Water Management in Potato Production

Anton J. Haverkort

Furrow irrigation

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International Potato Center
Apartado 5969
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Cable: CIPAPA-Lima
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Water Management in Potato Production

Objectives. Study of this bulletin should enable you to:

- discuss the importance of water for potato growth,
- explain relationships of plants, water and soil,
- explain possibilities and limits of water management without irrigation,
- describe irrigation methods, especially furrow irrigation,
- discuss principles of water supply (frequency and quantity),
- calculate water supply.

Study materials.

- A turgid and a slightly wilting potato plant.
- Potato plant including root system and tubers from an over-watered field.
- Deformed tubers resulting from excessive variation in soil moisture.
- Evaporation pan.
- Slides of different irrigation systems.
- Tensiometer.
- Examples of data necessary for calculating water supply (see section 9).

Practicum.

- Install and monitor an evaporation pan.
- Calculate ETP from Emax readings and crop coverage in different potato fields.
- Calculate drought limit assuming 20% available moisture.
- Practice and discuss furrow irrigation in the field.
- Estimate quantity of water supply with siphon or auxiliary supply channel irrigation in the field.
- Determine moisture status in fields utilizing the field guide table 7.1 or a tensiometer.
- Calculate water supply for a typical soil of your region according to section 9.

Questionnaire.

1. How much water does a well growing potato plant need per growing season?
2. For which functions is water necessary within the plant?
3. Why is the potato plant specifically sensitive to lack or excess of water?
4. How does soil moisture influence soil temperature?
5. Which are the indirect effects of drought?
6. What are the dangers of excess of water?
7. What are the effects of excessive variation in soil moisture?
8. What is Emax?
9. How is ETP determined?
10. On what else depends transpiration other than Emax?
11. What is the relationship between stomata aperture and potato yield?
12. What is saturation (of soils)?
13. What is drought limit?
14. List dryland potato cultural practices.
15. Under dryland conditions why should you use late potato varieties?
16. On which factor depends furrow length in furrow irrigation?
17. Discuss limits of furrow slope.
18. Describe how to determine manually the stage when the drought limit is reached.
19. How should the water status of soil be during potato germination?
20. With which water management can you stimulate deep root growth?
21. Why should soil be kept moist (not wet!) between crop maturity and harvest?
22. Which components determine water quality?

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Water Management in Potato Production

1 Introduction.
2 Importance of water.
3 Plant, water, soil relationship.
4 Water management without irrigation.
5 Irrigation methods.
6 Furrow irrigation.
7 Water supply.
8 Quality of irrigation water.
9 How to calculate water supply (example).
10 Additional reading.

1 INTRODUCTION.

Water is an important factor in potato cultivation. A good potato crop requires 400 to 800 mm of water, depending on climatic conditions and length of growing season. At a plant population of 40 000 plants per hectare, this corresponds to 100 to 200 liters of water per plant per growing season. Both natural rainfall and irrigation may provide water. Correct water management provides sufficient water for potato growth and avoids excessive loss or waste of water.

2 IMPORTANCE OF WATER.

Water, a major requirement for growth, is necessary within the plant for

- photosynthesis, respiration and other plant physiological functions,
- transport of minerals and photosynthetic products,
- turgidity of plant cells,
- transpiration and regulation of leaf temperature.

Compared to many other crops, the potato plant is sensitive to both lack of and an excess of water:

- Potato's relatively shallow root system limits the so-called *effective root zone* to 50 to 80 cm soil depth.
- The root system is weak and cannot penetrate compacted soil. This reduces the effective root zone even more.
- Root penetration may be restricted when the pH of the different layers in the soil profile vary.
- The suction power of potato roots is relatively low. Additionally, efficiency of roots may be affected by diseases and pests.
- The stomata of potato leaves close quickly upon lack of humidity. Stomatal closure leads to reduced transpiration and photosynthesis, heating of leaves, and subsequent reduced yield.

Lack of water. Lack of water is the most common stress. The potato does not compensate for drought periods by prolonged growth. Even a short period of drought affects the yield, especially after tuber initiation.

Dry soil causes reduction in number of stems. In a dry and cloddy soil only sprouts that have access to water develop.

At the beginning of tuber formation, drought favors attack by *Streptomyces scabies* (common scab). At later stages, drought cracks in soil favor tuber infestation by insects, especially tuber moth.

Drought influences yield directly by restricting transpiration and photosynthesis. Indirectly it leads to reduced evaporation from soil and leaves, increasing soil and plant temperature. High temperature is unfavorable for tuber initiation. Drought also contributes to physiological tuber defects, such as internal brown spot, especially later in the season when foliage is dead and soil exposed to the sun.

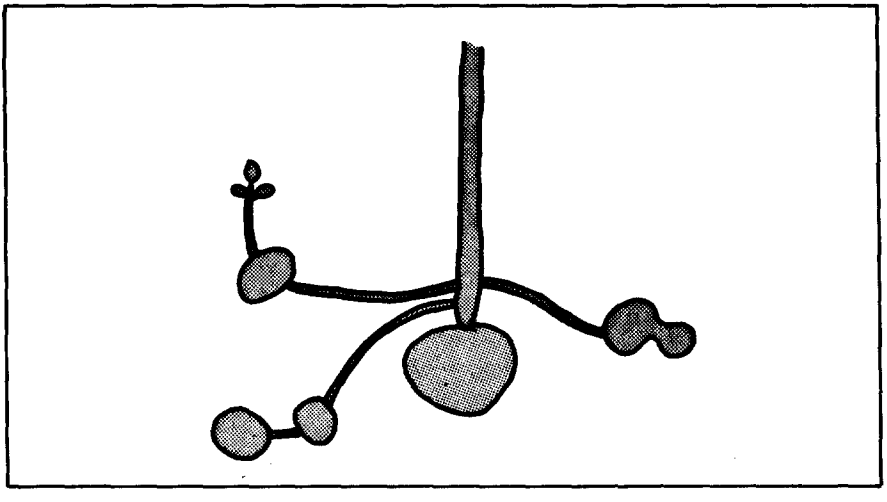
Dry soils form clods that make soil and crop management difficult and cause tuber damage at harvest.

Excess of water. Excess water may be caused by heavy rainfall, heavy irrigation, or inefficient drainage.

Too much water prevents oxygen from reaching underground parts of the potato plant resulting in poor root development and rotting of the newly formed tubers. Seed tubers are especially susceptible to tuber rot. Over-irrigation shortly after planting may reduce emergence because of excessive growth of lenticels which allows entrance of parasites. Over-irrigation also may cause tuber rot before harvest.

High moisture favors development of late blight (*Phytophthora infestans*). Excess water results in waste due to percolation or surface run-off. It also increases erosion.

Variation of soil moisture. Excessive variation in soil moisture affects tuber quality. Water after a prolonged drought may cause second growth. Tubers form bottle neck-like or knobby shapes and may crack. New haulm growth may be at the expense of tuber yield. A re-starting of tuberization results in formation of many small tubers.



Variation of soil moisture may initiate second growth, which results in bottle-neck-like or knobby tuber shapes.

3 PLANT, WATER, SOIL RELATIONSHIP.

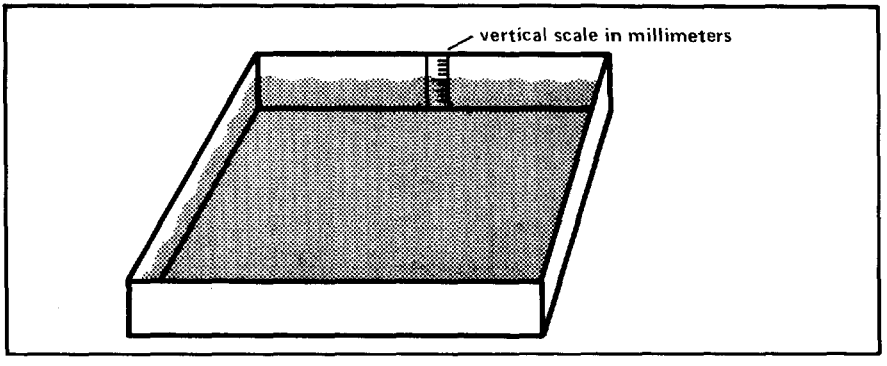
Water moves from the soil, through the plant, into the atmosphere. All three systems – atmosphere, plant and soil – interact closely.

Atmospheric conditions. Apart from stomatal opening, transpiration of water from a plant into the atmosphere depends on the *maximum evapotranspiration rate* (Emax) of the crop. This can be measured with an *evaporation pan*, consisting of an open tray or pan containing water and a vertical millimeter scale. Actual *evapotranspiration* (ETP), however, is determined by how much of the soil area is shadowed by leaves of the growing plant. ETP is obtained by multiplying Emax with a factor f for soil coverage:

$$ETP = Emax \times f.$$

TABLE 3.1. Relationship between coverage of a soil area with leaves and the factor f to calculate ETP from Emax.

coverage %	factor f
100	1.00
75	0.90
50	0.70
25	0.45



Evapotranspiration can be measured with an *evaporation pan* of any size and shape using a vertical scale in millimeters.

Plant conditions. The relationship between Emax and ETP reveals that an advanced potato crop transpires more than a young one. Transpiration depends also on degree of stomatal opening.

Stomata of potato leaves close at night, opening in the morning due to sunlight. They react to water lack by rapidly closing which prevents desiccation. This reduces transpiration (and subsequently photosynthesis and yield). In practice stomatal opening is influenced primarily by water supply.

Soil conditions. The potato plant extracts water from soil only when the suction force of its roots is greater than the force in the soil retaining the water. This suction force depends on soil water content and soil texture and is expressed as pF.

Limits for soil water content are: *saturation, field capacity* (FC), *permanent wilting point* (PWP).

Water content at all of these limits is lower in coarse soils than in fine soils (Table 3.2).

Additional important soil moisture characteristics are derived from these limits: *aeration porosity, available moisture, drought limit.*

TABLE 3.2. Moisture characteristics of typical soils. (Water content in volume percent).

moisture limit	pF value	water content		
		sandy soils	loamy soils	clay soils
saturation	0	40	50	60
field capacity (FC)	2.0	10	35	50
permanent wilting point (PWP)	4.2	2	10	35
aeration porosity		30	15	10
available moisture		8	25	15

The *aeration porosity* is the difference in water content at saturation and FC. Aeration porosity should be above 15% to supply sufficient oxygen in the root zone.

Water between PWP and FC is available for plant growth (*available moisture*). However, growth of a potato crop becomes reduced once a portion of this water is utilized. Growth reduction begins at the *drought limit*. The drought limit depends primarily on ETP (Table 3.3), but also on available moisture of soils. In soils with low available moisture, the drought limit is reached earlier.

Obviously drought stress occurs especially when effective root zone is small, ETP high and soil coarsely structured.

TABLE 3.3. Relation of ETP and drought limit for potato in soils with 20% available moisture and no drought stress. (Rijtema and Aboukhaled, 1973).

ETP (mm/day)	drought limit (in % of available moisture left in soil)
1	61
2	47
3	37
4	30
5	25
6	22
9	16

4 WATER MANAGEMENT WITHOUT IRRIGATION.

In **rain-fed** potato production, irrigation might be unnecessary. In **dryland** potato production, irrigation may not be possible and rain sparse.

Rain-fed potato production. The amount of soil water at planting time plus additional precipitation during the growing season sometimes is sufficient for potato production.

Excessive rain that provides more water than the soil is able to absorb may necessitate a field drainage system. Excessive rain combined with field slope, can cause serious erosion, resulting in soil loss and uncovering of potato tubers. Reduce this danger by making furrows with minimum slope (see section 6 below).

Dryland potato production. Dryland potato production is on soil that has stored enough water to support a crop during a dry growing season. A large amount of available moisture is advantageous. This is favored by a deep effective root zone (up to 120 cm), where additional water penetrates from deeper soil layers.

Dryland potato cultural practices:

- Plant at low stem density; soil water may not be sufficient to support as many stems as when planted under normal conditions. Use either small seed to reduce stem density (however, small seed may have insufficient energy for emergence under these conditions), or plant larger tubers at wider distance.
- Plant (up to 25 cm) deep.
- Reduce tillage and cultivation operations to decrease evaporation from soil.
- Use mulches (straw or leaves).
- Remove haulms in case the soil water resource has been utilized before the foliage matured naturally, to prevent water loss from the tubers.

Under dryland conditions, late varieties tend to yield better than early varieties. Early varieties may mature too quickly.

Only specific climates (not too hot and not too low relative humidity) and soil characteristics (deep volcanic soils) may support dryland potato production. It is better to grow a crop on a smaller area and to irrigate adequately than to produce potatoes on a large area with insufficient irrigation.

5 IRRIGATION METHODS.

Irrigation takes the place of precipitation where rainfall is not sufficient. Several irrigation methods are possible, including sprinkler, trickle and furrow irrigation.

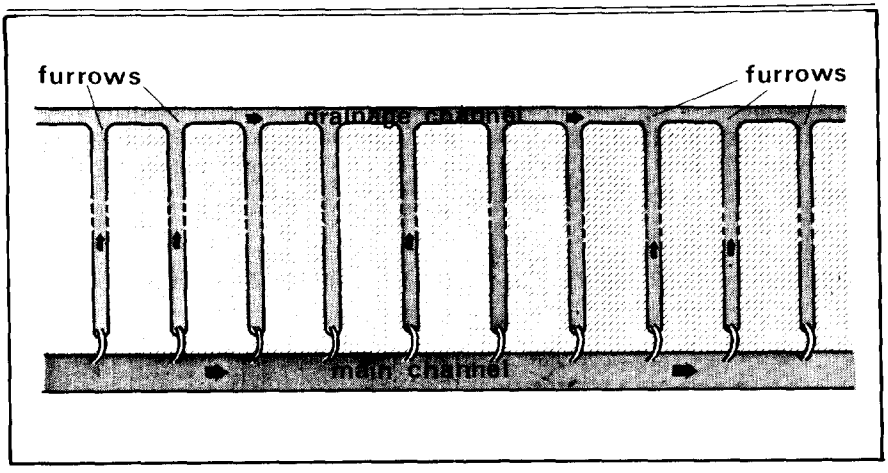
Sprinkler irrigation applies the water over the crop similar to rainfall, using rather expensive equipment. From the technical/agronomical standpoint it is the best system; it

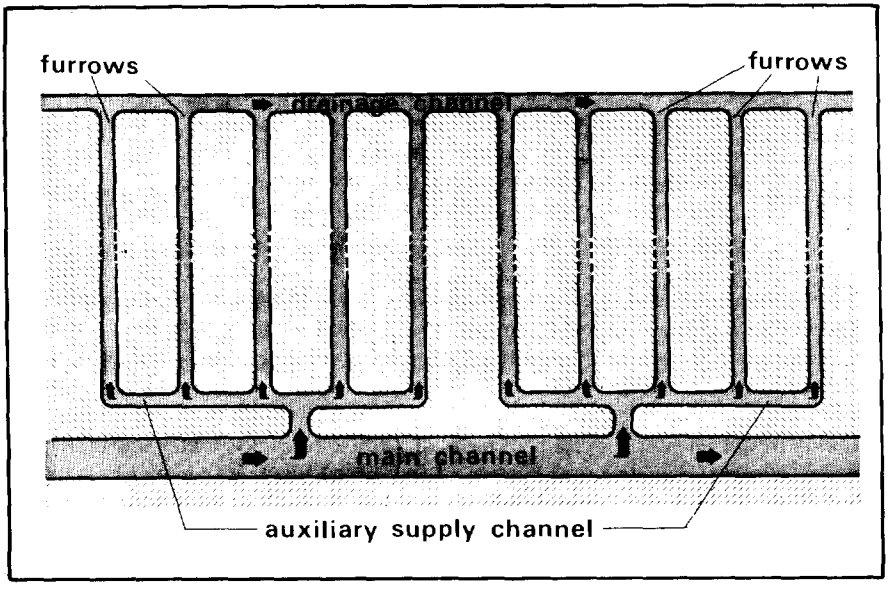
- can be applied on a slope; flat land is not necessary;
- supplies a uniform, exactly adjustable quantity of water;
- contributes to efficient utilization of water resources;
- minimizes erosion on sandy soils where furrow irrigation might be hazardous.

Prevent damage to soil structure and lack of oxygen in soils, by limiting sprinkler capacity to not more than 10 mm per hour under complete crop cover. Reduce sprinkler output to maximum of 6 mm per hour when the soil is not completely covered.

Trickle irrigation uses a system of pipes and tubes to trickle water under the soil surface directly over the root system of individual plants. It makes best use of limited water resources, reduces erosion and loss through evaporation. However, it is expensive and may promote soil salinity.

Furrow irrigation is the most widely used irrigation method in potato production. Water is supplied from a main channel by way of siphons or auxiliary supply channels into the cultivation furrows. Drainage channels are needed at the end of the furrows to drain excess water off the field. This helps also to provide a constant height of water throughout the furrow length and to avoid flooding at the field end. (See next section).





Furrow irrigation supplies water from a main channel through siphons (above) or an auxiliary supply channel (below) into the cultivation furrows.

6 FURROW IRRIGATION.

The most important factors for furrow irrigation are furrow distance, length and slope, and ridge uniformity.

Furrow distance. In potato, the distance between irrigation furrows varies from 60 to 90 cm depending on soil texture. In sandy soil, water leaks away rapidly and does not reach far; distance between rows should be smaller than in clay soils. In coarse sandy soils the distance between the furrows should preferably be around 60 - 65 cm, and in heavier clay soils around 70 - 80 cm.

Furrow length. Make furrows as long as uniformity of water supply and furrow slope allows. Maximum furrow length (Table 6.1) depends on slope of the furrows, soil type and recommended depth of water in the furrow. Water should not exceed half ridge height to avoid excess moisture in tuber region. In most cases up to 7.5 cm water depth may be recommended. If less water is applied maximum furrow length becomes shorter.

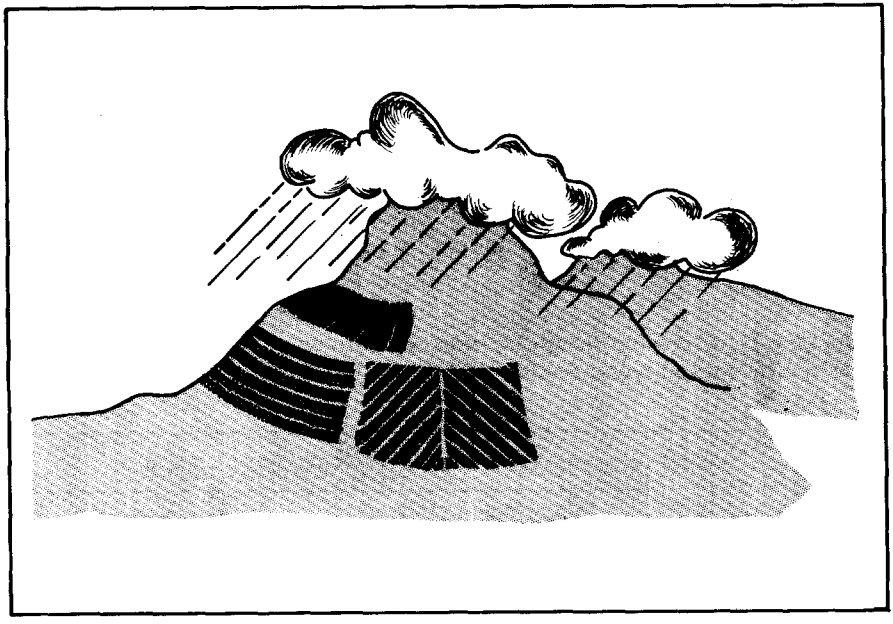
In some instances, such as unlevelled fields, short furrow irrigation (up to 10 m) may be necessary. Close furrows at the end. Stop water supply when the furrow is filled to half the ridge height. This procedure allows a rather homogenous irrigation but requires more space for auxiliary supply channels.

TABLE 6.1. Maximum length of irrigation furrows at different furrow slopes and in different soil types (Booher, 1974).

slope (%)	maximum furrow length (m) in		
	sandy soils	loamy soils	clay soils
0.05	90	200	300
0.10	120	260	340
0.20	190	300	370
0.50	190	325	400
1.00	150	275	280
2.00	90	210	220

Furrow slope. Serious erosion results when furrow slope exceeds 2% (2 m per 100 m row length). In rain-fed areas slopes in excess of 0.3% can cause erosion damage from intense rains. Change furrow direction if slopes exceed indicated maximums (Table 6.1). When the field surface is uneven furrows on the contour help prevent erosion and water loss. Contour irrigation is only possible when the field slope does not exceed 8 to 10%.

Ridge uniformity. Uniform ridges permit an even distribution of water to the potato plants.



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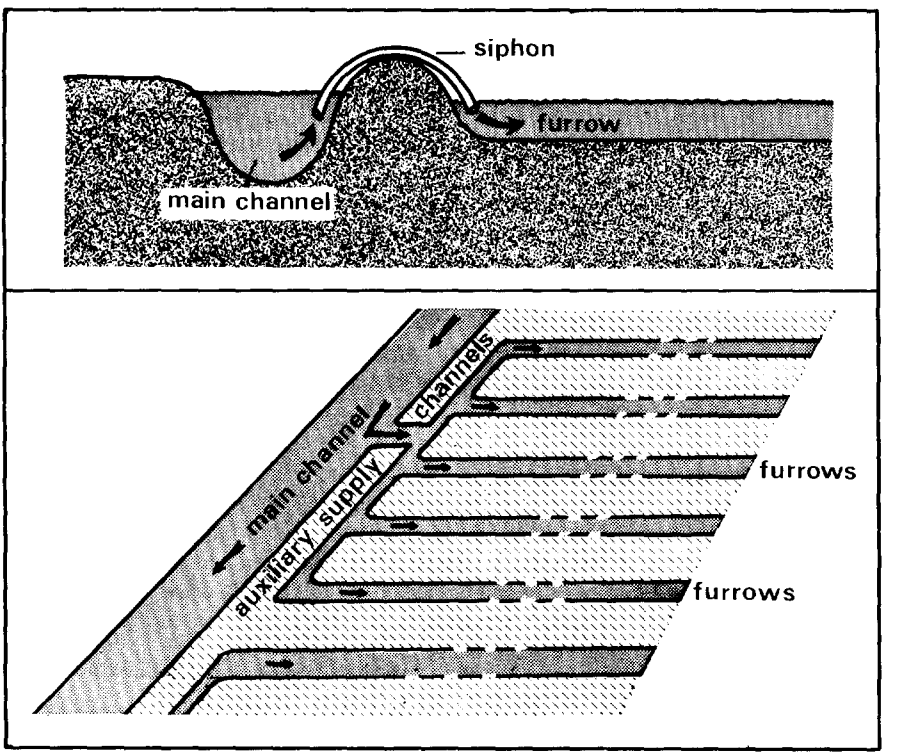
7 WATER SUPPLY.

Adjust the water supply to avoid lack, excess and large variations of soil moisture. Water supply is adjusted by quantity of water applied at each irrigation and frequency of irrigation (section 9).

Regulate water supply by management of siphons or auxiliary supply channels. During irrigation the number of siphons per furrow can be reduced when the water reaches the furrow ends; or use an auxiliary supply channel initially for a few furrows and then divert it to additional furrows. In this way beginning and end of a furrow receive same time of irrigation.



Regulate water supply by management of siphons (above) or auxiliary supply channels (below).

Quantity of water supply. It is not difficult to estimate the amount of water running through the field during an irrigation. When siphons are used, record the time necessary for a siphon to fill a 10 liter container. Then calculate water quantity from number of siphons and irrigation time.

When auxiliary supply channels are used, calculate the amount of irrigation water from cross section of the furrow (up to water level), speed of water flow, and irrigation time.

Water quantity (m^3) =

cross section (m^2)	x	water speed (m/min)	x	irrigation time (min)

Two methods may be used to determine when (and how much) to irrigate:

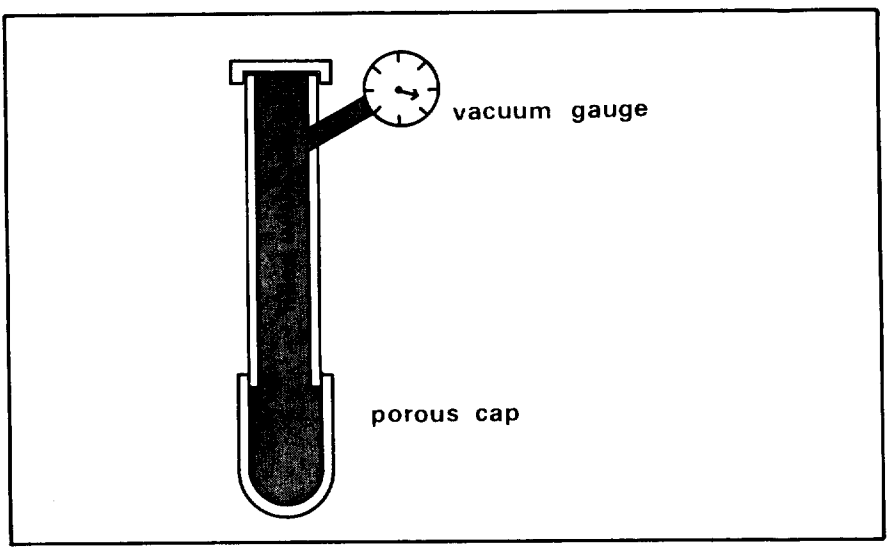
- a simple field guide,
- the tensiometer method.

Field guide. The consistency of a handful of soil roughly indicates when the drought limit is reached and irrigation is necessary. Take a handful of soil, squeeze it tightly and compare consistency of the soil ball with Table 7.1.

Tensiometer method. The tensiometer consists of a water-filled, porous cup connected to a manometer, preferably a vacuum gauge. Soil exerts a suction force to the water inside the cup according to soil's water status. The manometer indicates suction in centibars (cb; see manufacturer's instructions). The tensiometer is applicable between pF = 0 and pF = 2.9. It is the most popular and least complicated irrigation indicator. A potato crop should be irrigated before the tensiometer reading exceeds 40 cb (pF = 2.6).

TABLE 7.1. **Consistency of a soil ball formed by hand and amount of water necessary (in mm per 10 cm depth of effective root zone) at drought limit to bring the soil back to field capacity (Israelsen and Hansen, 1962).**

texture	coarse (sand)	moderately coarse	medium	fine (clay)
consistency at drought limit	soil does not form ball, appears to be dry	soil tends to form ball, however, it seldom holds together	soil forms a plastic, sometimes slicky ball	soil forms ball, ribbons out between thumb and fore finger
mm water required per 10 cm soil depth	1.5 - 4.0	3.0 - 6.5	4.0 - 8.0	5.0 - 10.0



The tensiometer, a popular device that indicates need for irrigation. The vacuum gauge shows suction of the soil in centibars (cb). Irrigate potatoes when the reading exceeds 40 cb.

Frequency of water supply. Frequency of irrigation depends on the stage of the potato crop, water capacity of the soil, and evapotranspiration rate (Emax).

Before planting, the soil should be moist but not wet. When soil structure allows, irrigate the field **before plowing**. This ensures a uniformly moist soil. Also, the prepared furrows may be irrigated **before planting**.

During germination little water is needed. The tuber should be surrounded by moist, but not wet soil. The germinating tuber is especially sensitive to wet conditions. In case the field was irrigated **before plowing**, a second light irrigation is usually necessary shortly after planting. When the prepared furrows have been irrigated shortly **before planting**, an additional irrigation is not required during germination.

Between emergence and tuber initiation, the root system develops. Assure that roots grow deep by limiting the water supply. Shallow root growth promoted by unrestricted water supply may be of disadvantage at later crop stages.

During tuber initiation, increased soil moisture enhances tuber formation, and reduces incidence of common scab (*Streptomyces scabies*).

During the tuber bulking stage until crop maturity water should be readily available. Lack of water reduces plant growth and tuber production. Irregular water supply leads to tuber deformations. Drought at the end of the growing period may result in the foliage withdrawing water from the tubers. Tubers lose weight and become flaccid.

Between crop maturity and harvest water uptake is minor. Nevertheless the soil should be kept rather moist to avoid soil cracking and clod formation. Cracks promote entrance of potato tuber moths and other damaging insects. Clods damage tubers at harvest.

Frequency of irrigation can be calculated when certain data are known (see example in section 9).

8 QUALITY OF IRRIGATION WATER.

The potato is rather susceptible to salt in soils or irrigation water. This is especially true in heavy soils. Salts are more easily washed out of sandy soils.

Sprinkler irrigation with salt containing water may cause "burn" damage to foliage. Of the anions Cl^-, SO_4^{--} and CO_3^{--}, Cl^- is the most phytotoxic. The cation Na^+ damages soil structure. A content of 4 g NaCl in one liter of water may cause up to 50% yield reduction.

When salt content of soil or water is high the drought limit is reached sooner. Such a soil should not be allowed to dry as under normal conditions. Soil salinity can be prevented or reduced by leaching it with salt-free irrigation water before potatoes are grown.

9 HOW TO CALCULATE WATER SUPPLY (Example).

A farmer may schedule his irrigation on the basis of the field guide explained in section 7 above. For large irrigation schemes, however, it might be worthwile to investigate soil and environmental characteristics and to calculate water supply, especially when water resources are scarce.

Assumptions (example; all figures of water content are on a volume percentage basis):

water content at saturation	50%
water content at FC	35%
water content at PWP	10%
depth of effective root zone	60 cm
coverage with green leaves	70-80%
Emax	4 mm/day
slope of field	1%
soil medium-fine textured (loamy)	(compare table 3.2).

Questions:

a) According to the field guide (Table 7.1) describe the consistency of the soil when irrigation is required.

b) At which limit and percent water content should be irrigated?

c) How much water should be applied?

d) How frequently should be irrigated at the given growth stage?

e) What is the maximum furrow length?

f) How big is the aeration porosity of the field and the air content at drought limit?

Answers:

a) **Soil consistency.** According to Table 7.1, irrigation becomes necessary when a soil ball formed by hand is **plastic.**

b) **When to irrigate.** Irrigation becomes necessary when the water content is at **drought limit.** According to Table 3.3, at ETP of 4 mm/day drought limit is reached when the water content decreased to 30% of available moisture.

Available moisture is the difference in water content between FC and PWP:

$$\text{Available moisture} = 35 - 10 = 25\%,$$
$$30\% \text{ of available moisture} = 7.5\%.$$

According to the assumptions above the water content at FC amounts to 35%; water content at drought limit is

$$35 - 7.5 = \mathbf{27.5\%}.$$

c) **Irrigation quantity.** According to b), water should be applied when 30% of available moisture = 7.5% of total water content has been used. To restore conditions of field capacity, 7.5% water should be given. At an effective root zone of 60 cm this corresponds to

$$60 \text{ cm} \times 7.5\% = 4.5 \text{ cm} = \mathbf{45 \text{ mm water}}.$$

d) **Irrigation frequency:** According to Table 3.1, at a coverage with green leaves of 75%, the factor to calculate ETP is 0.9.

$$ETP = Emax \times f$$
$$= 4 \text{ mm/day} \times 0.9 = 3.6 \text{ mm/day}.$$

According to c), 45 mm water are needed to restore field capacity. This gives an irrigation frequency of

$$\frac{45 \text{ mm}}{3.6 \text{ mm/day}} = \textbf{12 days}.$$

e) **Furrow length.** According to Table 6.1, the maximum furrow length in a medium textured soil (loamy soil) at a slope of 1% should **not exceed 275 m.**

f) **Aeration porosity and air content. Aeration porosity** of the soil corresponds to the difference of water content at saturation and FC:

$$50 - 35 = \textbf{15\%}.$$

According to b), at the drought limit, the water content is 27.5%. Thus the **air content** at drought limit is:

$$50 - 27.5 = \textbf{22.5\%}.$$

The aeration porosity of 15% is at the limit of good plant growth. Thus, to avoid lack of oxygen in the root zone the soil should not be kept at field capacity for an extended time.

10 ADDITIONAL READING.

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