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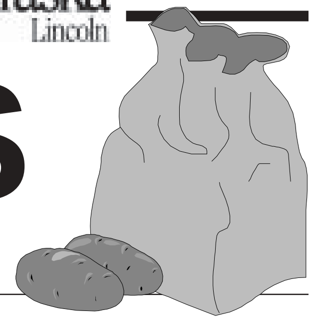
NEBRASKA

POTATO EYES



Vol. 15, Issue 2, Summer 2003 • Alexander D. Pavlista, Ph.D., Extension Potato Specialist
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Principles of Irrigation Scheduling

Scheduling irrigation is attempting to apply water to potatoes at the appropriate amount for a specific stage in the plants development and growth. The potato plant's use of water is primarily for transpiration and tuber production and, therefore, irrigation is most important from emergence to vine senescence. Transpiration is the movement of water through the vine, from roots to leaves, to compensate for water loss at stomates (pores) that are open to allow gas exchange (oxygen and carbon dioxide) between the plant and the atmosphere thereby supporting plant photosynthesis and respiration.

The basic principles of irrigation scheduling from a soil-water view are:

1. Soil moisture. Sites for monitoring soil moisture should be chosen to be most representative of the field. The purpose is to limit under-watering of the heavier soils and over-watering lighter soils. For precision irrigation where watering can be controlled in smaller areas within the field, more monitors would be needed and both better and poorer soils would need to be monitored.

2. Root zone depth. Root zone depth is the zone where most of the root structure is found. This varies with different potato varieties but as a general rule, roots develop down to 18 inches below the seed piece.

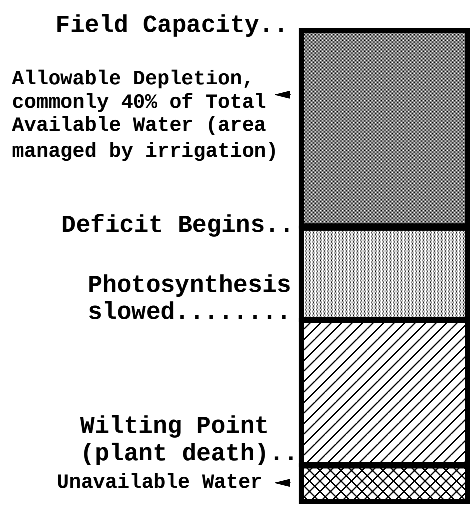
3. Water holding parameters (Figure 1). Two measurements would be important. The "fill point" is the wettest a soil can be before water drains below the root zone. This would be near 100% field capacity (FC) or 100% holding capacity of the root zone and depends on soil texture. In general, sandy soils have the lowest FC while silt loams have the highest with clays being intermediate. The "refill point" is the driest a soil can be before daily water use is lowered due to too little water in the root zone. This begins to induce the shutting of stomates resulting in reduction of carbohydrate synthesis (photosynthesis) and respiration (metabolism), and leads to wilting. This has a direct relation to yield.

The difference between field capacity and 40% depreciation is the "allowable depletion" (AD) amount of water and, for potato, is 20-25% FC or about half the total available water (about 40% FC). In sandy loam soils, the AD is three-quarters to one inch water up to a depth of 12 inches or one to one and a half inch for the root zone of a full-grown determinate potato variety (Curwen and Massie, 1994; Kranz et al., 1989; Yonts and Klocke, 1985). Soils that are compacted or tend to seal will lower water-holding capacity and reduce penetration of water into the soil.

4. Effective irrigation. Effective irrigation is the amount of water that actually gets into the root zone and is available to the plant. Some of the irrigation water (actual irrigation) is lost as run-off, evaporation or deep percolation.

5. Daily water use. Daily water usage by the potato is dependent on the growth stage of the plant and environmental conditions on that day. It is directly related to canopy development, mostly leaves which contain nearly all the stomates. Environmental conditions that affect daily water use are air temperature, relative humidity, wind, and solar radiation. An excellent guide to daily water usage is evapotranspiration (ET) data that is calculated from weather station data (Klocke et al., 1990). Most, if not all, land-grant universities like University of Nebraska-Lincoln calculate ETs for stations around the state and provide them on the web and for publication in local newspapers. ET is the total daily water use from both transpiration by the plant and evaporation from the soil and can be as high as a third of an inch in a day for potato. ET needs also to be adjusted for canopy size or row closure, canopy width divided by row spacing; 80% row closure is considered full canopy or 100% ET. Therefore, a potato crop that has row-closed on sandy loam at field capacity (three-quarters to one inch AD) can be carried for two and a half to three days under high ET conditions. From this, one can estimate a two to two and a half inches weekly irrigation requirement for potatoes during tuber bulking under high ET conditions — high temperature, low relative humidity, intense sunlight, high winds, and long days (July in the Nebraska Panhandle?). Seasonal ETs differ for crops due to duration at full canopy and growing season.

Figure 1. Allowable depletion and available water.



In summary, the key factors in managing irrigation are:

- how much water gets into the soil,
- how much water the soil can hold, and
- how much water is being used by the plant.

Inside this issue...

Measuring Soil Water

There are several ways of estimating soil moisture from the simplest and subjective to advanced technology. A compromise between practicality and accuracy needs to be made. How close to actual field capacity is needed? For most situation in scheduling irrigation in potato fields, an accuracy of 5% is acceptable. The keys are how much water is in the soil and where in the soil profile, in other words the depth of water penetration from irrigation and rain. Soil texture or the relative amounts of sand, silt and clay in the soil are the critical factors influencing the amount of available water to the plant (Table 1).

Table 1. Available water capacity of soils (modified from Klocke and Fischbach, 1984, and Kranz et al., 1989).

Soil Texture	Available Water (inches/foot)	Soil Texture	Available Water (inches/foot)
fine sand	1.0	silty clay loam	1.8
loamy sand	1.1	clay loam	1.8
sandy loam	1.4	loam	2.0-2.5
fine sandy loam	1.8	silt loam	2.0-2.5

Below is outlined three common methods for estimating water content of soil during the season: "appearance and feel," tensiometer and moisture blocks.

1. Appearance and feel (Klocke and Fischbach, 1984).

Different soil types respond in different appearance and feel using this method so it is necessary to know the soil texture. This can be identified from county soil maps at Cooperative Extension offices.

A soil sample needs to be extracted from the potato root zone using either a soil probe for up to 24 inches (bottom of root zone), a soil auger or, at minimum, hand-dug to the depth around the growing tubers. Using the appearance and feel method requires some experience and observation. When first learning it, start using it in the spring after a heavy rainfall when the soil should be saturated (field capacity, FC) and take samples every so often as the field dries until it is quite dry. Record your observations per field for reference. Table 2 lists the appearance and feel that represent different field capacity ranges for various soils. Representative pictures are shown in the NebGuide.

2. Tensiometer (Kranz et al., 1989).

Tensiometers are a common and simple objective way to monitor available soil water. It measures the force that a potato root needs to overcome to absorb water from the soil, and consists of a tube with a porous ceramic tip at the bottom, a vacuum gauge near the top and a scaling cup. The tube is filled with water before inserting it into the soil. Upon insertion of the tensiometer, water can move between the tube and the soil through the ceramic tip. During the drying of the surrounding soil, water leaves the tube creating a vacuum measured by the gauge, calibrated in negative centibars (cb), until an equilibium is reached. The final gauge reading is reached when water no longer flows out of the tube and measures the actual force required to remove water from the soil at that time and location. Therefore, suction pressure is actually measured. The wetter the soil :: the lower the value (less cb needed to remove water; and visa versa. Plants extract water easier from sandier soils than heavier ones due to the larger air spaces in sandy soils. But, note that sandier soils also hold less water.

For an outline on preparation, procedures and data interpretation of tensiometer use, refer to Kranz et al., 1989.

3. Moisture Block (Kranz and Eisenhauer, 1989).

For fine-textured soils such as loam and silt loam, a moisture block is recommended by UNL for measuring soil moisture; they are not recommended for sandy soils because of the large soil particles of these soils. The moisture block is made up of gypsum and is about an inch in size. The gypsum is attached via a wire to a measuring meter. Being measured is the electrical resistance between two wires imbedded into the gypsum block. Water from the soil enters the block saturating the gypsum. Electrical resistance through the gypsum decreases allowing more electrical flow between the two imbedded wires. This electrical flow is measured by the meter. A high reading indicates a moist soil while a low one indicates a dry soil. For details on preparation and use of moisture blocks, refer to Kranz and Eisenhauer, 1989).

Table 2. Appearance and Feel Guide, based on taking a hand full of soil at the depth, and squeezing it to form a ball (modified from Curwen and Massie, 1994).

Available Moisture	Soil Type or Texture	Appearance and Feel of Soil Ball in Hand
90-100%	Sand or Loamy Sand	No free water appears; ball leaves outline. Ball is slightly sticky; fingers outlined.
	Loam or Silt Loam but not muddy.	Water left on hand. Ball is like bread dough: wet, sticky and slick,
70-80%	Sand or Loamy Sand	Forms a weak ball. Fingers are outlined. Particles stick to palm.
	Loam or Silt Loam pieces. Hand is wet.	Damp, heavy and tight ball, slightly sticky. Ball shatters into large
60-65%	Sand or Loamy Sand	Forms a weak and brittle ball. Finger outline is less distinct.
	Loam or Silt Loam	Firm ball forms, distinct finger outlines. Feels damp, not wet; pliable, may fragment.
40-60%	Sand or Loamy Sand	Forms loose ball under pressure, not hold. Grains stick together.
	Loam or Silt Loam	Solid but brittle ball forms. No wet feeling. Soil fragments don't cling; fall and crumble.

Potato Growth and Irrigation Scheduling

All plants vary in their water requirements according to their size and growth stage as well as the length of their maturity and time of year of maximum growth. Possibly no other major crop varies in its sensitivity to water stress based on growth stage than potato. In this section, irrigation recommendations at key production periods are based on the S-shaped growth curves of roots, vines and tubers (Pavlista, 1995)(Table 3). Soil moisture requirements are related to different growth stages (van Loon, 1981). Quality effects of water deficit and excess during these stages are described (Curwen, 1994).

Table 3. Brief summary of problems resulting from water deficit or excess in soil moisture based on production period.

Production Period:
Pre-Planting -- Root Growth = preparation.
Preferred Soil Moisture = 70-80% FC (field capacity).
Water Deficit = soil clumping, poor root growth after planting.
Water Excess = muddy soil resulting in delayed planting.

Pre-Emergence -- Root Growth = log phase, Canopy Growth = lag phase.
Preferred Soil Moisture = 65-80% FC.
Water Deficit = poor root growth, poor seed-piece healing, poor sprouting, increase susceptibility to pathogens in soil.
Water Excess = poor root branching, increase populations of soil pathogens, decrease seed-piece health, poor sprouting.

Pre-Tuber Initiation (early Post-Emergence) -- Root Growth = log phase, Canopy Growth = log phase, Tuber Growth = none.
Preferred Soil Moisture = 70-80%.
Water Deficit = poor root and canopy growth, delayed tuberization.
Water Excess = poor root branching, stolon decay, black leg.

Tuber Initiation (Blooming) -- Root Growth = flat phase, Canopy Growth = log phase, Tuber Growth = lag phase.
Preferred Soil Moisture = 80-90% FC.
Water Deficit = tuber mis-shaping, sugar-ends, leaf aging, early blight, wilts, common scab, delayed tuberization.
Water Excess = brown center / hollow heart, black leg, early dying, leaf aging, early blight, micro-climate for late blight.

Tuber Bulking -- Root Growth = none, Canopy Growth = flat stage, Tuber Growth = log phase.
Preferred Soil Moisture = 80-90% FC, avoid fluctuations.
Water Deficit = reduced tuber growth, tuber mis-shaping, early dying, leaf aging, early blight and brown spot, wilts, common scab.
Water Excess = swollen lenticels, hollow heart, black leg, late blight, soft rots, white mold, leach nitrogen.

Plant Senescence / Tuber Maturation -- Canopy Growth = determinate varieties = dying phase, indeterminate varieties = flat phase, Tuber Growth = flat phase, maturing.
Preferred Soil Moisture = 60-70% FC.
Water Deficit = IBS bruising, delayed skin set, poor tuber maturation, poor russeting.
Water Excess = shatter bruising, tuber blight, water rots in storage.

1. Pre-planting to Planting:

A pre-plant irrigation is often recommended for two reasons. First, soil moisture should be about 70-80% field capacity. This will bear-saturate the field allowing some room for rains. This level amounts to around a quarter of the allowable deficit (AD) of the soil. Soil moisture should be acceptable to support the developing roots after planting and reach emergence. Another benefit from a “pre-irrigation” is the breaking down of clods and clumps for better planting.

2. Planting to Pre-emergence (Sprouting):

[early Stage I. Vegetative (van Loon, 1981)]

Soil moisture in the top foot of soil should be 65 to 80% FC. No irrigation is recommended during this production period. First, seed-pieces at a recommended size, 2 to 2.5 ounces, have sufficient water to support the sprout until emergence. Irrigating during this period would raise the soil moisture and lower soil aeration to a level that would support several pathogens, most notable bacterial soft rot or black leg (*Erwinia carotovora*), and stem and stolon canker (*Rhizoctonia solani*). Excess moisture will also decrease tuber respiration putting the seed-piece under metabolic stress. There is also good research data indicating that the soil population of *Verticillium albo-atrum* will increase and cause early dying at mid-season. Note, on the other hand, that a water deficit, too dry soil, will decrease the healing of the cut surfaces of seed-pieces, inhibit root growth and increase susceptibility to soil pathogens such as Fusarium spp. and Rhizoctonia. In short, pre-plant irrigation and seed-piece water are more than sufficient to carry the sprouting tuber.

3. Emergence to Tuber Initiation (early vine growth):

[Stage I. Vegetative]

This is the log phase of vine growth. Roots are in the second half of their growth. During this period, the vine grows very rapidly, as much as doubling the canopy every week. With rapidly increasing foliage every week, irrigation starts low, 0.5 inch, and gradually increases every week about 0.5 inches. At tuber initiation, about three weeks after emergence depending on variety, seed health, weather, soil, and cultural practices used, about 1.5 inches of irrigation is applied. A soil moisture of 70 to 80% is preferred, less than 65% FC would be considered a deficit. Water deficiency at this point would inhibit canopy and root growth, and indirectly weed control by less ground cover. An excess would retard root branching (development) by water-logging root hairs and promote nitrogen leaching. In short, with an increase in foliage and thereby transpiration, irrigation should begin and gradually increase as the canopy grows.

4. Tuber Initiation to Full Bloom:

[late Stage I. Vegetative or Stage II. Tuberization]

In determinate varieties, full bloom marks the end of vine growth while in indeterminate varieties, full bloom starts a noticeable slow down of vine growth, some branching still occurs. The first set of tubers are being initiated and these are in a slow growth, development stage, the lag phase of tuber growth. Irrigation becomes increasingly important and water stress becomes less tolerable. Transpiration reaches its highest rate. Optimal soil moisture is 80 to 90% FC. Irrigation increases from about 1.5 to 2.5 inch per week on sandy type soils. Water deficit would dramatically increase tuber malformations and sugar-ends. It can also weaken plants promoting early blight. Common scab (*Streptomyces scabies*) attack is promoted and the longer the deficit, the greater the attack and more pronounced and enlarged the blemishes. In areas and with varieties prone to common scab, maintaining soil moisture at 90 to 95% is suggested if possible. Excessive water will increase brown center and hollow heart of larger tubers, and promote early dying of the vine. Too much loose water, swampiness, can also promote late blight, and weaken plants promoting early blight. In short, soil moisture levels must be increased and therefore irrigation is increased. Note, also that this stage of the plant often corresponds with June and

July and the hottest of weather. The length of this period is also related to variety, weather and cultural practices. It may be prolonged by excessive nitrogen.

5. Full Bloom to Plant Senescence (Tuber Bulking):

[Stage III. Tuber Growth]

At this period, the canopy and roots are fully grown except for indeterminate varieties which have considerably slowed growth. However, now, tubers are growing rapidly and are in their log phase of growth. Here, it is key to keep in mind that tubers are 76 to 82% water and this water must come from the outside, rain or irrigation. This period runs about six weeks, usually in July and August. Irrigation plus rain should be 2 to 2.5 inches per week or about 15 inches for the period. Soil moisture should be at 80 to 90% FC. This is the period when plants have their highest demand for water and are the most sensitive to a deficit. Water deficits here will reduce tuber growth but also there would be increases in tuber malformations, early dying (Verticillium and Fusarium wilts), early blight and brown spot (*Alternaria solani* and *A. alternata*), and common scab. Water excesses increases hollow heart, swollen lenticels (stomates on tuber), black leg, late blight (*Phytophthora infestans*), and susceptibility to soft rot, leak (Pythium spp.) and pink rot (*Phytophthora erythroseptica*). In heavy vined varieties, white mold (Sclerotinia spp.) may occur. Note that from tuber initiation through tuber bulking, evapotranspiration is very high and therefore daily water use by the plant. In short, too little water will create stress making plants susceptible to opportunistic diseases, promote common scab, and drastically reduce yields and increase culls. Excessive water will increase water rots of vines and tubers, and create conditions for late blight infestation.

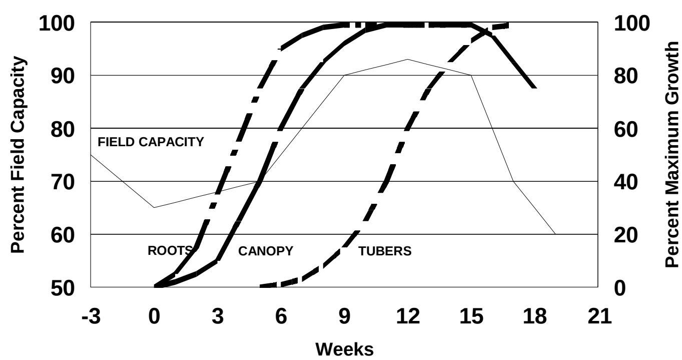
6. Plant Senescence to Harvest:

[Stage IV. Maturity]

This period is characterized by dying of the vine; in the case of indeterminate, lower leaves are dying. Tuber growth slows and is in the flat stage. Tuber maturation is a common term used here as tubers settle to their maximum content of dry matter and minimum content of reducing sugars, glucose and sucrose. As the vine dies, tuber skin sets, hardens and adheres to the tuber core (flesh meat etc.). Irrigation declines over this two to five week period depending on variety and climate. Soil moisture may decline to 60-65% FC. Some irrigation may benefit in wireworm and white grub control, and will avoid soil clumping making harvest easier. If the field has early blight, too much watering runs the risk of washing spores of this pathogen to the tubers. Excessive irrigation will not only stimulate tuber susceptibility to water rots, soft rot, leak and pink rot by swelling lenticels but also form an oxygen-deprived environment that promotes the pathogens the cause these rots. Water-rotted tubers can create a packaging and storage nightmare. Also too much water will increase tuber susceptibility to shatter bruise due to raised tuber water content. The reverse, too little soil moisture, can increase internal black spot bruising (IBS) as well as delaying skin set. Russeting of russet varieties is decreased.

Figure 2 summarizes the relations of the production periods and the relative growth of roots, canopy and tubers to field capacity or soil moisture. The graphic model is based on a determinate, mid-season variety such as Atlantic grown full season in western Nebraska. Planting would be around 1 May and emergence would be about three weeks later. Tuber initiation would be typically three weeks after emergence, mid-June. Tuber bulking would be from end of June to end of August with vine desiccation from then to mid-September and harvest from early September to early October.

Figure 2. Plant Growth and Soil Moisture Model
(Determinate, Mid-Season Potato Variety)



0 wk= Planting, 3 wk= Emergence, 5-6 wk= Tuber Initiation
8-9 wk= Full Bloom, 15 wk= Senescence, 18 wk= Vine Kill
Max. Growth Phases: <15%= Lag, 15-85%= Log, >85%= Flat

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The Nebraska Potato Eyes is on the WWW at:
www.panhandle.unl.edu/peyes.htm