

3.5 Irrigation (D. Tomasiewicz M. Harland, B. Moons)

Reliance upon irrigation varies significantly across the Prairies Provinces. In Manitoba, northern Alberta and parts of Saskatchewan, irrigation is used to supplement precipitation. In Southern Alberta and parts of Saskatchewan, the majority of the moisture required to produce a marketable crop comes from irrigation. For potatoes, average seasonal irrigation amounts applied are 16 18" (41-43 cm) in southern Alberta, 10" (25 cm) in Saskatchewan, and only 3.5" (9 cm) in Manitoba. Regardless of the production area or amount of precipitation received, the practice of irrigation is similar. All irrigators strive to eliminate soil moisture deficits to produce a high yield of good quality potatoes. To determine when and how much to irrigate, irrigators must understand both soil-water and crop characteristics.

3.5.1 Soil Water Characteristics

Knowledge about the amount of soil water available to the plant and the ability to estimate soil water content is a key aspect in determining irrigation requirements of potatoes. An irrigator must understand the following terms to estimate soil water content.

Available soil water (ASW) is a common term of reference describing soil water content. Understanding the concept of ASW requires understanding of two additional terms related to soil water content.

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Field capacity refers to the amount of water a soil holds after water has drained out of the larger pores and moved out through the soil profile due to the force of gravity. In coarse textured soils it may take a few hours for a soil to move from a saturated status to field capacity, in medium textured soils this may take approximately 24 hours, while in fine textured soils this may take several days.

Permanent wilting point refers to the amount of water a soil holds when only water within the smallest of the pores and spaces around individual soil particles remains. This water is not considered available to plants since the energy required to extract it is too great for the plant roots.

Figure 3.5-1 Available soil water and soil texture.

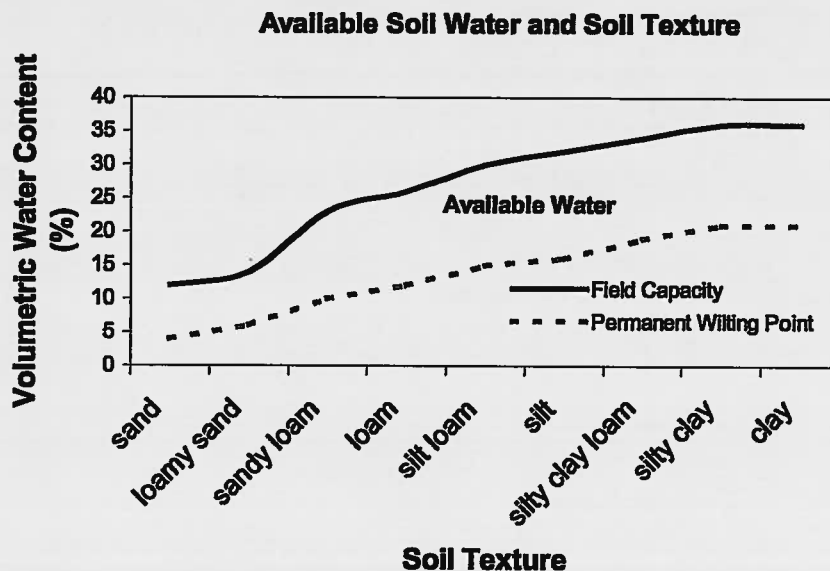


Table 3.5-1 Soil water contents for agricultural soils. Jensen, M.E., R.D. Burman, and R.G. Allen, 1990. *Evapotranspiration and Irrigation Water Requirements. ASCE Manuals and Reports on Engineering Practice No. 70. American Society of Civil Engineers, New York, NY.*

Soil Water Content on Volumetric Basis (%)								
Texture Class	Field Capacity		Permanent Wilting Point		Available Water		Water Holding Capacity (in/ft)	
	Average	Range	Average	Range	Average	Range	Average	Range
Sand	12	7-17	4	2-7	8	5-11	0.66	0.60-1.32
Loamy Sand	14	11-19	5	3-10	9	6-12	0.96	0.72-1.44
Sandy Loam	20	15-25	10	6-15	13	11-15	1.56	1.32-1.80
Loam	26	20-30	12	7-18	15	11-18	1.80	1.32-2.16
Silt Loam	30	22-36	15	8-21	16	11-19	1.80	1.32-2.28
Silt	32	23-36	15	12-18	17	12-20	2.04	1.44-2.40
Silty Clay Loam	34	30-37	19	17-24	15	12-18	1.80	1.44-2.16
Silty Clay	35	28-42	21	14-28	16	11-19	1.80	1.32-2.28
Clay	38	32-39	21	18-24	15	10-20	1.80	1.20-2.40

(Source: Jensen et al., 1990)

Any water held in the soil pores between the soil water contents of field capacity and permanent wilting point is considered available for extraction by plant roots for growth. The ASW capacity is the amount of water represented by the difference between field capacity and permanent wilting point. Soil texture is the main soil characteristic affecting ASW (Figure 3.5-1 and Table 3.5-1), however other factors such as structure, salinity, mineralogy and organic matter content also play a role.

3.5.2 Crop Characteristics

Potato is a moisture sensitive crop with a shallow active root zone compared to cereals and forages. Roots will penetrate to 3 feet (90 cm), however about 90% of the root activity takes place in the top 2 feet (60 cm) depth with a significant amount of that activity in the upper foot (30 cm). Availability of moisture in the root zone is crucial for high yields and is influenced by soil properties such as texture and percent organic matter. To maximize potato yield, maintain the soil moisture in the root zone above 65% of the ASW capacity.

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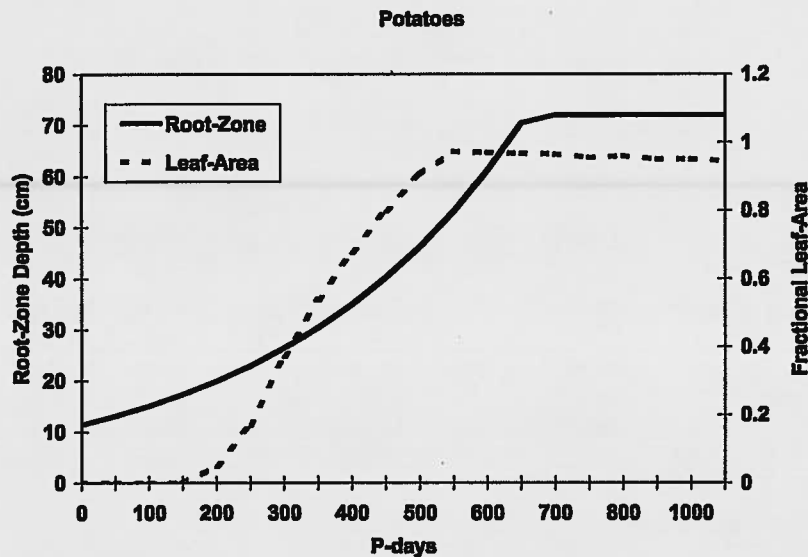
The optimum temperature for potato growth is 69°F (21°C). Severe growth restrictions occur when the temperature is below 45°F (7°C) or exceeds 86°F (30°C). This information is used to calculate heat units for potatoes, which are called P-Days. Figure 3.5-2

charts the rooting depth and growth stages of a Russet Burbank crop based on accumulation of P-Days. Root depth is important when estimating the amount of soil water available to the plant. A grower with access to P-Days for their production area can use the model in Figure 3.5-2 to estimate rooting depth and in turn the amount of soil water available to the potato plant. This use of root depth to determine ASW is discussed later in section 3.5.3 *Irrigation Management and Timing*.

The growth and development of potatoes can be broken down into five distinct stages, which are discussed in detail in Section 1.3 *Growth Stages*. The demand for moisture changes with each stage of growth as indicated in Table 3.5-2. Moisture demand increases as the crop begins to develop after emergence and peaks 7-9 weeks later during the tuber bulking stage of growth. Demand begins to decrease from the time of late bulking to maturation. To achieve maximum yield and quality, soil moisture should be maintained at or above 65% of ASW capacity for all stages of growth.

If soil moisture content is allowed to drop below 70% ASW during the tuber set/initiation, a reduction in tuber number per plant will occur. Water stress at any time during tuber bulking will reduce marketable yield. Low water levels or excessive fluctuation of water levels outside the desirable range can also reduce quality, contributing to growth deformities such as hollow heart, knobiness and growth cracks. Less water is required during maturation, but it is still important to ensure that there is sufficient moisture to maintain a healthy canopy to achieve high yields and specific gravity. Too much moisture during maturation can result in difficulties during harvest and increased storage rots.

Figure 3.5-2 Potato growth model for a Russet Burbank crop grown in Manitoba. (Courtesy of the Environment Canada, Winnipeg Climate Centre)



Growing a crop of potatoes requires 16–20 inches (400–500 millimetres) of water depending on weather and variety. This includes available soil moisture in the spring, which varies depending on soil type. Table 3.5-2 shows the rate of water use by potatoes at various stages of development and temperatures.

Note that at full canopy cover (7-8 weeks after emergence) and temperatures of 32°C, water use can be as high as 0.3 inches per day. Contact your provincial irrigation specialist to obtain a chart applicable to your production area.

Table 3.5-2 Daily potato crop water use as affected by maximum daily temperature and growth stage. (Courtesy of North Dakota State University)

Average potato water use (inches/day) (NDSU, 1988)															
Temp. °C	Weeks After Emergence														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10-15	.02	.03	.04	.05	.07	.08	.08	.08	.08	.08	.08	.07	.06	.05	.04
16-20	.03	.04	.07	.09	.11	.13	.14	.14	.14	.13	.13	.12	.10	.09	.07
21-26	.04	.06	.09	.12	.15	.17	.19	.19	.19	.19	.18	.17	.14	.12	.10
27-31	.05	.08	.12	.16	.19	.22	.25	.25	.25	.24	.23	.21	.18	.16	.13
32-37	.06	.10	.14	.19	.24	.27	.30	.30	.30	.29	.29	.26	.23	.19	.16
Growth Stage	Vegetative		Tuber Set			Tuber Bulking						Maturation			

3.5.3 Irrigation Management and Timing

The goal of irrigation management is to maintain soil moisture level in the crop root zone in a range where crop yield and quality are not reduced due to either insufficient or excess moisture, while minimizing the risk of leaching of soil moisture and nutrients below the root zone. The risks of excess moisture and leaching are greater in Manitoba than in many other potato-growing areas, due to heavier growing season precipitation.

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Effective rooting depth (Figure 3.5-2) must be considered when assessing soil moisture available to the crop for irrigation scheduling purposes. A depth of two feet (60 cm) is often assumed for management of irrigation scheduling for potatoes; this would be applicable for most of the irrigation season. It is generally recommended that irrigation be scheduled to prevent root zone soil moisture from dropping below 65% ASW. That critical ASW for irrigation is somewhat higher for fine-textured soils than for sands, since moisture is held more tightly in finer soils at a given ASW.

The amount of water a soil can hold between field capacity (100% ASW) and 65% ASW varies from about one-third inch per foot of soil (2.8 cm per m) for very coarse soils, to about two-thirds inch per foot (5.6 cm per m) for loam to finer textured soils. The amount of irrigation water applied with each application should be set to not exceed this capacity of the soil to hold water within the desirable range. Otherwise, leaching through the root zone will occur. For example, if water is to be applied at 65% ASW, and a 24" (60cm) effective rooting zone is assumed, routine application of 1.25" (3.2 cm) of water per irrigation would be acceptable on a clay loam soil, but only up to about half that amount on a very coarse soil. Therefore applications should be smaller and more frequent on coarse soils. If soil texture varies considerably within the field, the maximum application amount should be based on the capacity of the coarsest textured soil that occurs over a substantial portion of the field.

3.5.4 Irrigation Scheduling Methods

Most irrigation scheduling methods are based on either information from direct determination of soil moisture in the field (feel method), or on soil water balance calculated from estimated crop water use (*checkbook* method), or on a combination of the two approaches.

Variability in soil characteristics across the field, as well as with depth will result in uneven soil moisture content and must be considered in design and use of any irrigation scheduling system. In addition to soil characteristics and soil water holding capacity, other factors will result in variations in moisture availability across the field. These include:

- Variability in crop vigour and growth
- Plant spacing
- Slope, which moves rain and irrigation water off of the field before it can infiltrate into the soil
- Hilling, which can also affect run-off and infiltration
- Non-uniformity of irrigation water application.

A balance must be struck between the costs of

under-irrigating the driest parts of the field and those of over-irrigating the wettest portions. Experience, which includes years of checking soil moisture levels throughout the field under various conditions, is invaluable. Scheduling based on actual soil moisture determination should ideally incorporate many sampling/monitoring points within each field. With fewer points used, the grower should scout more frequently to verify that those points are representative of most of the field. Scheduling based on water budgeting methods should always include some field scouting for verification. The amount of scouting required increases with moisture variability over the field.

Soil Moisture Determination using the "Feel and Appearance" Method

The most basic approach for determining the amount of soil water involves sampling of the soil in the root zone and estimating moisture content by the "feel and appearance" method (Table 3.5-3). Many soil samples representing the different soil types in the field must be collected to obtain an accurate estimate of moisture content. Though this method is laborious and requires experience to interpret the soil moisture content, it can be an effective way of estimating the ASW. Table 3.5-3 is a useful guide in determining soil moisture level.

Soil Moisture Determination using Instrumentation

A wide range of instruments is commercially available to measure soil moisture for irrigation scheduling. These include neutron probes, tensiometers and resistance blocks. Some indicate how tightly the water is held by the soil (i.e. moisture *tension*). Many indicate the amount of water in the soil (i.e. moisture *content*), usually by volume. For both, it is necessary to understand the relationship between soil water tension and content for the specific soil to interpret the results for best irrigation management (see section 3.5.1 *Soil Water Characteristics*). Most of the instruments are installed in the soil at the beginning of the irrigation season, eliminating the need to obtain soil samples. Some can even be equipped to transmit readings by telemetry.

Soil Moisture Determination using Soil Water Budgeting (Check Book Method)

Water balance methods of scheduling are based on calculated soil moisture levels through the growing season. All inputs and removals of water from the root-zone are measured or estimated frequently (usually daily), and a running "balance" of soil moisture is calculated.

At the start of the season, soil moisture level is either determined (e.g. by feel method), or assumed to be at

Table 3.5-3 Guide for estimating soil moisture by feel and appearance. (Courtesy of the USDA)

Soil Texture	Available Soil Moisture (% volumetric)				
	0-25	25-50	50-75	75-100	100 (field capacity)
Fine sand & loamy fine sand	Appears dry, will hold together if not disturbed, loose sand grains on fingers.	Slightly moist, forms a very weak ball with well-defined finger marks, light coating of loose and aggregated sand grains remain on fingers.	Moist, forms a weak ball with loose and aggregated sand grains on fingers, darkened color, light uneven water staining on fingers.	Wet, forms a weak ball, loose and aggregated sand grains remain on fingers, darkened color, heavy water staining on fingers, will not ribbon.	Wet, forms a weak ball, light to heavy soil/water coating on fingers, wet outline of soft ball remains on hand.
Sandy loam & fine sandy loam	Appears dry, forms a very weak ball, aggregated soil grains break away easily from ball.	Slightly moist, forms a weak ball with defined finger marks, darkened color, no water staining on fingers.	Moist, forms a ball with defined finger marks, very light soil/water staining on fingers, darkened color, will not slick.	Wet, forms a ball with wet outline left on hand, light to medium staining on fingers, makes a weak ribbon.	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking, medium to heavy soil/water coating on fingers.
Sandy clay loam & loam	Appears dry, soil aggregations break away easily, no staining on fingers, clods crumble with applied pressure.	Slightly moist, forms a weak ball with rough surfaces, no water staining on fingers, few aggregated soil grains break away.	Moist, forms a ball, very light staining on fingers, darkened color, pliable, forms a weak ribbon.	Wet, forms a ball with well defined finger marks, light to heavy soil/water coating on fingers, ribbons between thumb and forefinger.	Wet, forms a soft ball, free water appears briefly on soil surface after squeezing or shaking, thick soil/water coating on fingers.
Clay, clay loam & silty clay loam	Appears dry, soil aggregations separate easily, clods are hard to crumble with applied pressure.	Slightly moist, forms a weak ball, very few soil aggregations break away, no water stains, clods flatten with applied pressure.	Moist, forms a smooth ball with defined finger marks, light staining on fingers, ribbons between thumb and forefinger.	Wet, forms a ball, uneven medium to heavy soil/water coating on fingers, ribbons easily.	Wet, forms a soft ball, free water appears on soil after squeezing or shaking, thick soil/water coating on fingers, slick and sticky.

field capacity. Soil water inputs are rainfall (less estimated runoff) and irrigation. Soil water removals are evapotranspiration (ET) and deep drainage through the root zone, which is estimated from inputs and soil water holding capacity. Evapotranspiration is a combination of moisture loss from the soil surface by evaporation and from the plant tissue by transpiration.

The simplest approach is to estimate daily ET based only on crop age or stage of growth and daily maximum temperature. The ET values are derived from a chart similar to the one in Table 3.5-2, but with ET values applicable to your production region. More accuracy can be obtained using more frequently measured atmospheric condition, such as solar radiation, wind, temperature, and humidity. Other approaches use a device from which water evaporates under the local conditions (e.g. evaporation pan, atmometer). Daily ET is then calculated from the amount of water evaporated, by application of a factor for the crop stage.

A computer is usually used to do the daily calculations of soil water levels from the water input/output data. Irrigation is used to keep the soil moisture in the desired range. Since the checkbook method uses only an estimate of ET, and relies upon several assumptions about water behaviour in the soil, the actual soil moisture should be checked periodically and corrected. Under normal soil and weather conditions, checks are recommended every two weeks. For a more detailed explanation of the checkbook method, obtain a copy of the fact sheet *Irrigation Scheduling by the Checkbook Method* from the North Dakota State University Extension Service.

Irrigation scheduling is conducted through the growing season when there are other pressing demands on growers' time, such as pest management, crop nutrition, irrigation, and harvest of other crops. For this reason, and due to the specialized instruments or skill needed for some of the methods, many growers contract scheduling services or purchase related information - e.g. soil moisture monitoring, software, ET estimates.