Soil Moisture and Temperature Consideration

Effect of Soil texture on water Storage and Water Movement

Differences in the ability of different soil types to store water do exist. Sandy soils hold about 101.6 mm (4 in) of available water within the depth of root penetration about 1.22 m (48 in), loams and clay loams 152.4 to 177.8 mm (6 to 7 in), and clays about 203.2 m (8 in).

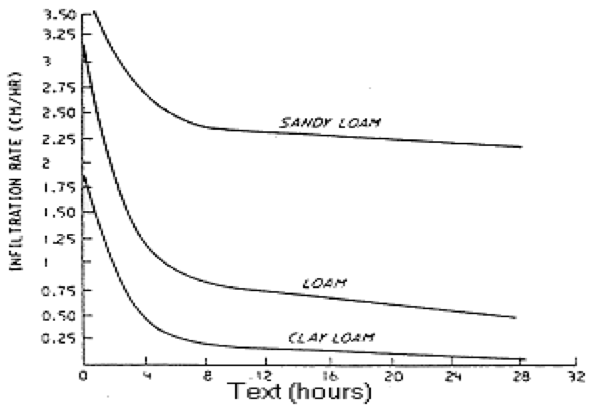

Figure 1 Change in infiltration rate with time.

The rates at which water penetrates the soil and moves in it depend mainly on soil texture, and it is called infiltration rate. Figure 1 shows the relationship between soil texture and water infiltration. A sandy soil has large pore spaces through which water will move quickly and easily, clay soils have smaller pore spaces, causing water to move more slowly.

Soil Water Management Strategies

There are two basic sources of moisture for crop use: Growing season precipitation and soil stored moisture (e.g snow) received during the nongrowing season. Any practice that keeps rain/ snow where it falls causes more water to enter the soil. Such practices include the following:

- Conservation of snow.
- Use of crop residues.
- Tillage operations.
- Summerfallowing.

Conservation of snow

Research work conducted at Swift Current and elsewhere on the prairies has shown that significant amounts of moisture may be conserved by leaving the stubble standing to trap snow during the winter, than if it was worked down or destroyed by fire. Fall cultivation of stubble resulted in 15 to 20 mm (0.59 to 0.78 in) less soil water recharge than standing stubble which also translated into measurable yield differences of approximately 20 kg/ha/mm (7.6 bu/ac/in). A modification of stubble management has recently shown some promise. At Swift Current, the use of cereal trap strips resulted in the conservation of 13 mm (0.51 in) of extra available soil moisture compared to stubble cut at a uniform standard height. Interestingly, it was noted that significantly higher spring wheat yields were obtained in the stubble trap strip compared to those of short stubble especially in the dry years. When the soil is dry, up to half of the snow fall or 10 - 15 % of annual precipitation, can be stored in the soil provided the snow is held in the field.

Moisture from snow retention can provide the crop a good start in the spring, but it cannot alleviate a drought if rainfall during the growing season is inadequate.

Use of crop residues

Crop residue left on the surface reduces soil erosion. It also helps to conserve water by decreasing evaporation and runoff and by increasing snow retention and water infiltration. The effectiveness of crop residues in conserving water depends on the amount left on the soil surface.

Tillage operations

Tillage operations (direction and frequency) can have effect on moisture conservation. Tillage across, rather than up and down, hilly land helps to prevent rapid runoff of water. The number of tillage operations directly determine the amount of crop residue left on the soil surface. In other words, each tillage operation reduces both the amount of residue, and consequently the amount of water conserved.

Zero tillage or direct seeding places the seed directly in the seedbed with no prior tillage. This prevents drying out the seedbed through tillage and ensures a firm, moist seedbed for rapid germination. The soil temperature will, however, be slightly cooler due to a greater reflectance of solar radiation by the crop residue than on a field with less crop residue due to tillage operations.

Summerfallowing

The practice of summerfallowing requires that the soil possess the capability to capture and store available water during the 21 month period of fallow preceding spring sowing. As mentioned earlier, different soil types possess different water holding capacities. As a result, there have been claims that summerfallowing is inefficient in conserving moisture. Supporters of summerfallowing contend that:

- Higher yields on summerfallow illustrate that moisture is conserved and nitrogen is increased in the soil during the summerfallow period.
- Frequent cultivation reduces weed population and consequently reduces chemical costs.
- Summerfallowing also distributes the workload more evenly throughout the year.
- It stabilizes farm income and reduces or eliminates the problems caused by insufficient quotas.

On the other hand, non-supporters of summerfallow point to its negative aspects, they claim that:

- Wind and water erosion are increased.
- Organic matter in the soil is reduced, this lowers the water holding capacity of the soil and in some cases increases soil salinity, resulting in decreased fertility and consequently reduced yields.

On average summerfallowing is most effective in conserving water in areas with intermediate spring soil water content and on soils with a higher available water holding capacity. Soil water contents at heading were greater underwheat fallow rotation compared to continuous wheat and increased with increased available water holding capacity. Given the conditions that exist in the arid regions of the Brown and Dark Brown soil zones, it would appear that any little amount of moisture conserved through summerfallow in these regions may be quite beneficial at the start of the season.

Plant Available Water

Plants can readily use water held in the soil between field capacity and the permanent wilting point. This is called available water. It is measured in millimetres or in inches of water per unit depth of soil. The relationship between the various categories of soil moisture and soil texture is shown in Figure 2. Medium and heavy textured soils hold much more available water than coarse or sandy soils.

Field Capacity

A soil is at field capacity after being thouroghly soaked and allowed to drain freely for a few days. For most soils this is the best moisture condition for plant growth because the soil holds maximum amount of available water to the plant. Field capacity also depends on soil texture in that clay soils hold more water at field capacity than sandy soils.

Permanent Wilting Point

As crops draw water from the soil, it becomes increasingly difficult for them to use the water that is left. If no water is added to the soil, at some point plants will not be able to extract enough moisture to meet their requirements, consequently they begin to wilt. At this point the soil water is referred to as Permanent Wilting Point. That is the point at which soil water is no longer available to plants.

Determination of Soil Moisture

The simplest way to determine soil moisture content is by the "feel" method. By feeling, squeezing and observing a handful of soil, one can determine the soil texture. Based on the soil texture and depth of moist soil one can determine the amount of moisture present in the soil. The only equipment needed is a shovel or auger to obtain samples of the soil from the desired depths. Figure 3 outlines determination of soil texture by the "feel method". The Brown Soil Probe is an effective tool for determining the depth to which the soil is moist.

Effects of Moisture on Plant Growth

Moisture and germination

Moisture availability has been regarded as the major factor determining the onset of germination. Germination is assumed to start if the soil moisture content is higher than 1.2 times Wilting point. As long as this condition is satisfied, germination proceeds unhampered through its various phases, until at the end of seven days germination is assumed to be completed and emergence occurs. If the soil dries out to less than 1.2 times Wilting point within 4 days after the onset of germination, the process is halted and will resume after rewetting from the point where it stopped. If drying out occurs four or more days after the onset of germination, deterioration of the germinating seeds takes place. If the dry conditions persist for more than six days, the seeds are assumed dead and there will be no crop established from that seed.

Functions of water in the plant

Water serves four general conditions in plants: the major constituent of the physiologically active tissue; As a reagent in photosynthetic and hydrolytic processes; As a solvent for salts, sugars and other solutes and water is essential for the maintenance of turgidity necessary for cell enlargement and growth .

Water requirements

The amount of water used by the crop or evapotranspiration at any time depends on the growth stage of the crop, air and soil temperature, wind speed, relative humidity, plant physiology and available soil water. Research in Alberta has indicated that for Hard Red and Soft White Spring Wheats under irrigation, water use ranges from 1.0 to 3.0 mm/ day (0.04 to 0.12 in/day] during the early stages of growth, rising to 7.0 to 7.5 mm/day (0.28 to 0.30 in/day] during the boot to bloom stages. This conforms with the report of Dunlop and Shaykewich (1982) that the rate of water evapotranspiration at the beginning of the season is low, perhaps 30% of potential evapotranspiration but equals potential evapotranspiration as soon as the leaves provide complete ground cover. It remains at this level until the crop begins to mature at which time water use drops off rather rapidly.

Water uptake and extraction patterns are related to root density. In general 50 to 60 percent of the total water uptake occurs from the first 0.3 m (1ft), 20 to 25 percent from the second 0.3 m (1ft), 10 to 15 percent from the third 0.3 m (1ft) and less than 10 percent from the fourth 0.3 m (1ft) soil depth. Normally 100 percent of the water uptake occurs over the first 1.0 to 1.5 m (3.3 - 5.0 ft).

Moisture stress at various growth stages and yield

As previously mentioned, the wheat plant requires different amounts of water at different stages of growth. Research has shown that water stress at some of the stages of growth can significantly reduce grain yield.

Campbell (1968) in Saskatchewan using Chinook Wheat cultivar, determined the effect of soil water stress applied at various growth stages. The wheat was grown in clay loam soil in a growth chamber at 80% relative humidity. Different combinations of "dry" and "wet" periods were maintained for comparisons. The dry period involved re-wetting the soil to field capacity (25% by soil weight] after water was depleted to near permanent wilting point (10% by soil weight]. The wet treatment involved re-wetting after soil was depleted to 16% by weight. It was found that the highest yields were obtained when plants were grown under dry conditions to shot blade stage (stage immediately preceding emergence of the head from the sheath] and wet conditions thereafter. This treatment apparently had the highest number of heads per pot, along with good seed set. The lowest yields were obtained when the water conditions were reversed. This treatment had the lowest number of heads even though the seed set was over 60%. Similar findings come from the work of Lehane and Staple (1962) who found that grain yields on loam soils subjected to stress during early stages of growth were more than twice those of late stress. Crops with early stress yielded about two thirds of optimum and those with late stress one third of optimum. The optimum yields were obtained under optimum moisture conditions (i.e soils were brought up to field capacity each time the available moisture was reduced to 75% of its initial value) and optimum yields differed little with soil texture. It was noted that crops with late moisture stress on heavy clay suffered much less resulting in significantly greater yields than those on loams. The greater yields were attributed to reduced growth and transpiration in early stages of the crop so that more moisture was left for heading and filling.

The most critical stages for rainfall is at planting to emergence and at five-leaf stage to early dough for wheat grown on stubble, and at Shot blade to Soft dough for wheat grown on fallow.

Campbell et al., (1988) reported that for both fallow and stubble systems, precipitation received during grain development (five leaf to soft dough) was very important, but for stubble seeded crops on dryland, precipitation at seeding was just as important since it is required for proper plant establishment. It was noted that precipitation at seeding has not been fully emphasized in the past because of the higher stored soil moisture in fallow and that the influence of growing season precipitation on yield only becomes critical after the five leaf stage - when stored water would normally become depleted if early growing precipitation was low.

Table 1. The importance of rainfall by stage of growth for wheat at Swift Current.

Wheat growth stage	Relative Importance(%)	
	Stubble	Fallow
Planting - emergence	29	14
Emergence - 3 leaf	8	16
3-leaf - 5 leaf	1	10
Shot blade - soft dough	16	42
Soft dough - harvest	11	3

Water use efficiencies - general
Water use efficiencies (WUE) have varied depending on the wheat type, soil zone, and type of cropping (fallow vs stubble). For instance, in Manitoba, Rourke (1989) recently reported WUE values of 10.5 and 13.7 kg/ha/mm (4.0 and 5.2 bu/ac/in) of water for Hard Red Spring and Canadian Prairie Spring wheats respectively. See Table 2.

Table 2 - The effect of water use on grain yield of wheat.

Market class	Cultivar	Threshold value**	bu/ac/in*	Years	Location	Source
HRS	various	5.4	4.9	1925-52	Swift current,SK	Staple and Lehane, 1954
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HRS	Sinton	3.5	4.0	1977-79	Outlook,SK	Henry, J.L. unpub. data
HRS	Neepawa	1.4	3.5	1981-85	Brooks,AB	McKenzie, R.C. unpub. data
SWS	Fielder	4.5	4.1	1977-79	Outlook,SK	Henry, J.L unpub. data
SWS	Fielder	2.1	5.4	1981-85	Brooks, AB	McKenzie, R.C. unpub. data
Extra Strong	Glenlea	4.4	4.4	1977-79	Outlook, SK	Henry, J.L unpub. data
CPS	HY 320	3.2	5.6	1983-85	Brooks, AB	McKenzie, R.C. unpub. data

± HRS=Hard Red Spring: SWS= Soft White Spring: CPS= Canada Prairie Spring
*Marginal yield increase= Additional bu of grain produced for each inch of moisture above threshold value.
**Threshold value=Minimum amount of available moisture needed to produce a grain crop.
Source, Henry et al., 1986

Soil temperature and germination
Soil temperature affects the germination and growth of cereal crops. Soil temperature varies with time and depth, and is determined by the radiation reaching the soil surface, the quality of the surface thermal conductivity and heat capacity of the soil.

Spring cereals seems to emerge rapidly at soil temperatures ranging from 24 to 28°C. The rate of emergence of spring wheat increased from 6 to 24°C, however, final emergence was not affected. The minimum temperature for germination of cereal crop is 4°C and preferred temperature is 20°C.

Soil temperature and plant growth
Soil temperature affects plant growth indirectly by affecting water and nutrient uptake as well as root growth. At a constant moisture content, a decrease in temperature results in a decrease in water and nutrient uptake. At low temperatures, transport from the root to the shoot and vice versa is reduced.

The optimum temperatures for root growth are probably lower than for shoot growth and can differ with growth stages. The optimum temperature for root growth of spring wheat was found to be 22°C or less.

Temperature and plant growth
Temperature determines the rate of crop development and consequently affects the length of the total growing period of the crop. Growth starts at some minimum temperature (4-5°C). As temperature increases, rate of plant growth increases until an optimum temperature is reached. Mean daily temperature for optimum growth and tillering is between 15 and 20°C. The rate of growth will decline as the temperature rises above this otimum range. At the end growing season, growth will stop when air temperature falls below 5°C.

The interval between floral initiation and anthesis is shorter at high temperature (30°C) than at low temperature (10°C). Increased light intensities resulted in an increased rate of elongation of the developing inflorescence and earlier anthesis (flowering).

Growing Degree Days

Growing degree days (GDD) are calculated as the difference between mean daily temperature, and a (base) threshold temperature taken as 5°C for wheat. In the literature, the base temperature has ranged from 0 to 5.5°C. The growing degree days are calculated for each day of the growing season and summed to give an accumulated degree days for the growing season.

Cumulative growing degree days has been shown to be a reliable estimator of hard red spring wheat pre-anthesis (flowering) development rate and grain dry matter assimilation rate. The utilization of GDD has been used as an estimator of change in spike (head) and grain water concentration, hence the stage of maturity. It was found that GDD accounted for 90% of the variability in spike water. Research is still underway in North America to more fully determine the relationships between GDD and other characteristics associated with growth stages.