Information Sheet

5.20 Operating Rules of Irrigation Systems

Introduction

An irrigation system is carefully designed to apply a specific amount of water (**application depth**), over a set amount of time (**stand** or **set time**) for a given frequency/return period (**cycle length**). To meet the irrigation requirements of the crop, the irrigation system hardware is always accompanied by specific operating rules. Designers are responsible for equipping farmers with the operating rules, which are generally specific to the site and design. Depending on the type of irrigation system, operating rules could include, for example:

- the stand or set time (maximum operating hours per shift),
- the number of shifts per day,
- the cycle length (minimum interval between successive irrigation applications, or minimum time required to complete a cycle and return to the starting position).

The typical range of target application depths and associated operating rules for common irrigation systems in the South African sugar industry is presented in Table 1.

The values in Table 1 are guidelines and can be adjusted for specific site variations, provided they fall within acceptable irrigation design and management practices, and have minimal negative impacts on the crop, or soil and water resources.

Table 1: Typical operating rules and target application depths for different irrigation systems

	Dragline & Semi-Permanent sprinkler	Centre Pivots	Drip
Stand/set times (hrs)	5 – 12	N/A	2 – 6
Shifts per day (No.)	2 – 3	N/A	Multiple
Cycle length (days)	4 – 12	2 – 6	1 – 3
Target Application Depth (mm)	30 – 60	12 – 40	4 – 10

In this Information Sheet, we illustrate how the operating rules are used in conjunction with the irrigation hardware to meet the crop water requirements with minimal wastage of water. The negative effects of not adhering to the operating rules of an irrigation system are also presented.

Interaction between irrigation hardware and operating rules

An irrigation designer will determine the crop water demand and then select the equipment and operating rules required to meet the crop requirements. As an example, this is illustrated in Figure 1 for sprinkler irrigation. While sprinkler irrigation is used as an illustrative example, the principles relating to operating rules are applicable for all irrigation systems.

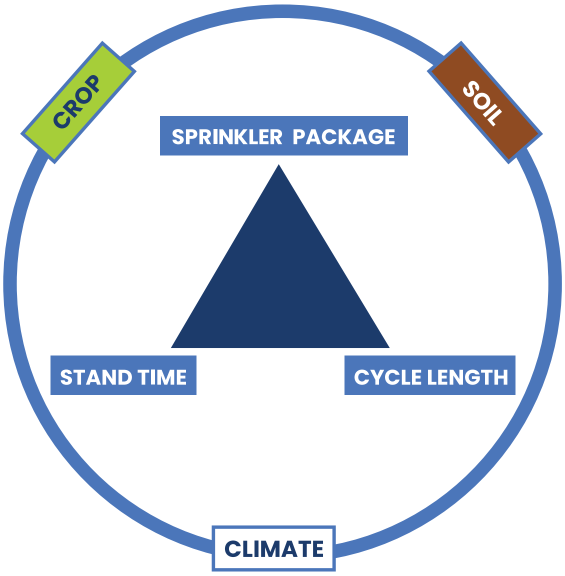


Figure 1: Illustration of irrigation parameters to be selected for sprinkler irrigation.

In Figure 1, the crop, climate and soil represent existing or fixed parameters that would be used to determine the crop water requirements and accordingly the target application depth. The irrigation designer would then select the sprinkler package, the stand time and cycle length (all in conjunction with one another) to supply the crop water requirements and associated target application depth. This is best explained with the following illustrative example.

Target Application Depth

The target application depth refers to the amount of water applied in mm over a single irrigation event. One can also think of it as the amount of water that will be captured by a catch can/rain gauge, when the system is operating as per design. The irrigation designer would determine the soil water storage capacity, normally referred to as the Total Available Water (TAW) (Figure 2).

More information on how to calculate the TAW from clay % can be found in a document titled "Understanding the FAS soil report", which is freely available on the SASRI website www.sasri.org.za/e-library. As a norm, the stress point is 50% of TAW. As soil water is depleted below the stress point, the crop will begin to show increasing levels of water deficiency stress. Therefore, design norms typically allow for depletion of 50% of TAW and irrigation aims to replace the water removed. For example, if the TAW is determined as 80 mm, then the target application depth would be set at 40 mm.

Design Rule: Target application depth (mm) ≤ 50% Total Available Water

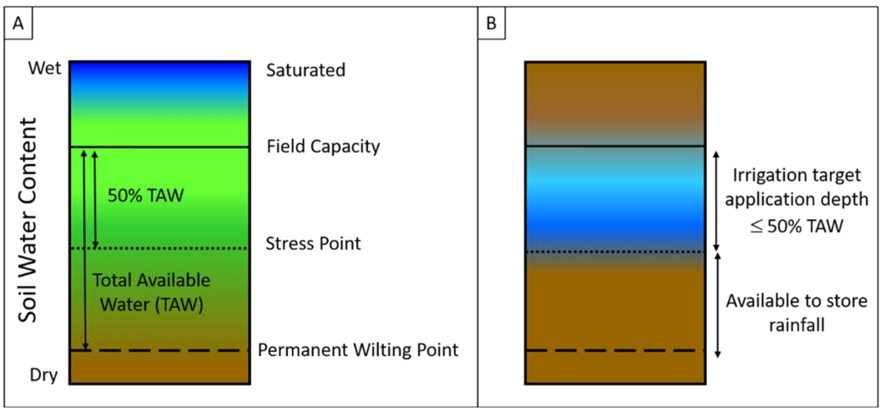


Figure 2: Illustration of the (A) Total Available Water (TAW) and (B) the design rule where the target irrigation application depth must be less than or equal to 50% of TAW.

Stand time

The stand time refers to the number of hours required per shift to apply the target application depth, for a given sprinkler delivery rate. In other words, the sprinkler package is selected in conjunction with the stand time, to supply the desired target application depth. In Table 2, we demonstrate how different combinations of sprinkler options and stand times can be considered, to meet a target application depth of 40 mm. In selecting which sprinkler option to make use of, the designer would also need to ensure the sprinkler application rate is less than the (terminal) soil infiltration rate.

Design Rule: Sprinkler application rate (mm/hr) < soil infiltration rate (mm/hr)

Table 2: Illustrative example of sprinkler package and stand time options to meet the desired target application depth of about 40 mm

Sprinkler Package Options	[2]Application (precipitation) rate (mm/hr)	Stand time (hours)	[3]Application depth (mm)	[4]Modified Application depth (mm)	
				stand time – 2 hours	stand time + 2 hours
Option 1: [1]Can deliver 1.3 m³/hr* with a 3.8 mm nozzle at 280 kPa pressure, at 18 m x 18 m spacing	4.01	10	40.12	32.08	48.12
Option 2: [1]Can deliver 1.6 m³/hr* with a 4.2 mm nozzle at 300 kPa pressure, at 18 m x 18 m spacing	4.94	8	39.51	29.4	49.4
Option 3: [1]Can deliver 2.2 m³/hr* with a 4.8 mm nozzle and 380 KPa pressure, at 18 m x 18 m spacing	6.79	6	40.74	27.16	54.32

[1] *Information normally taken from technical sheets provided by the sprinkler manufacturer/supplier*

[2] *Application rate* $= \frac{\text{Sprinkler Flow Rate Q}}{\text{Area covered by one sprinkler}}\left[\frac{m^3/hr}{m^2}\right] \times 1000, \text{e.g. Option 1} = \frac{1.3\ m^3/hr}{18m \times 18m} \times 1000 = 4.012\ mm/hr$

[3] *Application Depth (mm) = Delivery Rate (mm/hr) x Stand time (hrs)*

[4] *Modified application depth illustrates the detrimental effect of under-irrigation when the stand time is reduced by 2 hours, or over-irrigation when the stand time is increased by 2 hours.*

* *1 m³ = 1000 litres. Therefore, 1.3, 1.6 and 2.2 m³/hr = 1 300, 1 600 and 2 200 litres/hr*

Once the sprinkler package has been selected and installed, the system should be operated according to the corresponding stand time. Any deviation from the stand time would result in either over- or under-application of water, relative to the target application depth. This is illustrated in the last two columns in Table 2, where the modified application depth corresponds to reducing the stand time by 2 hours or increasing the stand time by 2 hours, respectively.

Cycle Length

The cycle length refers to the minimum number of days before the same position is irrigated again. Given the target application depth, the designer would next use the long-term crop evapotranspiration (ET) and/or effective rainfall values to determine the Net Irrigation Requirement (NIR). The NIR is the amount of irrigation required to meet the daily crop water requirement (See Information Sheet 5.18: ET Calendars). The cycle length in days is simply calculated as the ratio of target application (mm) depth to NIR (mm/day).

Example:

Suppose the peak NIR in Komatipoort is 6.1 mm/day, then the cycle length is determined by:

Cycle length (days)= $\frac{\text{Target Application Depth (mm)}}{\text{NIR}\left(\frac{\text{mm}}{\text{day}}\right)} = \frac{40\text{ mm}}{6.1\text{ mm /day}} = 6.6\text{ days, round down to 6 days}$

In other words, if the irrigation system applies 40 mm of water, and in the peak growth season the crop extracts 6.1 mm/day, then it would take the crop 6 days to deplete the soil water before irrigation is required again. If irrigation is delayed for more than 6 days and no rainfall is received, then the crop would experience stress during peak periods. If irrigation is applied again before the 6-day cycle, that would result in excess irrigation and wastage of water, plus potential crop stress if the soil becomes saturated.

Note: The irrigation system capacity is determined as 40 mm divided by 6 days, which is equal to 6.67 mm/day (well matched to the peak NIR).

Interaction of irrigation scheduling and operating rules

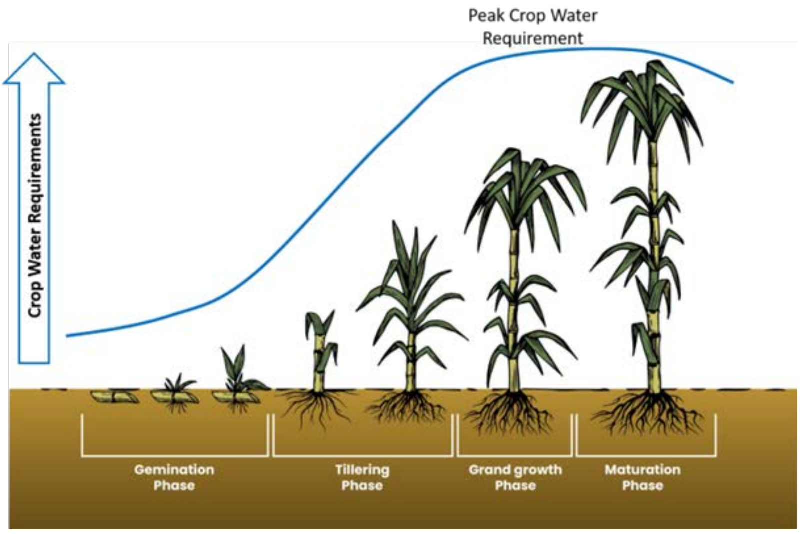
The act of deciding when, where and how much water to apply is called irrigation scheduling. Daily irrigation amounts can never be fixed across a season because the crop requires different amounts of water, depending on:

(1) Crop growth stage (stage of canopy development) as illustrated in Figure 3,

(2) time of year in relation to hotter summer or cooler winter periods, and

(3) the amount and distribution of rainfall on a daily or weekly basis.

It is important to note that the irrigation hardware and associated operating rules are selected/designed to meet the expected peak/maximum crop water requirements for a specific site. The peak crop water requirements only occur at full canopy development and/or in hot summer months and **not** for the entire crop season. Therefore, irrigation has to be adjusted to apply less water when the crop is younger (before full canopy development) or during the cooler winter months. Irrigation also needs to be adjusted for rainfall events.



▲ Figure 3: Crop water requirements in relation to the sugarcane crop growth stages.

Thus, outside of the peak crop water requirement period, irrigation is scheduled by adjusting the operating rules in a planned and intelligent manner. The adjustments should be informed by accurate irrigation scheduling tools. When the crop requires less water:

- the stand time can be reduced to apply less water than the design target application depth, keeping the cycle length the same, or
- the stand time is kept the same and the cycle length is extended to allow more time for soil water depletion before the next irrigation cycle is triggered. In other words, since the crop is extracting water from the soil at a slower rate, one can complete an irrigation cycle and wait the extra days for the soil water to be depleted to the desired level before irrigating again.

Understanding the interrelationships between the crop water requirements, TAW, target application depth, sprinkler application rate, stand time and cycle length is necessary to understand the consequences of adjusting the operating rules of an irrigation system. Intelligent and calculated adjustments of the operating rules to apply different amounts of water during different crop growth stages and for different times of the year (schedule irrigation) is acceptable.

The consequences of adjusting operating rules without understanding the interrelationships, however, can be negative and costly:

- The design stand time should never be exceeded (e.g. forgetting to move a set of sprinklers and they are left in the same position for two shifts). Application of water for more hours than the specified design stand time will result in applying more water than the soil can store, resulting in wastage of water, unnecessary electricity costs, leaching nutrients out of the root zone, waterlogging that causes crop stress due to lack of air in the root zone and sometimes soil erosion. Where there is consistent and long-term over application of water due to use of longer-than-designed stand times, this can lead to the development of shallow water tables and saline or sodic conditions, which are much more difficult and expensive to resolve.

- The cycle length should never be shorter than the specified/design cycle length. This will also result in over-irrigation (not allowing enough time for the crop to extract water from the previous irrigation cycle before applying water again). This can result in the same problems as noted above.

- Extending the cycle length for younger stages of the crop is acceptable due to lower water requirement, however, care must be taken not to delay irrigation excessively. Crop stress can easily occur if, for example, unseasonably warm weather ("hot days") occurs during the generally colder winter period. Irrigation scheduling tools should inform the extension of cycle length when the crop is not experiencing the peak crop water requirements.

Summary

The sprinkler/dripper package, stand/irrigation time and cycle length are selected in conjunction with one another to supply the peak crop water requirements, which only occur for a portion of the growing season (during full canopy and hot summer months). The operating rules can be adjusted to apply less water for the periods outside of the peak crop water requirements. Irrigation stand time can be reduced in a planned and intelligent way to apply less water than the design target application depth. If the stand time is exceeded, this will result in applying more water than the soil can hold.

Similarly, the cycle length can be increased to allow more time for soil water to be depleted during cooler periods and for younger crops. Irrigation cycle lengths should never be shorter than the design cycle length.

Adjustment to cycle lengths and/or stand times should always be informed by accurate irrigation scheduling tools. Uninformed changes to stand times and cycle lengths can result in wastage of water, unnecessary electricity costs, crop stress, and many other negative consequences. Finally, irrigation hardware and operating rules such as the stand time and cycle length are interlinked, and adjustment on any one component will have a knock-on effect on the other.

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