufficient moisture. Bacterial wilt pathogen can survive in seed tubers, potato plant leftovers for several seasons, in soil for periods up to 2 years after the crop harvest and in water for up to four years. Infected seed can also be a source of the disease in the field.

The control measures of the bacterial wilt are given below:

- Don't allow irrigation water to run freely over or below the soil surface pumped to any other irrigation source.
- Use certified seed from reliable sources.
- Discarded tubers and crop debris and weeds.
- Clean and disinfect machinery removed from the paddock with a disinfectant solution in an area dedicated to equipment wash-down.
- Use non-infected organic compost
- Rotate potato crops with other non-solanaceous (e.g. beans, corn, cabbage) or fallow for about a year for heavy infected fields
- Bio-fumigation with Brassica residues can reduce disease pressure on heavily infected fields.
- There is no chemical control and once infection occurs there is no treatment.
- Crop rotation with non-host plants because it reduces inoculum potential in the soil.

Simple test for bacterial identification
Procedure:

1. Cut a 2-3 cm piece of stem from the base of the suspected plant.
2. Discard the lower and upper parts.
3. Tie the piece with the string provided.
4. Suspend the piece of stem horizontally in the glass full of clean clear water and wait for about 15 minutes.
5. If the plant was infected with bacterial pathogen, it will exude white smoky liquid/ milky threads down wards from one or both ends of the cut stem.

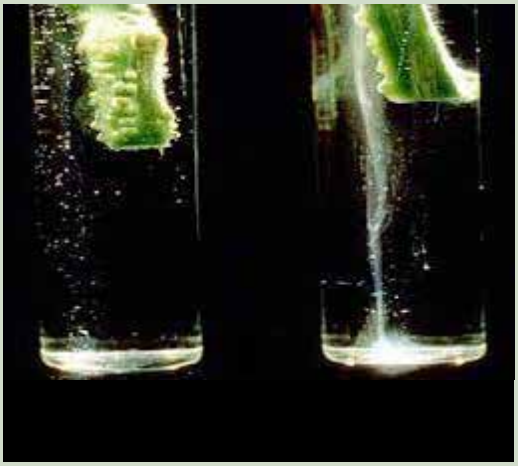


Figure 25. Test for bacterial identification (Source: AVRDC.org)

5.8.4 Blackleg and soft rot *(Erwinia carotovora)*

On vines, the disease is called black leg. On tubers, the disease is called Bacterial Soft Rot. It is usually an early season wilt but can occur late in the season under certain weather conditions. Early symptoms are the stem becomes black and slimy, and oozes. Stunting and delaying emergence is common. The late attack may cause the collapse of fully developed haulm. Infected tuber becomes very soft and turns into creamy to tan color.

Figure 26. Potato showing blackleg symptoms (Source: Ken Frost, 2017)

The cultural control for the management of blackleg and soft rot is:

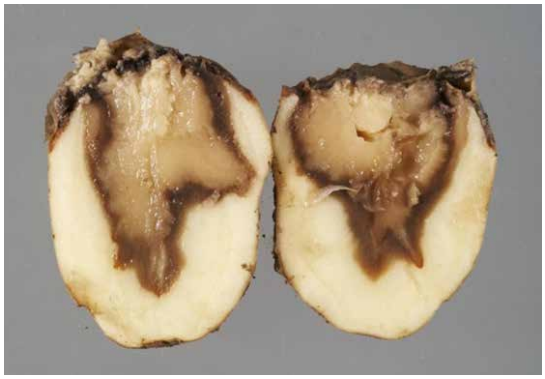


Figure 27. Soft rot infected potato tuber (Source: AHDB)

1. Minimize the bacterial contamination in seed tubers.
2. Good sanitation practices.
3. The temperature of the store should be kept low by using an adequate ventilation system.
4. The use of hot water treatment on seed tubers may reduce inoculum level.
5. Crop rotation will help reduce the disease.
6. Seed tuber temperature should be similar to the soil temperature at planting to avoid formation of condensation on the tuber surface.

5.8.5 Common Scab *(Streptomyces scabies)*

Figure 28. Common scab of potato (Source: 2021 DPIRD)

Common scab comes from a soil-borne bacterium and is spread by spores on seed, in the soil, in soil water and can hitch a ride on nematodes or insects. The bacteria cause hard, corky, raised, small and wet brown spots to develop on the skin of the tuber. Tubers are most susceptible to infection of Streptomyces species during the first three to four weeks after tuber initiation, when compared to six to eight weeks after tuber initiation. Irrigation or rain during the time of tuber initiation (moist soil) is also effective against common scab.

The management of the common scab is as follow;

1. Use of healthy seed tubers and Cultivation in un-infested fields.
2. Destruction of diseased plant debris.
3. Cultural practices to stop spread.
4. Use acid producing fertilizer like ammonium sulphate, DAP at land preparation to lower the pH
5. Use gypsum (calcium sulphate) to improve soil texture. Do not use this in combination with acid fertilizer as gypsum will counter its effect
6. Long rotation and Destruction of host plants etc.

5.8.6 Potato leaf roll virus

Initial infection of potato crops by PLRV occurs when plants become infected by virus-carrying aphids during the growing season (primary infection). Infection also occurs when seed stocks containing infected tubers are planted, and infected potato plants grow from them (secondary infection). Aphids then spread the infection further. Symptoms of primary infection are visible in the young leaves with upward rolling of the leaf margins. This occurs mainly in the part of the leaf near the base. The integrated management of the PLRV virus is as follow;

Figure 29. Potato leaf-roll virus causes stunted plants (Source: 2021 DPIRD)

1. Planting PVY and PLRV resistant varieties
2. Planting only high-quality virus-free potato tubers
3. Using plastic or straw mulch to suppress aphids
4. Rogueing out virus-infected plants
5. Spray aphid suppressing mineral oils
6. These remove virus from aphid stylet as it feeds
7. For vector control, recommended pesticides should be used

5.8.7 Potato mop top virus

The Potato mop-top virus causes tuber quality problems. Infection on tubers may be expressed as arcs or rings on the tuber surface, deep cracking and distortions to the skin that compromising tuber quality. Symptoms on potatoes include yellowing of leaves and shortened internodes, resulting in stunted growth, hence the name “mop-top.” Secondary infection may include the primary symptoms and/or tubers may have deep cracking, a network of cracking or distortions to the skin that appear as blotchy surface markings.

Figure 30. Potato mop top virus (Source: PotatoPro)

Some other important viruses in Pakistan are:

- Phytoplasma
- Potato virus S
- Potato virus A
- Potato virus X
- Potato virus M
- Potato virus Y

Some cultural control recommendations regarding viral diseases are:

1. Use virus free, certified seed potato
2. Control the aphid vector and use resistant varieties
3. Rouging and Heat treatment of tubers
4. Modification of cropping procedure
5. Chemical control of vector (Insects, nematodes and fungi)
6. Non-chemical control of vectors (barriers and reflective mulches, oil sprays, biological control by predators).

5.8.8. Root-knot Nematode

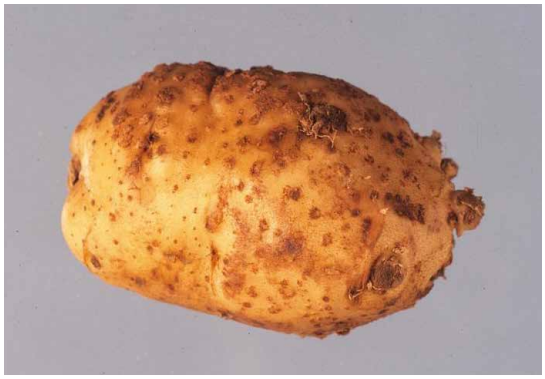


Figure 31: Bumpy tuber surface is an indication of infection by root-knot nematode. (Gerald Holmes)

Root-knot nematode infection rarely causes aboveground symptoms in potatoes. External symptoms are distinct pimple-like bumps and lumps on tubers. Sometimes usually produces a more general swelling on the tuber or none at all. Root-knot nematodes produce brown spots within the vascular ring, within 0.25 inch of the tuber surface. The spots should not be confused with symptoms of heat necrosis, which produces spots of similar size but more diffused. Soil sampling is recommended. Sample soil any time before planting potatoes, provided the soil is not frozen or too dry or wet. However, it is best to sample in late summer or early fall, when nematode populations are higher, than in early spring.

Following are few measures to control root-knot nematodes:

1. Use only certified seed inspected for nematodes.
2. Do not return tare dirt from potato or other crops to your farm.
3. Avoid moving soil from infested farms or fields by cleaning machinery and equipment.
4. Avoid using waste ditch water for irrigation. Settling ponds reduce nematode spread; nematodes settle to the bottom and eventually die.
5. Use non-host crops such as cereals (wheat and corn) in rotation with potato to suppress or minimize population increases of root-knot nematodes.
6. Weed control within rotation crops is critical because many weeds are suitable hosts for root-knot nematodes.
7. Plan an early harvest in fields infested with some species of root-knot nematodes, even if using proper control measures. Harvest as soon after vine kill as possible. Do not leave tubers in the ground for a long period after vines have died.
8. Avoid storing tubers harvested from a field infested with root-knot nematodes.
9. Green manure crops and rapeseed effectively suppress nematode populations. These are grown after short-season crops such as wheat or corn, in early August. Fodder crop is incorporated in fall before frost, rapeseed in spring 3 to 4 weeks before planting potatoes.

10. Application of Carbofuran (Furadan 3G) @ 3 kg /ha is recommended for control of nematodes. The pesticide is applied in two split doses, first at planting and second during earthing up has been found effective in controlling nematodes population. Indiscriminate use of these nematicides causes soil and environmental pollution and farmers are not careful in the use of these nematicides and other toxic chemicals.

5.8.10. Potato Cyst Nematode

Figure 32: Potato cyst nematode (Source: Pests and Diseases Image Library (PaDil) Australia)

Potato Cyst Nematodes (PCN) or potato rootvematodes (Globodera rostochiensis) and are 1 mm long roundworms belonging to the genus Globodera. They live on the roots of plants of the Solanaceae family, such as potatoes. PCN cause growth retardation and, at very high population densities, damage to the roots and early senescence of plants. Reflect those of plants with an inefficient roots system i.e., poor growth, wilting during periods of water stress, early senescence, reduced tuber size and reduced tuber yield up to levels in excess of 80%.
Few of control measures for the potato cyst nematodes are given below:

- Plant certified seed purchased from recognized, certified seed producers.
- Avoid sharing equipment with other growers. The most common way of spreading PCN is in soil or on equipment.
- Thoroughly clean all equipment.
- Practice crop rotation.
- Regularly examine your crops for patches of poor or yellow potato plants.

5.9 Safe use of pesticides

Figure 33: Spraying of pesticide on potato crop

Pests and diseases are among the most important constraints to potato production in Pakistan. If not adequately controlled, yield losses from fungal and bacterial diseases alone can reach up to 100%. The absence of environmentally friendly approaches for management of potato pests and diseases has left farmers with no option other than use of chemical pesticides on a routine basis. Farmers get exposed to toxic pesticides by eating while spraying, entering into freshly sprayed fields, inhalation, and direct contact of the skin with any form (liquid, powder, or aerosol) of pesticides. Misuse of pesticides can lead to illness

which reduces the availability of family farm labour and increases the resistance of pests to pesticides due to low pesticide rates and the frequent use of the same active ingredients.

5.9.1 Precautions

1. The label: The label should be in English and in the local language, and should indicate the contents, safety instructions (warnings) and possible measures in the event of swallowing or contamination.

Poison: Identification

Figure 34: Read the safety label of pesticides

WHO color code on condtainer.

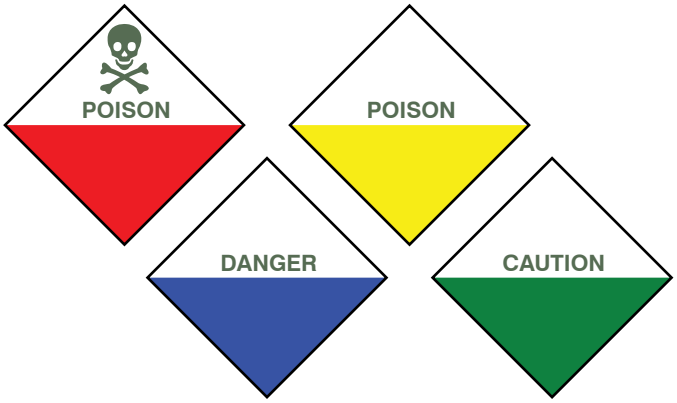


Figure 35: Poison identification

5.9.2 Storage and transport

Store pesticides in a place that can be locked and is not accessible to unauthorized people or children. Keep them dry but away from fires and out of direct sunlight. Do not carry them in a vehicle that is also used to transport food.

5.9.3 Disposal

Left-over insecticide suspension can be disposed of safely by pouring it into a specially dug hole in the ground or a pit.

5.9.4 General hygiene

1. Do not eat, drink or smoke while using insecticides.
2. Keep food in tightly closed boxes.
3. Use suitable equipment for measuring out, mixing and transferring insecticides. Do not stir liquids or scoop pesticide with bare hands.
4. Use pressure-release valve of the pump or a soft probe to clear blockages in the nozzle.
5. Wash the hands and face with soap and water each time the pump has been refilled.
6. Eat and drink only after washing the hands and face.
7. Take a shower or bath at the end of the day.

Figure 36: Proper storage of chemicals (FAO)

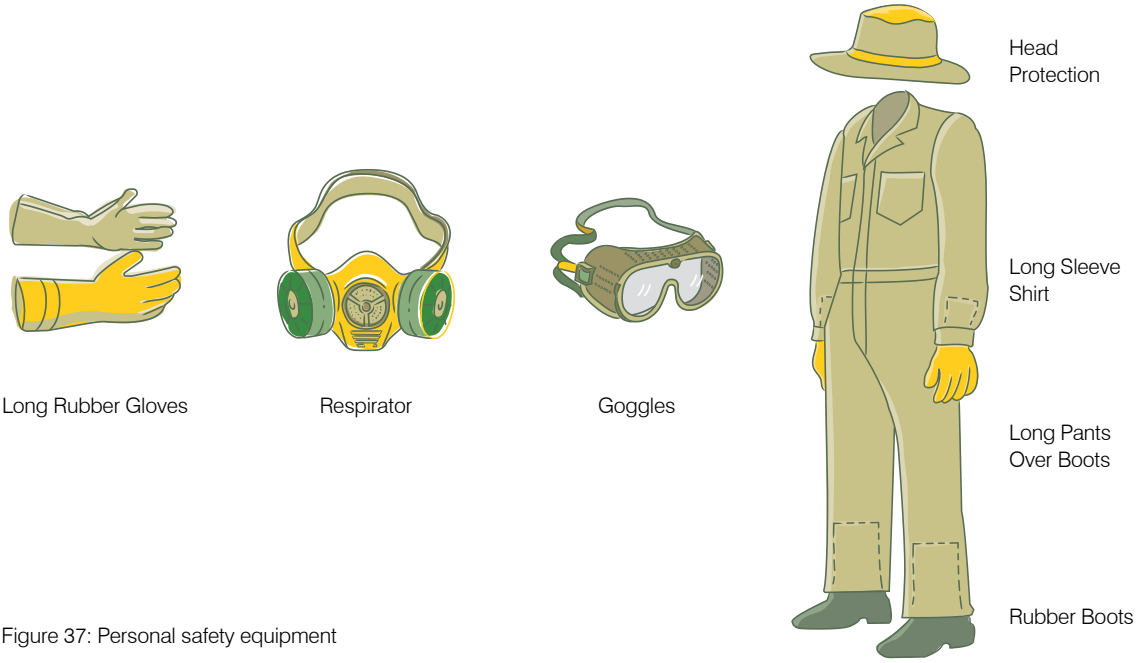


Figure 37: Personal safety equipment

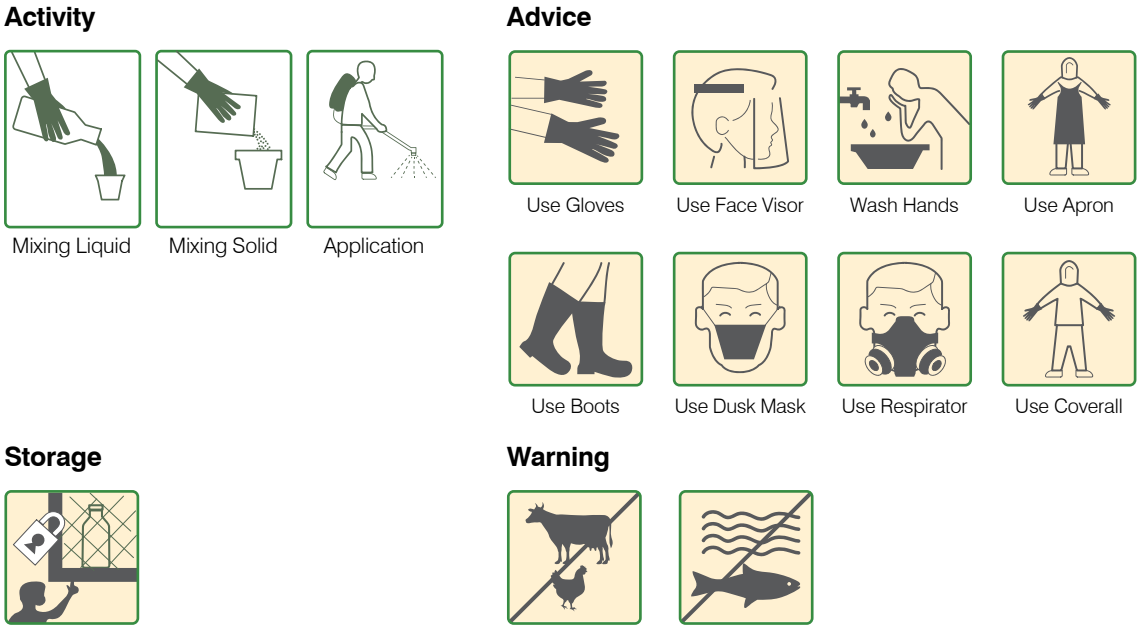


Figure 38; Safety pictograms for pesticide labels

5.9.5 Spraying technique

The most important goal in the application of agricultural pesticides is to get uniform distribution of the chemicals throughout the crop foliage. The spraying technique is important because it helps to find out how to get pesticide from package to the target? The deposition of pesticide should be 100%, not more and not less pesticide losses due to drift or deposition on soil results in reduced effect. Wrong and unsafe application leads to health risks.

a. Equipment and operator

To get the maximum benefits from the use of any crop protection product, as well as reducing risks of any potential human or environmental contamination, it is important to apply the product in the optimum way. Best maintenance, calibration and use of the knapsack are critical to the success of any application and will ensure that you get maximum value, effect and safety from the products used.

I- Knap sack sprayer

Knapsack sprayers are indispensable agricultural tools. Understanding how to use them is essential for the successful application of agricultural chemicals. In order to successfully use herbicides and pesticides, their application must be accurate and uniform. Nozzles, spray tips, multiple nozzle booms, pressure regulation and sprayer calibration are the essential components of the spray-application technology.

Some guidelines to follow while using knap sack sprayer are;

1. Check sprayer for leaks with clean water (always before use)
2. Calibrate sprayer output (at least once per season)
3. Ensure an even and uniform application
4. Clean sprayer after each use

II- Nozzle

Nozzle has effect on the amount of chemical applied, uniformity of spray, coverage of chemical on surface and Drift. There are two types of nozzles on the basis of pressure; high and low.

(a) Types of nozzles on the basis of materials mentioned in table:

Material	Life span	Price
Brass	Short life	Cheap
Plastic	Short life	Cheap
Ceramic	Long life	Cheap/ expensive
Steel	Long life	Long life- expensive

(b) Types of nozzles on the basis of target :

Target	Nozzle type
Weedicide	Coarse
Fungicide	Medium
Insecticide	Medium to fine

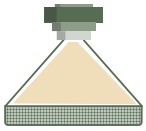
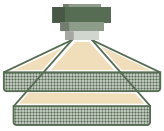
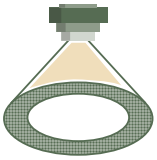
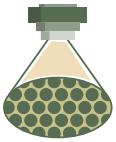
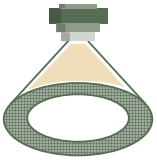
	 Even Flat Fan	 Twin Even Flat Fan	 Hollow Cone	 Full Cone	 Disc and Core Cone
Herbicides					
Pre emerge	Very Good	Good		Good	
Post emerge contact	Good	Very Good	Very Good		
Post emerge Systemic	Very Good	Good			
Fungicides					
Contact	Good	Good	Good		Very Good
Systemic	Very Good				Good
Insecticides					
Contact		Good	Very Good		Very Good
Systemic	Very Good				Good
Growth Regulators	Good			Very Good	

Figure 39: Nozzle guide for band and directed spraying

III- Precautions

Following are few precautions that should be kept in mind while spraying;

1. Replace nozzle frequently especially brass nozzle as it has short life. After fifty hours there is a 25% increase in flow rate which means 25% more water, pesticides, labor and costs. More pesticides sprayed and more droplet distribution will be poor.
2. The reduced droplet size produce increase number of droplet and increase the coverage.
3. Maintain an even uniform forward speed. Sprayer output may vary as you pump, reducing the ability to apply an even application rat maintain the nozzle height e.
4. Keep the proper nozzle height. Change of height influences spray pattern and volume per surface unit.
5. Important to keep nozzle at fixed height and steady movement as much as possible.

5.9.6 Practice spraying

Calibration:

1. Fill tank with approximately with 5-liter water
2. Take a bucket
3. Spray in bucket for 1 minute
4. Maintain pressure as you would do while spraying in the field
5. Measure water in bucket
6. repeat this
7. Try this with an old nozzle and a new one if possible and discuss what the impact is.
8. Check spray pattern of nozzle
9. Use concrete floor or place a piece of paper on the soil Pressurize sprayer
10. Place nozzle at 30 cm above soil and just squeeze for 1 second trigger
11. Evaluate spray pattern (even distribution, droplets)
12. Try this also with an old and a new nozzle.

Procedure:

Mark an area in the field and try to have a complete cycle of about 20 50 m^2. Measure the exact area to be sprayed and Walking distance. Fill tank of knap sack sprayer with exact volume of water (measure, e.g. 10 liter). Attach water sensitive paper in crop and then spray the crop.

- Time in minutes how long it took
- Measure the left-over water volume in the tank after each test spraying
- Evaluate WSP on coverage

Calculations:

- Sprayed area = width of bed x length (x nr of beds)
- Walking distance = 2 x length + 1 x width
- sprayed volume
  (Start End volume) l / sprayed surface m^2 x 10000 = volume in liter per hectare
  500 600 l/ha should be ok, > 1000 is excessive
- Walking speed
  Meters walked / time in minute x 0.06 = km/ hr
- Liter per minute (start end volume) in l / time in minutes

5.10 5-Golden rules for safe use of pesticides

1. Before using any crop protection product, always read the label and make sure you understand and follow all safety needs
2. Handle crop protection products carefully at all times to avoid contact or contamination
3. Maintain sprayers well, fixing, for example, any leaks before starting an application
4. Practice good personal hygiene
5. Use appropriate protective clothing as last line of defense and not to become careless and increase.

6

Harvest and Post-harvest Handling

KNOWLEDGE FOR LIFE

Harvesting and post-harvest operations of the potato crop are an important part of the entire potato production and marketing operation. Crop yield and quality cannot be increased during harvest, but they can be decreased, sometimes drastically.

6.1 Harvest management

6.1.1 Haulm destruction

This is carried out to control seed size and having the skin set on the tubers, less damage and entry points for diseases like fusarium dry rot at time of harvest. In the Central Punjab, if the autumn seed crop has been planted before 10th October, it should be ready for haulm destruction around 10th January. There is slightly difference amongst the varieties and some delays due to physiologically young seed:

Figure 40: Haulm destruction

Patrones, Ultimus, Desiree and Lal-e-Faisal may be ready some 5-8 days earlier than other varieties.
Cardinal and Diamant may be delayed by 2-5 days.

Crop raised from seed tubers directly transferred from the hills to the plains may be delayed by 5-10 days due to difference in climatic conditions.

The decision to destroy the haulms must be taken after an assessment of the field condition. This can be carried out during the first two week of January. Uproot one running meter of crop per plot planted on the same date and with the same seed lot; if more than 75% of the tubers are bigger than 35 mm, the haulm (Vine kill) destruction can be done on 10th January. No matter what may be the size of the tubers, in the Central Punjab the haulms must definitely be destroyed by 20th January due to sudden increase in temperature in Feb- March to avoid rotting of tubers. Irrigation should stop at least 4 days before haulm destruction.

The haulms are usually destroyed by cutting them, pulling and taking them out of the field. In the central Punjab they are currently in demand as animal fodder. A supervisor is essential for a clean operation. If rains or accidental flooding trigger regrowth from the cut haulms, a spray with specific caustic herbicides has to be applied to the stubbles. Before the spray, exposed tubers should be removed from the field.
These herbicides can be used are:

- Glufosinate ammonium (Basta) 20 SL at the rate of 1 liter per acre
- Diquat (Reglone) at the rate of 4 liter per acre
  The tubers then require so much water that, with their suction power, diquat could possibly also be absorbed. In the case of a large dose of Reglone, this could lead to necrosis at the stem end of the tubers

6.1.2 Harvesting time

Harvest time has to be carried out at least 15 days and not later than 30 days after haulm destruction. Harvesting time depends on the following factors:

6.1.3 Skin maturity

The skin on the whole potato tuber must be hardened. The skin at the rose and of the tuber should not peel off when pressured with the thumb.

6.1.4 Temperature

The soil temperature in the ridge should be well above 10 ^{0}C to avoid tuber cracking, blue and black spot. If harvesting takes place during frosty periods, digging up the tubers must be restricted to the warmest hours of the day. Otherwise the tubers tend to crack at the slightest blow or bruise. If the harvesting gets delayed and the temperature increases, the tubers start rots ultimately affecting the yield.

6.1.5 Soil moisture

The mature seed plot should receive a light irrigation before the start of the harvest carried out 2-4 days after this irrigation. At harvest, the soil in the ridges should be humid and crumbly and should not stick to the hand when pressed.

6.2 Harvesting indices

Maturity (seed & ware) Period range between 3 – 4 months after planting depending on the variety.

Tubers harvested while still immature tend to have low dry matter content and to suffer more skin damage, resulting in easier infection by fungal and bacterial pathogens. Immature tubers have higher respiration resulting in weight losses in store.

Seed potatoes are often harvested early, to avoid virus infection that may occur during the latter part of the growing season.

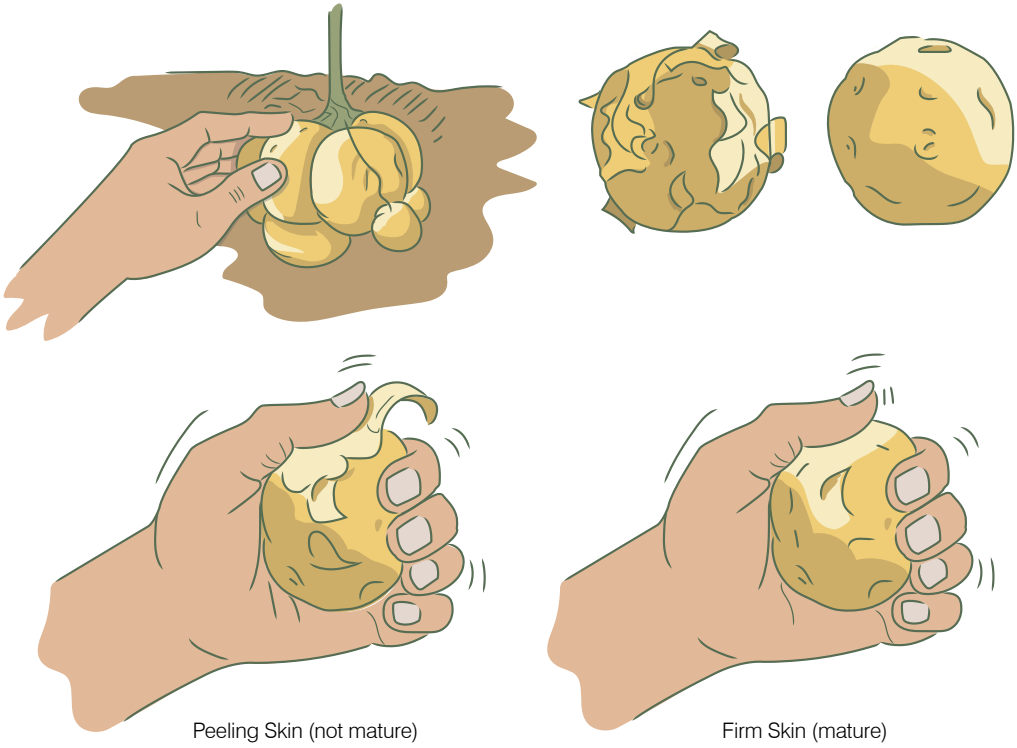


Figure 41: Field testing of maturity by rubbing randomly selected tubers between fingers (A) Immature if skin peels and (B) Mature if skin does not peel

Some important points to consider are:

1. Tubers should be completely covered with soil during the growing season to reduce greening.
2. Harvested tubers should be covered and should not be left in the field overnight to prevent the attack of the potato tuber moth.
3. Cutting vegetative material 2 weeks before harvesting hardens the skin of tubers (dehaulming)
4. Hardening of skin tuber reduces damage of tubers during harvesting & post-harvest handling.
5. Harvested potato tubers should be stored clean, dry with mature skins free from wounds, insect pests and diseases.

6.3 Harvesting techniques

Potato crop matures in 100 – 120 days. Drying of vines, hardening of potato skin and yellowing of leaves are the indications that the tubers have gained maximum size and weight. Potatoes are reaped either using a mechanical harvester or manually using spade for their digging.

Figure 42. Potato harvesting through potato digger (Source: Punjab tractors)

In majority of potato growing area digging is done with hand tools like khurpa, spade and plow. In areas where tractor is main source of farm power tractor operated two row plows and digger elevator are commonly used.

i) **Multipurpose digger:** This low cost, tractor operated tools can be used for early (without cutting haulms) as well as main crop after cutting vines.
ii) **Digger shaker:** In this machine soil, clods and trashes are separated from tubers in two stages. This machine drops tubers gently on soil surface and causes less damage to tubers.
iii) **Digger windrower:** A lot of man power is required for picking of tubers after the operation any kind of digging machine. Digger windrower lifts potatoes from under the ridges and place these into a narrow band where picking becomes easier and less labour is required for collection of tubers.

Tubers if kept under shade for 2 – 3 days harden their skin to avoid its removal during grading and packaging. Tubers are graded for separate packaging of superior grade to get high prices.

Potato tubers which are uninjured, clean, dry and free from diseases are packed in clean, disinfected and unspoiled bags. Potatoes to be kept for seed purposes are stored at 3-4°C while the ones to be marketed after 2-3 months can be stored at 10 – 15°C.

6.4 Post-harvest management

The correct harvest operation only ensures the collection of undamaged tubers from the field. In Pakistan, between harvest and final sale of the seed, there is a time span from 2 to 7 months. Most of the seed is kept in cold stores.

6.4.1 Picking and heaping up

The operation will be carried out in different ways, depending on the time of harvest. The crop, harvested in late January or early February during cold and usually dry weather conditions, is unearthed at rather low temperature are turgid and brittle and tend to crack easily. It is therefore recommended leaving the tubers up to 5 hours on the swath or in small heaps on the field for drying. Only then can the tubers be either heaped up in the field or at

some other dry and elevated storage place, preferably at the site at which grading will take place.

A tractor driven; adaptable elevator belt is recommended for a correct heaping operation. It can be used to make the heaps in the field or to fill the trailer if heaping and grading takes place at another site.

Figure 43: Harvested potatoes picking after digging

6.4.2 Wound healing and drying

The These heaps are covered with a thick layer of rice straw, sometimes fixed with a layer of 5-20 cm of soil. The average outside temperatures are low in February, storing in the traditional heaps has a positive effect on wound healing, drying and skin maturity during this month. If potatoes are produced commercially, the following adaptations should be added to the traditional management.

- Make the heaps on well-drained, elevated platforms of gravel or concrete, on a layer of rice straw.
- Attach means of forced ventilation to the heap. This would decrease the formation of water condensates on the tubers and maintain the quality of the produce.
- This implies that the ungraded potatoes would have to be loaded on trailers in the field and mechanically heaped up the grading place.

The following are the recommendations of the wound curing temperature and duration of curing:

Potato temperature	Duration of wound healing
20 °C	5–7 days
15 °C	7–12 days
10 °C	9–16 days
05 °C	4–8 weeks

6.4.3 Grading

Existing grading system of the potatoes is done by hand as well as by graders. The different practices of grading of potato are as follows:

i) Grading of potatoes with a set of rectangular sieves having round holes of varying diameters, where a pair of sieves placed above the one another are shaken from and to by two persons and third person continuously feds the upper sieve.
ii) Grading of potatoes through sieves hung on ropes and move fore and back.
iii) Grading of Potatoes by mechanical grader, where the sieves are mounted on the

Figure 44: Manual Grading of the potatoes

oscillation of frame as operated mechanically by power. This grader can be operated with 1.0 H.P electric motor, engine or tractor.

iv) Grading of potato with power operated potato grader with conveyer attachment gives better grading efficiency (90%). The power attachment is 1.5 H.P. the rubber roller type of potato graders. It can grade based on different sizes. The system consists of mainframe grading rollers conveyor belt and power transmission system. The grader is operated by 2 H.P electric motor.

a. Grading of seed before storage

Basic seed potatoes descended directly from pre-basic or Basic category seed, should be sorted before storage. Successful storage will depend on the quality of the material loaded in the store. Therefore, all poor-quality tubers must be graded out before storage. Certified seed are descended directly from Pre-basic, Basic or Certified category seed and are mainly intended for the production of potatoes other than seed potatoes. Certified seed or other seed potato categories meant for sale, are graded according to size and quality, following the approved minimum standards and considering the special requirements of the seed owner.

Figure 45: Manual grading of the potatoes in field carried out by female laborers

b. Grading size

There shall be three/four Grades for Potato fresh and Potato Stored i.e. Super, Grade-A and Grade-B. Grade-C shall have any size with defects but saleable.
The size requirement for these grades shall be as follows:

Variant-Size	Super/ Premium	Grade-A	Grade-B	Grade-B
Store	>65 mm	46-65 mm	35-45 mm	35-45 mm
Fresh	>65 mm	46-65 mm	35-45 mm	35-45 mm

6.4.3 Defect and size tolerance (By weight)

External defects are blemishes or discoloration (either internally or on the surface) due to exposure to light, mechanical, pathological or pest agents.

(a) Minor defect - A unit affected by disease, dark or intense discolouration, eye material, or dark peel covering an area or a circle greater that 3 mm but less than 7 mm in diameter; pale brown peel or light discolouration of any area greater than 3 mm in diameter.
(b) Major defect - A unit affected by disease, dark or intense discolouration, covering an area or a circle greater than 7 mm but less than 12 mm in diameter.

(c) Serious defect - A unit affected by disease, dark or intense discolouration, an area or a circle of 12 mm in diameter or more.

The types of defects and their quality is as follow:

Types of defects	Super (%)	Grade-A (%)	Grade-B (%)
Minor defects	10	10	20
Major defect	02	02	10
Serious defect	01	01	02
Size tolerance	05	10	20

Figure 46. Potato grading in stores (Source: DOWNS)

6.4.4 Sorting after storage

If the seed potatoes are intended for marketing after a storage period of more than two months, it is strongly recommended to undertake re-sorting of the material prior to marketing. The following should then be done:

1. Warm up the seed potatoes slowly and allow two days for drying before sorting.
2. Sort preferably by hand on a wooden inclined table and dust with fungicide immediately after or during the sorting process.
3. Pack, re-seal and transport to the marketing outlets immediately after this operation.

6.5 Storage

For the storage of perishable goods such as potatoes the main basic rule is that: “the results of the storage operation will only be as good as the quality of the produce loaded into the store.”

6.5.1 Small-scale short-term storage options

a. Pit storage

Pit is rectangular in shape and measures 4.5 x 3.6 x 14 m while pit is normally circular in shape with a diameter of about 4.2 m. The ware potato in pits are covered with 0.3 m thick of available straw material (wheat, barley, rice, grasses). Maintain an average 25.6 oC of temperature and 66 percent relative humidity.

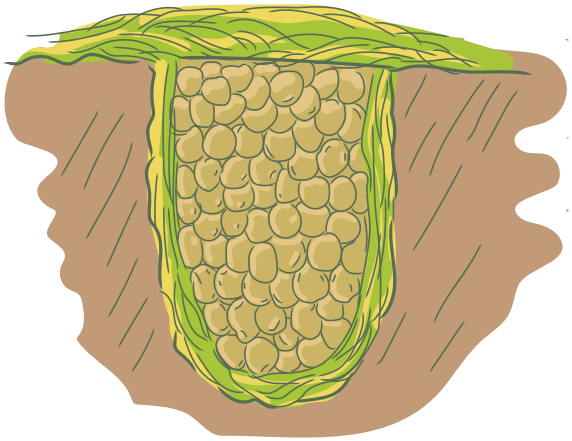


Figure 47: Pit storage

b. Room in house

Make small special rooms built of brick /stones near the residence. The potatoes are stored in heaps, gunny bags or in bamboo baskets. The bamboo baskets provide better aeration to the tubers. The smallest size holds 10 -12 kg and the largest size 100 kg potatoes. Once the wounds and abrasions of the tubers have healed over, sufficient cold air should be admitted to remove excess moisture and reduce the temperature to from 45 to 40 degrees F. This temperature is sufficiently low for the first three or four months, after which a temperature of 38 should prove satisfactory. In general, a RH of 92-97% for dry, healthy potatoes and 85-90% for wet, leaky potatoes is recommended.

c. Clamp storage

Dig a trench in the ground and heap tubers on a bed of straw of width 5 to 6m. A top height is about 1.7 to 2.5 m and length of approximately 25m. It can store 3,000 to 3,500 kg. Insert a ventilating duct on the floor in the center of the heap and cover with a layer of about 20cm of compacted straw or 30 cm if not compacted. The clamp must be in a well-drained location.

Clamp A: the temperature in the clamp is close to the average outside air temperature, the potatoes are well ventilated but are not well protected against rain.

Clamp B: the ventilation of the potatoes is poor, the temperature is higher than the average outside air temperature and the tubers are well projected against rain

Clamp C: the temperature of the potatoes in the clamp is close to the average outside air temperature, the potatoes are reasonably well ventilated and are well protected against rain

Clamp D: as C, but ventilation is better than in clamp C

Clamp E: conditions in clamp E close to conditions in clamp C

Clamp F: potatoes in direct contact with plastic are subject to condensation and heat by sun irradiation. Use only for short period to protect tubers from sudden unexpected rain.

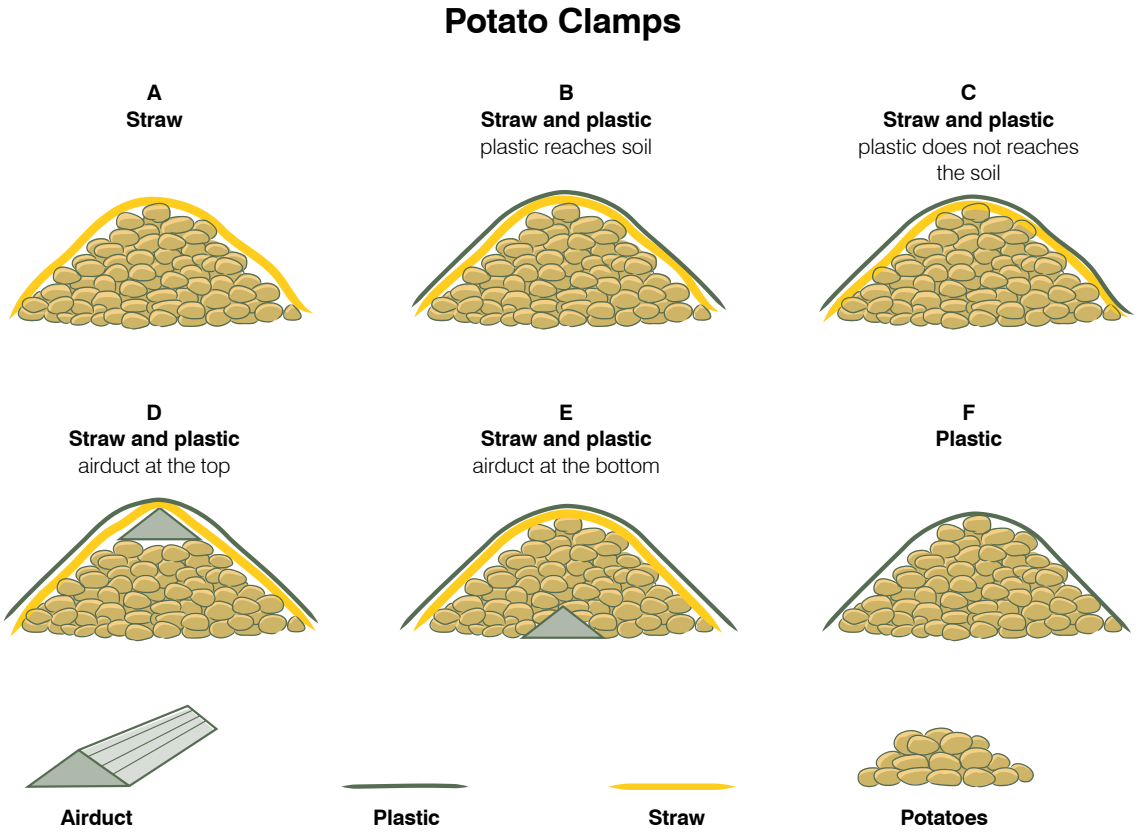


Figure 48: Potato clump storage

Figure 49: In field storage of harvested potatoes

6.5.2 General store management

A store management committee with a quality control manager must be in place to oversee general management of the store. The following guidelines should be followed for store management:

1. A clean store, free from discarded tubers, dust and debris should be maintained.
2. The temperatures, relative humidity and Carbon dioxide are measured both internally and externally.
3. A storage building should be equipped with a flushing system in order to prevent too high level of CO_2 these levels should be well below 2,500 ppm.
4. Crop monitoring and regular sampling and assessment of the stored crop is vital to optimize storage conditions, minimizing storage problems and monitor the effectiveness of store management.
5. The store should be monitored regularly for any signs of silver scurf, black dot, skin spot, dry and soft rot.
6. Quality should be ensured through good record keeping which allows to quickly identify weak points in a storage system.

Temperature and relative humidity guidelines for potato storage

Intended use	Temperature (°C)	Relative Humidity (%)
Seed purpose	3-4	95
Table purpose	4-5	95
Processing purpose	6-8 (French fries)	95
	7-9 (Crisps)	

The longer potatoes have to be stored, the lower the storage temperature should be without dropping to below these minimum values in order to control sprouting and to prevent senescence and cold induced sweetening reducing sugar formation.

6.6. Potato quality

There are three main criteria which define the quality of potato: tuber quality, skin finish and storage and cooking quality. A balanced crop nutrition program is important to help manage all of these criteria.

6.6.1 Tuber quality

Tuber quality, whether it is dry matter content, starch content, internal disorders or cooking ability is critical for the end user. Potato quality is determined by the following:

6.6.1.1. Size shape grading

Size, shape and shallow eyes are important with regard to the appearance of the product and the influence on wastage during peeling.

- French fries producers prefer long oval or long tubers with a size of at least 50 mm.
- For the production of crisps, round tubers are required with a size range of 40- 60 mm.

6.6.1.2. Injuries defects diseases

Internal bruising through rough handling during harvesting and transportation.

- Black spot occurs during transport and grading when potatoes are not treated properly temp induced
- External cuts, bruises, skin abrasions, sunburn, green tuber, sprouting, frost injury, diseases
- Internal hollow heart, black hearts, internal sprouting, diseases, spots < 2 mm are not considered to be a defect.

Susceptibility	Temperature (^{0}C)
Low susceptible	12
Moderate susceptible	15
Highly susceptible	18- 20

Figure 50: Potato diseases and defects (Source: PotatoPro)

6.6.1.3. Dry matter content

Dry matter content is important for both fresh markets and processing. Tubers with dry matter above 18-20% tend to be more susceptible to bruising and tubers disintegrate more readily when cooked. However, for processing high dry matter content is required to achieve a good fry colour. Nitrogen, potassium and magnesium can all have influences on tuber dry matter content. The following table shows the value added products of potatoes and their dry content as well;

Texture end- product	Dry matter content (%)
Fresh	16- 19
French fries	20- 22
Crisps	22- 24
Flakes	>21

6.6.1.4. Frying color

To test the quality of potatoes for processing as French fries a test can be performed which is given below:

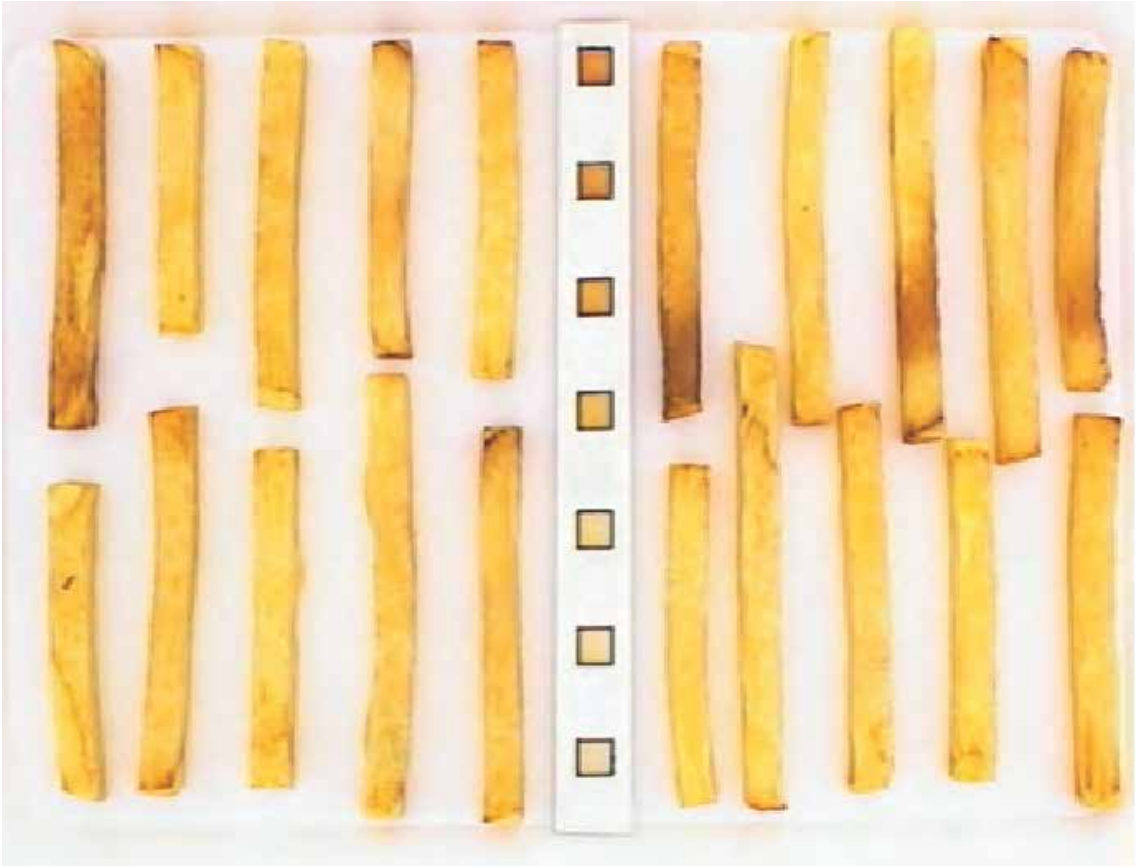


Figure 51: Image analysis with 7 colored squares (Source_ F. Pedreschi et al., 2007)

1. Cut the 20 sticks from the center of 20 tubers.
2. Fry the sticks in the cooking oil for 3½ minutes at 160 °C till final moisture 40-50 %.
3. The color of fried sticks is compared with the color charts.

To check the processing of potatoes as crisps for, a following test can be performed:

1. Fry 50 slices from cut from the center of tubers.
2. Fry to final moisture content 45% at 180 °C (still bubbling like (still bubbling champagne).
3. Compare the result with color charts.

7

Gender Focus in Potato Value Chain

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Women play an active role in almost every sphere of agriculture. In Pakistan, rural women form about half of the total population and an enormous proportion of agricultural labor force. About 70% of the female labor force is engaged in agriculture sector. Women participation contributes 25-45% of labor input in rural economy. Women's share in agriculture or agriculture related activities is 69% compared to 38% for men in these activities. Nearly 36-38% of women work in their own family farm. The aim of the project is to raise awareness of gender issues among stakeholders, addressing these gender gaps strengthens the potato value chain. This leads to an overall increase in potato production to build women's capacity for their roles in the potato production process and to empower women through approaches such as provision of information about access to financial and market opportunities.

7.1 Women in potato value chain

The participation of women in potato value chain ranked higher in the sorting and grading of seed potatoes followed by harvesting in picking and packing of potatoes during and after harvest practices such as value addition.

Figure 52: Role of women in potato seed sorting and grading

Women's roles in the potato value chain are labour intensive, time consuming and earn the women little or no income. Understanding the gender gaps that women face across the potato value chain that affect overall potato production and income is important. This project aims to enhance potato production by strengthening the participation of women in potato value chain processes to in order to promote improved potato yield. The increased capacity in relation to their traditional roles in the cultivation process, ultimately leads to women's increased contribution in farm decisions, addressing gender related gaps in the potato value chain, increased yields, and increased income.

7.2 Key constraints faced by females in Punjab

Female farmers are major contributors in agricultural production in Punjab but have limited access to the land ownership. This limits their capacity to access agriculture finance and to strengthen their involvement in the different parts of the potato value chain that they are involved in. Distribution of time between farm and household chores is a key constraint to their participation. Due to small land holding, women and children have to do intensive labor to make the ends meet.

7.2.1 Visibility and voice

Women play a key role in the rural economy and their participation in agriculture enhances food security. As per the agriculture department Punjab, about 93 percent women in Punjab do not own land, half of them are engaged as farm and family labor. For gender mainstreaming, agricultural policy must need to support and ensure their right to own land and access to other agricultural policies, productive resources and opportunities at farm level such as credit, inputs, links to markets, and agricultural extension services.

7.2.2 Social and cultural norms

In Punjab, there are restrictions on the movement of women, their employment possibilities, participation in spectator parks and access to education which affect the role of women in the society. Women are responsible for domestic work and child rearing. This affects their ability to enter the labour market. Majority of women prefer to stay at home and look after their children. Also, the cultural barriers not only affect the extent to which women actually engage in income generating activities, but also the reporting of activities during the time of labour force surveys or census. Pakistan's culture limits women's participation in paid labour.

7.2.3 Access to and use of agriculture machinery

In central Punjab, most of the agricultural operations like seeding, weeding, harvesting of potatoes, as other post-harvest operations are performed by women manually, in spite of the fact that farm machinery for these tasks is available. They lack access to agricultural equipment to make their work efficient and ease their labour intensive tasks in the potato value chain as they balance household care work and providing labour in potato production. They do not have access to such machinery because, culturally their ability to operate such machines is undermined.

7.2.4 Lack of access to agriculture extension services and social safety nets

In the current set up, extension department is mainly responsible for communicating and transferring important and new information to farmers. Their efficacy is questionable in Punjab where they are very few in number and also have limited extension facilities. Their contribution to uplifting of agricultural production and awareness of women farmers in the use of modern farm machinery, implements and equipment has not been significant and effective. The extension services are not gender inclusive and are more targeted towards men. Women farmers are not allowed to get training from male extension workers due to social norms. Poor and older people including women have limited access to social safety nets, even though women have access to finance through microfinance institutions, majority of these loans are used by the male head of the household.

7.3 Role of the public and private sector

The government has initiated trainings and workshops for women in general, and for women in agriculture. This includes financial literacy and financial management. In 2019, the Ehsaas Program was launched. Under this program,

- Ehsaas Kafaalat Program provides monthly stipend,
- Ehsaas Interest Free Loans program gives the interest free financial assistance and
- Ehsaas Aamdan program to livelihood opportunities to the female beneficiaries. Pakistan Poverty Alleviation Fund (PPAF), is working through its Partner Organizations (POs) through a network of Community Organizations (COs) across rural areas (Union Council UC) specially focusing on women to mobilize, provide technical and vocational training, empower and provide grants/loans for start-up their own business including in agriculture sector.

7.4 Access to finance

Access to finance plays and important role in bringing a change for the better. However, since the women do not have collateral, they do not receive credit from traditional banking system. Even micro-finance banks (like ZTBL, Khushhali Bank etc.) do not consider them worthy to do business. The KashF Foundaion provides micro loans to female workers- and farmers. Although they mainly have (semi-) urban programs, they have also started the rural program NGOs like “Mojaz Foundation” and KashF Foundaion provides micro loans to female workers- and farmers.

7.5 Activity mapping and the identification of gender-based constraints (and design of possible actions to address these)

I. Use this tool

Men and women play different roles and have different responsibilities in the activities involved in a potato production. They face different constraints in accessing and controlling

the resources needed to carry out their activities. These constraints have an impact on the potato value chain, because they can affect yield and quality of the produce. By gaining insight in these different constraints, this tool helps to think of actions to address each of these constraints (and to contribute to a successful potato value chain-upgrading intervention.

II. Benefits

- Insight in the division of work (activities for men, women, youth) within different steps of potato value chain
- Insight in constraints faced by different gender groups in undertaking their activities in different stages of the potato value chain
- Support to define interventions to address these constrains.

III. Application of this tool

It is best used with the small-scale farmers, initially with separate focus groups of men and women, followed by validation with both groups.

IV. Procedure

- This tool can be used to analyze gender-based constraints in a potato value chain, well known by the participants.
- The tool needs at least 20 minutes to fill in; longer if you work with your farmers in separate focus groups (men/women).
- In order to save time, the facilitators can fill in sections pertaining to actors, chain stages and activities prior to using the tool in focus groups.

1. **Identifying the actors in value chain**
   Identify the actors in the different nodes of the value chain Use table 1: “Gender involvement in potato production”.
2. **Activity mapping and degree of responsibility of activities**
   List and analyze activities carried out by the different actors identified in step 1 and mark who is responsible (male and female)
3. **Identify constraints per activity**
   Identify constraints faced per activity for male and female that limit access and control of resources to carry out the activity.
4. **Analyze the constraints**
   Fill in table 2: “Production constraints”. Take over the identified constraints and put them in column 1.
   Analyze the effect in terms of the rating of the constraints faced by the male and female farmers and agriculture labour (column 2).

Table of Gender involvement in potato production

Sr. No.	Crop management activities	B1. Who perform the activity		B2. Gender involvoment (specify field operations)		
		Family labour = 1	Family labour = 2	Male = 1	Female = 2	Both = 3
A1.	Land preparation					
A2.	Variety selection					
A3.	Seed treatment					
A4.	Seed sorting and grading					
A5.	Seed sowing					
A6.	Fertilizer application					
A7.	Manual Weeding					
A8.	Weedicide application					
A9.	Earthing up					
A10.	Irrigation					
A11.	Spraying insecticides and pesticides					
A12.	Haulm destruction					
A13.	Harvesting/Picking/ digging					
A14.	Drying					
A15.	Sorting					
A16.	Grading					
A17.	Packing					
A18.	Loading/ Unloading					
A19.	Storage					
A20.	Marketing/Selling					
A21.	Financial (borrowing/ lending)					
A22.	Others (Specify)					

V. Production constraints

How often do the following constraints/challenges affect your crop production? Please rate each constraint on the scale of 1-5.

Sr. No.	Constraints/Challenges	Rating				
		Strongly disagree	Disagree	Unde-cided	Agree	Strongly agree
C1.	Inadequate availability of good quality local seed	1	2	3	4	5
C2.	Inadequate availability of good quality imported seed	1	2	3	4	5
C3.	Health hazards during seed treatment	1	2	3	4	5
C4.	Less daily wages	1	2	3	4	5
C5.	Lack of decision making	1	2	3	4	5
C6.	Inadequate availability and poor quality of water	1	2	3	4	5
C7.	Inadequate availability of labour	1	2	3	4	5
C8.	Insects Pests and disease attack	1	2	3	4	5
C9.	Safe spraying techniques	1	2	3	4	5
C10.	Lack of storage facilities	1	2	3	4	5
C11.	Lack of access to technical information	1	2	3	4	5
C12.	Lack of extension services	1	2	3	4	5
C13.	Lack of access to agricultural implements	1	2	3	4	5
C14.	Limited access of land ownership	1	2	3	4	5
C15.	Inadequate access to social safety nets	1	2	3	4	5
C16.	Other	1	2	3	4	5

VI. Formulate possible interventions to address the constraints

Identify potential interventions pertaining to the factors causing the gender-based constraints.

7.6 Gender focus in the capacity building project

The project will address gender specifically through the following points:

- One of the seven training modules for CABI Trainers is devoted to gender.
- Ensure gender balance in participation at the different stages of the Training of Trainers program.
- Understanding the gender gaps that women face across the potato value chain that affect overall potato production.
- For the extension activities, separate training sessions and visits of the demonstration plots and field days will be organized for men and women, and extension materials produced for this project will address gender to raise awareness and sensitize farmers and other stakeholders.
- Women will be motivated to participate in trainings and also apply practices in their fields.
- Women could also be empowered through information on financial and market opportunities.
- The project encourages mutual decision making between head of family and spouse in a household, and will highlight the potential benefits for overall potato production.

8

Communication

KNOWLEDGE FOR LIFE

Exchange of ideas, facts or feelings between two or more people in ways that each gains a common understanding of the meaning is called communication. In agricultural context, it involves purposeful and collaborative interaction between farmers and extension field staff with the purpose to uplift the living standard of farmers through increased farm production and improved farm income.

8.1 Elements of communication

I. Communicator

Extension agent is the communicator who starts the process of communication.

II. Message

The recommendations from the research, the technology, constitute the content or subject matter of the message.

III. Channel

Channel of communication constitutes the medium through which information flows from the sender to the receiver.

IV. Treatment and presentation

Treatment means the way a message is processed so that the information gets across the intended audience. Presentation means how the message is communicated or placed before the audience.

V. Audience

An audience may consist of a single person or a number of persons who receive the message. An audience may be formed according to occupation groups such as crop farmers, fruit farmers, dairymen, fish farmers etc.

VI. Feedback/audience response

Response of the audience to the message of the source is the ultimate objective of any communication. Feedback is mirror of communication. Response of an audience to messages received may be in the form of some kind of action, mental or physical. Until the desired actions are received, extension communication does not achieve its most essential objective.

8.2 Qualities of an extension worker

Some of the qualities of a good extension worker are;

- Facilitator
- Good communicator
- Motivator
- Helper
- Coordinator
- Good manager
- Technical Knowledge
- Administrator
- Appreciator
- Creative
- Mature
- Character
- Planner
- Motivator
- Responsible

8.3 Characteristics of extension

Some features of the extensional services are;

- Cooperative
- Educational
- Teaching oriented
- Informal
- Flexible
- Broad in scope
- Family centered
- Voluntary

8.4 Principles of extension teaching

The principles of the good extension teaching are described below;

- It should be according to democratic procedure
- Be according to local conditions
- Should be based on felt needs
- Beneficial for maximum number of learners
- According to the principles of helping people to help themselves
- Give importance to the feedback of learners
- Motivation for betterment
- Organize people for improvement of living style, environment and economy
- Be clear to everyone

8.5 Role of extension workers

The following are the few important roles of the extension workers;

- Conduct survey
- Use most appropriate extension methods
- Create group leadership
- Improve rural life
- Propagate improved practices and methods
- Organize people
- Impart knowledge in rural masses
- Act as a catalyst in the change process
- Introduce desired changes in behavior of people
- Teaches needed skills
- Help in social mobilizations
- Demonstration/Meetings
- Gender awareness and the use of gender sensitive intervention approaches

8.6 Types of demonstration

There are two types of demonstration, method demonstration and result demonstration. Method demonstration is a short time demonstration given before a group to show how to do a certain practice. In result demonstration the results of a new method are compared with the results of the traditional method and thus the superiority of the new method is proved and established. The following points should be kept in mind while conducting demonstration/meetings/training

- Specific purpose of demonstration is that the extension worker should be very clear about what he/she wants to achieve through demonstration.
- Visiting the demonstration site prior to actual conducting of demonstration to be sure that everything is properly arranged.
- Duration should be decided keeping in view the convenience of farmers.
- Venue should be suitable for demonstration.
- Material and equipment needed for demonstration would be available as and when needed.
- Training should be planned by involving local leadership/organization.
- Appropriate selection of the demonstrator is very important. A co-operative and resourceful farmer who actively participates in extension activities. He must have a good piece of land preferably on roadside where maximum farmers could easily come and see the demonstration.
- Other agricultural allied agencies related with learning; provision of inputs can also be involved.
- Proper publicity should be made in advance to inform the people about demonstration meetings.
- Regular supervision of the demonstration is mandatory for maintaining the interest of the demonstrator and to check the progress.

- The trainers must ensure all the facilities like sitting, drinking water, print material, audio-visual aids are available at meeting venue.
- The meeting should not be arranged at open place.
- Keeping the complete record of cost and return data with regard to both improved and traditional practices to be used as a reference at the time of comparison between the two practices.
- Ensuring maximum gathering at different stages when the comparison is to be made between the old and new practices through holding meetings of farmers at demonstration site.
- Taking pictures, summarizing the main conclusions and publishing the results.
- Making follow up visits to those who have shown some interest in the improved/new practices demonstrated.

8.7 Cone of experience

There is a linkage between learning, activity and participant involvement. According to this Dale's cone of experience it is tended that 10% was remembered what we read, 20% of what we hear, 30% of what we see, 50% of what we hear and see, 70% of what we say and 90% of what we both say and do.

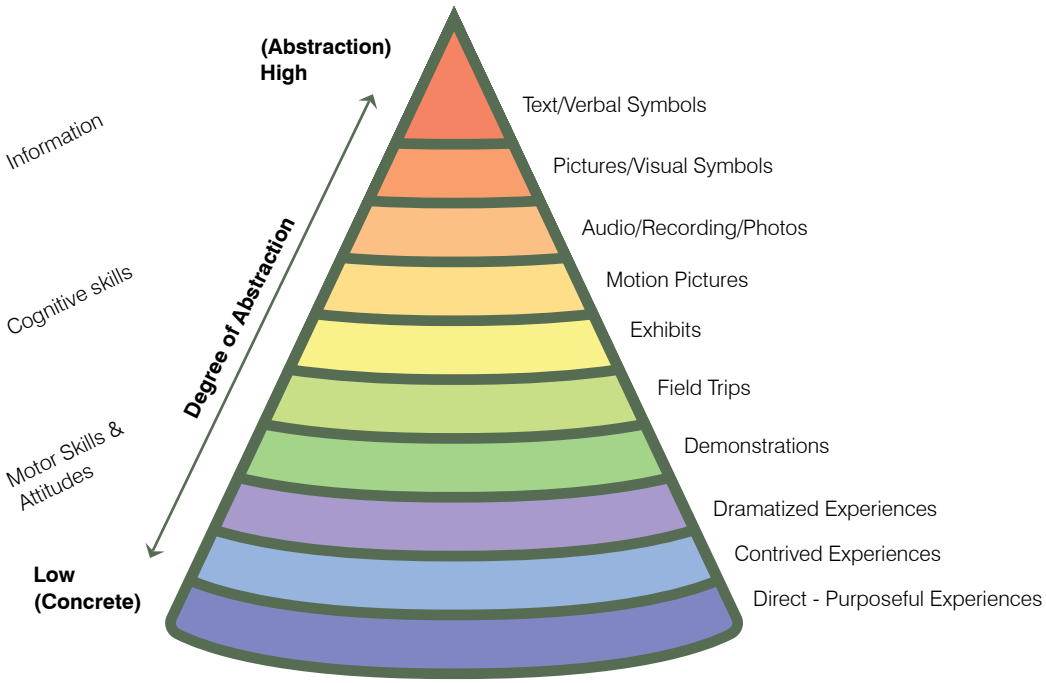

Figure 53: Cone of experience (Source: Edward L. Counts Jr.)

8.8 Audio-Visual aids

These are instructional devices which are used to communicate messages more effectively through sound and visuals. These aids are classified in to three categories: Visual Aids, Audio Aids and Audio-Visual Aids

8.8.1 Visual Aids

- White or black board
- Photographs
- Exhibitions
- Posters
- Graphs representing data
- Handouts/Leaflets/Books

8.8.2 Audio aids

- Record player with discs to paly
- Tape recorder
- Radio
- Telephone
- Public address equipment
- Microphone
- Loudspeaker
- Headphone

III. Audio-Visual aids

- Television
- LED
- Multimedia
- Smartphone

8.9 Adult learning

The process of bringing desirable or positive change in the behavior of adults. It refers to non-formal education for being out of school education. It includes all activities with an educational purpose undertaken by mature people who use part of their time and energy to acquire useful knowledge. Through adult education programs we can provide organized learning opportunities to adults who intend to develop themselves and their communities. The principles of adult learning are:

- Strong desire to learn
- Adults learn best when they like and trust the teacher
- Adults learn best when they understand what is being taught
- Adults learn best when the lesson is presented in a variety of ways
- Adults learn best when they actively take part in the learning activity
- Adults learn best when they practice until they acquire the necessary degree of skill

- Adults learn best when they receive satisfaction from what is being taught
- Adults learn best just before they have an opportunity to use new knowledge or skill
- Adults learn best from their reciprocal colleagues
- Adults learn best when no other urgent task is immediately pressing

8.10 Communication channels

Communication and knowledge are very vital in adoption of innovations but where these are poorly disseminated as a result of poor delivery, agricultural production becomes highly impeded. Communication channels are need to be gender sensitive in order to communicate to both male and female farmers and actors in the potato value chain. Communication channels to be used between master trainers and farmers on the adaptation of the potato farming.

8.10.1 Mass media communication

Mass media are essential ingredients needed for effective transfer of technologies that are designed to boost agricultural production. Mass media will be used to disseminate extension information on potato production i.e., Social networking, mobile phone, Posters, brochures and leaflets. Production and distribution of printed material helps farmers in the transfer of new information and technologies. Printing helps in preserving the technologies in the form of books/booklets, magazines, newspapers and brochures.

8.10.2 Interpersonal communication

Extension officers used farmer schools, seminars, meetings, home and farm visits, fellow farmers, field days, phone calls and demonstrations to convey messages. Seminars and mobile phone calls are also used to disseminate information to group leaders of farmers or contact farmers who in turn passed across the message(s) to their members. Demonstrations were used to teach good agricultural practices and they were carried out in progressive farmers' farms.

8.10.3 Most preferred communication channels

The most preferred channels of communicating information on the potato production practices for the project are farmers school, demonstrations, field days, meetings and brochures. All farmers asserted that all face-to-face communication channels were good because they will be able to ask questions and get instant clarification from the trainers. Some farmers also think that demonstrations are good because they are able to imitate what we see the trainers doing. There is a lot of practical work in demonstrations so the farmers practice what they have learned in their training sessions. Another aspect of the training is to raise awareness of the master trainers about gender fair training approaches, and communication. We will use a combination of many channels to get the message across to as many farmers as possible.

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