1. INTRODUCTION

Over the years, potato has become an important crop for both farmers and consumers in Pakistan. It is the fourth most important crop by volume of production and it gives high yields and high returns to farmers. Potato having a high nutritive value and these contributes more protein and iron than other vegetables in the average diet and are also useful sources of thiamine, niacin and several other nutrients including fiber. Almost 86% of potato area and production of Pakistan is achieved from Punjab i.e. Okara, Sahiwal, Kasur, Sialkot, Sheikhupura, Jhang, Narowal, Pak pattan, Gujranwala, T.T Singh, Khanewal and Lahore. Remaining share is produced by KPK 9%, Baluchistan 4.5% and Sindh 0.5%.

Pakistan is self-sufficient in potatoes for household consumption and relies for more than 99% on locally produced seed potatoes. Presently, it is estimated that the total annual domestic production amounts to around 2.02 Million MT of which 280000 MT is used as seed and 1.7 Million MT is available for consumption after post harvest losses. With a population of roughly 150 Million, this accounts to 11 Kg per Capita per annum.
Provincial Shares in Area and production

Punjab, Sindh, KPK and Baluchistan respectively account for 86, 0.5, 9 and 4.5 percent of the total area and 88.3, 0.3, 7.2 and 4.2 percent of the production of potatoes in the country.

The shares of autumn, spring and summer crops in the annual production are estimated at 75, 10 and 15 percent, respectively.

Important Potato Growing Districts of Pakistan

**Punjab:** Okara, Sahiwal, Kasur, Sialkot, Sheikhupura, Jhang, Lahore, Narowal, Pak pattan, Gujranwala, T.T. Singh and Khanewal.

**KPK:** Nowshera, Dir, Swat, Balakot, Sakardu and Mansehra.

**Baluchistan:** Pishin, Killa Saifulla and Kalat.

**Gilgit Bultistan:** Gilgit

These are the important potato growing districts, accounting among themselves for 78 percent of the total production of the crop.

2. **NUTRICIUOS VALUE**

Potato is a tasty, nutritive and highly digestible vegetable with 75 percent water contents. One hundred grams of potato possesses 22g carbohydrate, two gram protein, 90 kilocalories energy, 13mg calcium, 17mg vitamin C, 11mg riboflavin 1.2 mg niacin and traces of certain other minerals and fiber. Potato is eaten intensively in a variety of forms such as boiled, baked, and cooked. As vegetable it is eaten alone as well as mixed with other vegetables and as snacks, the most popular of them being the finger chips. It has medical significance also.

3. **GROWTH STAGES**

a. **Sprout Development**

- Sprout development from eyes on seed tubers and grow upward to emerge from the soil.
- Roots begin to develop at the base of emerging sprout.

b. **Vegetative Growth**

- Leaves and branch stems develop from aboveground nodes along emerged sprouts.
- Roots and stolons develop at below ground nodes.
- Photosynthesis begins.
c. Tuber Initiation

- Tubers form at stolon tips but are not yet appreciably enlarging.
- In most cultivars the end of this stage coincides with early flowering.


d. Tuber Initiation

- Tuber cells expand with the accumulation of water, nutrients and carbohydrates.
- Tuber becomes the dominant site for deposition of carbohydrates and mobile inorganic nutrients.


e. Maturation

- Vines turn yellow and lose leaves, photosynthesis decreases tuber growth slows and vines eventually die.
- Tubers dry matter content reaches a maximum and tuber skins set.

4. CLIMATE

Potato is grown under temperate, subtropical and tropical conditions. It is essentially a "cool weather crop", with temperature being the main limiting factor on production. Optimum temperature for germination, vegetative growth and tuber formation in potato is 25°C, 20°C and 16-24°C respectively. Tuber growth is sharply inhibited in temperatures below 10°C (50°F) and above 30°C (86°F); while optimum yields are obtained where mean daily temperatures are in the 18 to 20°C (64 to 68°F) range.
5. VARIETIES
Red and white skin potato varieties are cultivated in the country. The white skin varieties are Santé, Multa, Diamant, Hermes, Lady Rosetta, Ajax and Patrones while the red skin varieties include Lala Faisal, Ultimas, Desiree, Cardinal, SH – 5, Kuroda, Oscar and Symphonia.

6. SOIL
The potato can be grown almost on any type of soil except saline and alkaline 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. Soil with a pH range of 5.2-6.4 is considered ideal.

To prevent the build-up of pathogens in the soil, farmers avoid growing potato on the same land from year to year. Instead they grow potato in rotations of three or more years, alternating with other dissimilar crops such as maize, beans and alfalfa.

7. LAND PREPARATION
Potato is propagated vegetatively. Well decomposed farm yard manure at 200-250 maunds per acre is recommended to be incorporated in the soil before land preparation. Field is given a soaking irrigation nearly two weeks before sowing to provide seed tubers with ample moisture for germination.

Good water penetration and aeration is must for proper growth and tuber formation. Excessive tillage and land preparation causes compaction and should be avoided. To be effective the soil should be plowed below any compacted layer within the normal root zone and then disk harrowed before planting. Spike-tooth harrowing to break clods and level the soil may be needed just prior to planting.

8. SOWING METHOD
For autumn and summer sowing potatoes complete potato is used. Potato tubers about one week before sowing are taken out from cold storage and spread at a cool and ventilated place usually under the shade of a tree. It starts bud development in 7-9 days and is sown when the
sprouts are 1cm long. Potato seed remains dormant for 12 – 16 weeks so the tubers obtained from autumn crop and spring crop tubers is not used. Seed tubers are treated with fungicides like dithane-M, captan or Benlate to protect them from fungal infections.

Potato tubers can be planted either on flat beds, in the furrows or on the ridges; however ridge sowing is the most preferred method. Ridges are 30cm high and 60cm wide. Ridges are marked at 2 to 2.5 feet apart and the seed tubers are kept at 6 – 7 inches distance and at the end, the ridges are made using a tractor drawn ridger to cover the seed with soil. Potato accomplishes its growth very speedily and has high nutrient requirements.

There are several types of planters available that place the seeds in the soil and apply fertilizer and systemic insecticides in one operation. Seed depth should be about 4 inches below the top of the planted bed. Soil is ridged over the row by throwing soil to the plants during early cultivation, so that about 6 inches of soil cover the seed tuber when tuber formation occurs.

For spring sowing potatoes tuber can be cut into pieces before sowing but the weight of each piece must be nearly 50g possessing 2-3 eyes. However, the cut pieces are more vulnerable to diseases. Sowing of sprouted seed is preferred which results in higher yields than the un-sprouted ones.

9. SEED AND SEED RATE

The seed contributes about 35-40% of the total cost of production in Pakistan. Formal certified seed production is limited and faces technical, economical and managerial problems. Lack of availability of sufficient quantities of good seed and low purchasing power of the farmers, forces them to rely on seed sources of doubtful quality or own production for which most of them do not have the proper skills.

For acquiring optimal potato yield certified, healthy, vigorous and disease-free seed tubers are indispensable. Seed tubers must be of uniform size and shape without any sign of infection. Use only certified seed tubers. Seed required to plant an acre depends upon seed size and seed spacing. Potato seed tubers required 25 – 35 maunds per acre and it should be medium in size.
10. PLANTING TIME

Potatoes are easy to grow, but they prefer cool weather so you should try to get them into the ground at the right time. The time for plantation of autumn crop, which contributes more than 70% of the total yield, starts in early October and ends in mid-November. Spring crop contributing less than 10% to the total yield, can be sown from mid-December to mid-February while the summer crop contributing more than 15% is sown in early April up to mid-May.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Time of sowing</th>
<th>Crop Season</th>
<th>Time of harvesting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Indus Plan</td>
<td>Mid to late January</td>
<td>Spring</td>
<td>April /May</td>
</tr>
<tr>
<td></td>
<td>Half of September</td>
<td>Autumn</td>
<td>January</td>
</tr>
<tr>
<td></td>
<td>August (F. Abad)</td>
<td>Autumn</td>
<td>November</td>
</tr>
<tr>
<td>Baluchistan</td>
<td>March to June</td>
<td>Summer</td>
<td>November</td>
</tr>
<tr>
<td>Northern Mountains</td>
<td>April /May</td>
<td>Hilly crop</td>
<td>Sept/Oct</td>
</tr>
<tr>
<td></td>
<td>February</td>
<td>Spring</td>
<td>June</td>
</tr>
<tr>
<td></td>
<td>August</td>
<td>Autumn</td>
<td>November</td>
</tr>
<tr>
<td></td>
<td>September</td>
<td>Autumn</td>
<td>December</td>
</tr>
<tr>
<td>Lower Indus Plan</td>
<td>Mid October</td>
<td>Autumn</td>
<td>January/February</td>
</tr>
</tbody>
</table>

11. IRRIGATION

**Pre-irrigation:** Before planting for the Punjab autumn crop, pre-irrigations may be required twice. The first one is required about 15 to 20 days before planting. It will allow annual weeds to germinate. Soil preparation should resume some 7 – 10 days after the first pre-irrigation. If there have been rains in this period and the soil is humid, this irrigation may not be required. The break in soil is still essential.

The second pre-irrigation should be applied about 3 – 4 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 germination.
After-Planting Irrigation

Soil moisture is probably the most important factor determining potato yield and quality. About 15 – 20 inches of water is needed with center pivot irrigation system to produce a potato crop in Pakistan. When irrigation is practiced to supplement rainfall it should be applied in frequent light amounts. Secondary growth and growth cracks occur when irrigation or rainfall occurs after moisture stress. The soil should be kept uniformly moist until tubers have reached full size. For irrigation management decisions:

- The effective rooting depth of potatoes is two feet.
- The soil should not be allowed to dry below 65% of field capacity.
- Moisture levels above field capacity will seriously affect yield and quality.

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.

**Typical Potato Crop Irrigation Schedule Naushero Feroz Sindh Pakistan**

<table>
<thead>
<tr>
<th></th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET0</td>
<td>4.9</td>
<td>3.3</td>
<td>2.7</td>
<td>2.8</td>
<td>3.7</td>
<td>5.1</td>
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<tr>
<td>Kc</td>
<td>0.5</td>
<td>0.9</td>
<td>1.15</td>
<td>0.95</td>
<td>0.75</td>
<td>0.6</td>
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<tr>
<td>ET mm</td>
<td>2.45</td>
<td>2.97</td>
<td>3.10</td>
<td>2.66</td>
<td>2.77</td>
<td>3.06</td>
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<tr>
<td>Days</td>
<td>15</td>
<td>30</td>
<td>31</td>
<td>31</td>
<td>28</td>
<td>15</td>
</tr>
<tr>
<td>ET for the period mm</td>
<td>37</td>
<td>89</td>
<td>96</td>
<td>82</td>
<td>78</td>
<td>46</td>
</tr>
<tr>
<td>Precipitation for the period</td>
<td>3</td>
<td>2</td>
<td>8</td>
<td>12</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Net CWR in mm</td>
<td>34</td>
<td>87</td>
<td>88</td>
<td>70</td>
<td>60</td>
<td>29</td>
</tr>
</tbody>
</table>

**12. FERTILIZER**

Well decomposed farm yard manure at 200 – 250 maunds per acre is recommended to be incorporated in the soil before land preparation.

Recommended NPK per acre is three bags of urea, 2 bags of DAP and one bag of SOP 50kg. All DAP & SOP is broadcasted at the time of 2nd pre-irrigation to easily dissolve in the soil. Urea is applied in different splits through fertigation system from 25 – 65 days after sowing. Contact between fertilizer and seed is avoided as it results in deterioration of seed tubers. Zinc sulphate 10kg bag 25% is also necessary to cure zinc deficiency.
13. DISEASES

The Potato crop in Pakistan is affected by many pests and diseases. From these diseases potato viruses, powdery scab, potato cyst nematode, aphids and white grub are the most damaging ones. Surveys done by Pakistani workers have revealed that viruses, powdery scab and aphids are widespread, white grub are serious problems in the northern hilly areas.

a. FUNGAL DISEASES

I. Black Scurf (Rhizoctonia solani)

Black Scurf is a fungal disease of potatoes and is caused by Rhizoctonia solani. It is usually found as irregular, black, scab-like marks on the skin of the tubers. They are easily scraped off with a fingernail and this releases a distinctive ‘fungal’ smell. These black masses are the resting phase of the organism and are made up of compacted mycelia, called sclerotia. They do not spoil the flesh of the tubers and they are still edible; also the sclerotia do not become any larger during storage.

II. Late blight

Late blight is caused by the fungus Phytophthora infestans. Unlike most pathogenic fungi, the late blight fungus cannot survive in soil or dead plant debris. It is a serious disease and found major yield limiting factor in high hills and is also a serious problem in plains; it may reduce the yield up to 70%. Usually no symptoms appear before the month of December.
Symptoms:
Late blight appears on potato leaves as pale green, water-soaked spots, often beginning at leaf tips or edges. The circular or irregular leaf lesions are often surrounded by a pale, yellowish-green border that merges with healthy tissue. Lesions enlarge rapidly and turn dark brown to purplish-black. During periods of high humidity and leaf wetness, a cottony, white mold growth is usually visible on lower leaf surfaces at the edges of lesions. In dry weather, infected leaf tissues quickly dry up and the white mold growth disappears. Infected areas on stems appear brown to black and entire vines may be killed in a short time when moist weather persists.

III. Early blight
Early blight is caused by the fungus Alternaria solani, which survives in infected leaf or on stem tissues or in the soil. This fungus is universally present in fields where Potatoes and tomatoes have been grown. It can also be carried on tomato seed and in potato tubers.

Symptoms:
On leaves of both crops, the first symptoms usually appear on older leaves and consist of small, irregular, dark brown to black, dead spots ranging in size from a pinpoint to 1/2 inch in diameter. As the spots enlarge, concentric rings may form as a result of irregular growth patterns by the organism in the leaf tissue. This gives the lesion a characteristic "target-spot" or "bull's eye" appearance. There is often a narrow, yellow halo around each spot and lesions are usually bordered by veins. When spots are numerous, they may grow together, causing infected leaves to turn yellow and die. Usually the oldest leaves become infected first and they dry up and drop from the plant as the disease progresses up the main stem.
IV. **Powdery scab or Soil borne disease**

Powdery scab of potato is caused by Spongospora subterranea. Potato cultivars that are susceptible to the disease present sponge-like galls on the roots, stolons and scabby lesions on the tubers. Potato plants that are infected with the pathogen develop necrotic and deformed roots, which may affect plant vigor. The reduction of plant vigor can potentially influence the development of large tubers that are needed for processing.

**Symptoms:** of this disease are confined to below ground parts of the potato plant. Infected roots and stolons may have white gall-like growths, which turn brown as they mature. These galls are the enlargement and proliferation of infected cells. It can occasionally attack other species of Solanum (black nightshade, eggplant) but does usually not produce resistant spores on these plants.

**Recommended Control Measures for Fungal Diseases**

- Wet poorly drained areas should be avoided for potato cultivation.
- Use disease free seed combined with seed treatment with benomyl.
- Seed should be planted on raised beds and in well-drained soil to encourage fast growth of the seedlings.
Harvest the crop as soon as the tubers are mature, which can reduce the number of sclerotia on tubers.

- Apply boric acid before storage.
- Destroy and burn the plant debris before sowing.
- Harvest carefully to avoid bruises and injuries to potato tubers.

**b. Diseases caused by Bacteria**

- Bacterial wilt Ralstonia (Pseudomonas) solanacearum
- Black leg and soft rot (Erwinia carotovora spp. carotovora and carotovora spp. Atroseptica)
- Common scab (Streptomyces scabies)

**Recommended Control Measures for Bacterial Diseases**

**i. Preventative Measures**

- Use of healthy seed tubers and Cultivation in un-infested fields.
- Destruction of diseased plant debris.
- Cultural practices to stop spread.
- Long rotation and Destruction of host plants etc.

**ii. Curative measures**

- Disinfection of seed tubers.
- Spray.

**c. Diseases Caused by Viruses**

- Potato leaf roll virus, Potato mop top virus and Phytoplasma
- Potato virus A
- Potato virus M
- Potato virus S
- Potato virus X
- Potato virus Y

**Recommended Control Measures for Viral Diseases**

- Use virus free, certified seed potato
- Control the aphid vector and use resistant varieties
- Rouging and Heat treatment of tubers
- Modification of cropping procedure
- Chemical control of vector (Insects, nematodes and fungi)
- Non-chemical control of vectors (barriers and reflective mulches, oil sprays, biological control by predators)
- Assess the health of tuber stocks by serological tests through ELISA, after harvest
d. **Diseases Caused by Nematodes**
   - Potato cyst nematode
   - Root knot nematode (Meloidogyne spp.)

**Recommended Control Measures for Nematodes**
   - Nematodes cyst on root can be observed at flowering stage.
   - Soil analysis for extraction of cyst also provides an excellent mean of diagnosis.
   - Use of resistant and tolerant varieties.

e. **Diseases with Mycoplasma Pathogens:**
   Mycoplasma was found a serious problem in major potato growing areas of Punjab and 45% reduction in yield was recorded in research trials.

**Cultural Control**

Pests cause direct damage to tubers, stems and leaves, sometimes transmit diseases and often interfere with the rouging operation. Potato diseases are often transmitted through the seed tubers to the next crop. Their control in seed potato multiplications is therefore essential.

There is no chemical control for bacterial and viral diseases but they can be controlled by regular monitoring (and when necessary, spraying) of their aphid vectors.

Recommended control measures include regular monitoring and steps to protect the pest’s natural enemies. Even damage caused by the Potato Beetle, a major pest, can be reduced by destroying beetles, eggs and larvae that appear early in the season, while sanitation, crop rotations and use of resistant potato varieties help prevent the spread of nematodes.

Neem extract two per cent solution is effective to control aphids and jassids in potato crop. Cutworms incise young potato plants at ground level and feed on tubers.

They get suppressed by flooding of the field. Moreover, application of carbafuron 3G at 10 Kg per acre controls cutworms and leaf hoppers in potato.

**14. WEEDS**

Weeds 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 per cent losses of the crop.
Weed Control

Weeds should be controlled in potato fields, since they cause many problems besides being hosts for insects and diseases. An effective weed control program takes into account the weed problem, cultivation, and herbicides. Fields containing perennial weeds should be avoided. When herbicides are used, the choice of which one or ones to use should be tailored to the specific weeds problems and when these weeds germinate. Methods of application vary from pre-plant incorporation, post-plant and pre-emergence, to post-emergence applications. Pre-emergence application of either of the herbicides Glyphosate (Roundup) or Gramoxone effectively control potato weeds.

15. HARVESTING

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. 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.

Poor post-harvest handling, including transport and storage practices, causes unnecessary damage and losses and reduction of consumption quality. Sufficient cold store space is available in Pakistan. The handling of potatoes in storage is unsatisfactory and poorly managed. Finally, the farmers and consumers are faced with serve cyclical fluctuations in price, as production moves from glut to shortage, so preventing the farmers from enjoying a reliable income and inhibiting the consumer from including potato as a regular staple part in his diet.

16. Yield

The average yield of potato is 20-30 tons/ha, however it depends upon the variety, cultural practices, and location.
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AGRONOMY