Supplemental irrigation for improved water use efficiency and productivity of wheat in rain fed agriculture, Morocco

SUMMARY:

Climate Change has had negative effects on the water availability for agriculture in Morocco within the last few decades. Generally, the amount of rainfall declined while at the same time temperatures increased, putting pressure on water supplies for agriculture. Throughout the Central and West Asia and North Africa region (CWANA) fluctuations and reductions in annual rainfall are provoking frequent droughts. But, not only climatic factors led to a more severe water scarcity, also the increased demand of available water for municipal and industrial purposes, has resulted in perpetually decreasing allocations for water in agriculture. However, a large part of the agricultural water use in Morocco is reserved for irrigated agriculture purposes.

70% of the total cropping area in Morocco is used for cereals, amounting to a total of about 5 million hectares. More than half of the area is used for the production of wheat as the main cereal crop, most of it bread wheat varieties. The growing season consists of up to 160 days of cultivation between November and June, depending on the date of planting (usually between November and January). During these months, most of the precipitation needed for wheat production occurs. Thus, wheat crops usually do not suffer from moisture deficits before the month of March. However, rainfall rates usually drop in early spring (March-April) and most of the stored soil moisture is lost through evapotranspiration (ET). This is when a stage of increased soil moisture deficit begins. The uneven distribution of rainfall causes that the crop suffers from water deficit in later stages of growth, leading to reduced production due to terminal moisture stress. This phenomenon not only occurs in Morocco, but throughout the entire CWANA region. Generally, the actual productivity of rain fed systems throughout the region remains below the potential rain fed productivity.

This practice presents a way to increase the efficiency of water use by supplemental irrigation (SI) in rain fed wheat production in Morocco. Emphasize is given to the different crop growth stages of wheat and the approach of supplemental irrigation (SI). The different stages of wheat growth are explained, outlining the most appropriate approach of SI. When, how and how long should be supplemental irrigation applied to ensure a higher yield for wheat in a rain fed system in Morocco? The practice aims at answering these principal questions, next to an explanation of the basic concept of supplemental irrigation.

The practice has been tested and validated by a research campaign, conducted within the project: ?Community-Based Optimization of the Management of Scarce Water Resources in Agriculture - Improving water and land productivities in rain fed systems in CWANA?. The International Center for Agricultural Research in the Dry Areas (ICARDA) conducted various on-farm trials in the Tadla region of Morocco for the identification of the best approach of supplemental irrigation for the production of the major crops.

KEYWORDS:
- supplemental irrigation [1]
- dryland farming [2]
- dryland management [3]
- drylands [4]
- conserving water [5]
What is supplemental irrigation?

In rain fed agriculture of semi-arid and arid regions, water is the most limiting factor. That entails the need for additional sources of water in case of lack of rainfall. Irrigation systems can help to solve the problem, but what if the sources for irrigation water are very limited?

Usually, wheat crops do have little need for moisture in early stages of growth (November to January). This is due to a low rate of water uptake, when the seedling is young. Hence, during the early stages of crop growth throughout the winter months, there is more water through rainfall available than would be needed by the crop. At later stages of growth (during the dryer months), there usually is less water available than the growth and inflorescence of the crop would require (compare figure below).
An adapted system and technology, to uphold even soil moisture levels and balance the scarcity of soil moisture in later growth stages could be the supplemental or additional provision of water to rain fed agriculture by means of irrigation. This technology is called supplemental irrigation or SI. The technique consists of applying small quantities of water during critical periods to improve and stabilize yields, save water and balance low water availability with a sustainable production level.

Supplemental irrigation (SI) is especially effective in very dry years, and it has been shown that it can even triple the yield when applying relatively small amounts of irrigation water.

Three aspects define supplemental irrigation (SI):

1. Supplemental water is applied to a crop that usually yields without the need for irrigation;
2. Supplemental water is only added when there is a lack of rainfall and the water that usually is provided by rain is missing. It is a supplemental (additive) water provision to the common rainfall water provision;
3. Supplemental irrigation is meant to provide additional water in critical growth stages and not to ensure moisture stress-free conditions for the crop. Rather to ensure that the minimum amount of water is available for the critical stages of crop growth. Little water stress to the crop in early stages might even be beneficial for root formation.
How much of supplemental water?

Supplemental water is given to the crop in specific amounts during or before different growth stages. There are stages that are more and stages that are less susceptible to water deficits. Thus, it is important to understand how much and at which stage of crop growth supplemental irrigation water should be best applied. In general, one to three supplemental irrigation applications of not more than 100 mm each between late March and early May are recommended.

Research by ICARDA has shown that it is recommended to use deficit supplemental irrigation when there is not enough water available for full supplemental irrigation. It is as follows:

- Applying SI, using 50% of the full SI requirements to the whole farm is more efficient than applying full SI to only half of the farm with the other half purely rain fed. Yields are higher by around one third;

- One to two thirds of the full amount of water that would be used when applying full irrigation is more efficient for the water productivity. It is highly recommended to use only 33 to 66% of the full amount of irrigation water for a higher yield. Research conducted in Syria has shown these results, indicating that farmers usually tend to overuse their water resources.

Timing

Applying supplemental irrigation also can help to ensure to sow wheat in early November, when the onset rainfall for sowing is missing. In the lowlands, it is recommended to sow in early to mid-November and support it by supplemental irrigation when onset rainfall is missing. Also in the highlands, where the crop is dormant, it is beneficial for yields to proceed with SI, when early rain is missing. Here, only a good early
crop stand can ensure the survival during dormancy and increase water productivity.

Supplemental irrigation has to be adapted to the needs of the wheat crop. This means that supplemental irrigation should be added at the right moment, which is exactly before a critical growth stage and only when direct rain water is missing or soil moisture is poor. The efficiency of water use with supplemental irrigation is much higher than when using constant irrigation. This saves scarce water resources and helps to increase crop yields at the same time.

Temporal planning

The exact date of SI application cannot be determined in advance, because it is supplemental in character. SI should be applied when soil moisture drops below critical levels. It is recommended to measure soil moisture on a regular basis, in order to be prepared for applying supplemental irrigation. Usually, farmers rely on their experience related to the crop appearance and the amount of rainfall. When there is water supply, they tend to irrigate more frequent than would be necessary, just to ensure that yields are stabilized. It is recommended to check national weather services for adapting supplemental irrigation to the actual rainfall predictions. A simple visual soil moisture assessment in the field could be appropriate to measure the day-to-day soil moisture.

Sources of irrigation water

The water used for supplemental irrigation can originate from groundwater sources like rivers and lakes, or surface water reservoirs. Also water harvesting is a good source for irrigation water. Recently, waste water has been tested for the use in irrigated agriculture and supplemental irrigation.
Irrigation systems

The general irrigation systems can be used for SI. The main difference with SI is the management of when and how much to irrigate, thus, the exact irrigation planning. The following systems are commonly used for
Surface irrigation techniques, like basin, furrow and border irrigation; Sprinkler irrigation methods, i.e. set systems, traveling guns and continuously moving systems; Trickle irrigation systems, comprising drip irrigation, micro-sprinklers and sub-surface systems.

**Surface systems** are used in areas, where SI is applied only once or twice a year. Investments for these systems are low and if irrigation water is not too expensive, they are economically sound.

**Sprinkler systems** are applied when water is expensive, labor costs high and the surface not suitable for a full irrigation system.

Also **water harvesting structures** are highly recommended as water source. Macro- and micro water harvesting systems can be used for collecting water and storing it in surface tanks and or groundwater aquifers.

**Supplemental irrigation in wheat production in Morocco**

In Morocco, the technology of supplemental irrigation is applied during the growing season to overcome lack or delay of precipitation and by this sustain crop water needs. The quality and quantity of the crop is determined by supplemental irrigation, since the country has undergone severe droughts since the 1980s.

**Main crop growth stages and water requirements during the single stages**

Nearly the half of the crop production area of the Tadla region is used for cereals. In the last years, bread wheat production increased, with a concurrent decrease of durum wheat. The dominant rotation is wheat/sugar beet, with some cultivation of vegetable crops and alfalfa after cereals. Growth periods of wheat occur between planting after the first rains in autumn (60% in December and 33% in January) and harvesting, which starts in May and can range till mid-June. The moisture in the grain should be around 10%, in order to be harvested. The whole cycle of crop growth endures around 160 days.

There are 4 different stages of crop growth that can be distinguished:

1. **Germination to the beginning of stem elongation:**
   - This is the stage from when the plant emerges from the seed until the seedling is established. Usually, the plant has three detectable tillers. The last stage of this main stage is also called ?tillering stage?.

2. **Beginning of stem elongation to heading stage:**
   - This stage ranges from the beginning of the growth of the main stem of the crop to the inflorescence when blossoms are fully developed.

3. **From heading to milky grain stage:**
   - This is the period of plant growth, where the plant flowers and develops the fruits (grains). The milky grain stage is the first stage of ripeness of the fruits (grains).

4. **The grain maturation stage:**
   - It comprises the ripening, the maturing and the senescence of the fruit (grains)

Application of irrigation water in different stages of crop growth

- Vegetative stage (stage 1: germination to the beginning of stem elongation):
  - Wheat crops are little susceptible to drought in the first stage (germination to beginning of stem elongation). The water absorption of the crop is slow and it is limited to the top 40 cm of the soil, because the root is in a very young stage and it is not able to uptake the water that is deeper than 40cms in the soil. The plant can tolerate a bit of water stress because it helps to stimulate root growth. After the root has grown deeper into the soil, it can easily reach water in deeper soil layers. That means that the wheat seedling can well resist drought and could rely on rainfall alone, the crop does not necessarily need supplemental irrigation in this stage.

- Reproductive stage (stages 2 and 3: Beginning of stem elongation to milky grain stage):
  - The water requirement of the plant increases during the reproductive stage. This stage lies between the beginning of stem elongation and the flowering (stage 2 and 3). It usually coincides with moisture deficit during the dry spring time. The number of flowers determine the yield and so it is important to maintain a good provision of water for the crop at this stage of growth. Usually, the water is taken up in the top layer of the soil. For keeping the water in the soil and protect it from being evaporated a mulch cover might be of help;
  - Also during the grain maturation stage (stage 4), water stress can have severe consequences for the grain yield. Especially, the first 10 days of the grain maturation are important, otherwise, the grain shrivels, affecting the crop yield.

The table below shows the duration of growth stages of wheat in Ouled Gnaou in Tadla. This is a research station, where the growth stages have been measured over 24 crop cycles. The wheat varieties used, were semi to late bread wheat varieties and were planted between November 15 to January 15.

<table>
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<tr>
<th>Stage I</th>
<th>Stage II</th>
<th>Stage III</th>
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<td>60</td>
<td>45</td>
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Planting dates and the climatic conditions of the site have an effect on the duration of the growth stages. That means that it can take less days or more days for every stage, depending on the weather. In the Tadla region, this might lead to a different length of growth for the 4 stages:

- From 54 to 72 days for the stage 1 (germination to stem elongation);
- From 22 to 44 days for stage 2 (Beginning of stem elongation to heading);
- From 24 to 39 days for stage 3 (Heading to milky grain);
- From 24 to 44 days for stage 4 (Grain maturation stage).

**How much water to supplement and when?**

- The amount of supplemental water is always dependent on the local average annual rainfall (mm/year) and the water requirements of the respective crop. There are some varieties that are adapted to water shortages by breeding;
- At 60 mm supplemental irrigation, the best results occurred when irrigating at tillering stage (stage 1). Also at heading stage supplemental irrigation is more effective than when applied at grain filling stage;
- The increase in yield is always very closely related to the growth stages in which the supplemental water is applied. Water that is given before the anthesis (flowering), has more effect on the yield than after anthesis;
- The best way to apply supplemental water is to target the three critical stages of wheat growth: tillering (during stage 1), heading (end of stage 2) and grain filling (stage 4). 60-70 mm per stage should be applied;

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<td>Irrigation</td>
<td>14.90</td>
<td>13.10</td>
<td>11.82</td>
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<tr>
<td>Tillering stage</td>
<td>19.10</td>
<td>13.90</td>
<td>15.25</td>
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<td>Heading stage</td>
<td>18.00</td>
<td>16.10</td>
<td>12.85</td>
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<tr>
<td>Grain filling stage</td>
<td>16.10</td>
<td>13.40</td>
<td>12.26</td>
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The recommended steps for the temporal application of supplemental water are:

- At rainfall deficit early in the season, apply first irrigation at planting or during tillering (when plant is in the vegetative stage 1). To avoid rainfall deficit plant early. Planting from mid-November to mid-December is recommended. General rule: **If there is less than 35 mm rainwater during the first 10 days after planting (DAP), apply supplemental irrigation**;
- Apply supplemental irrigation during booting-heading (stage 2), when the flowers start to be developed. At this stage a water deficit could lead to high yield losses (up to 40%). This stage needs enough water, so that abundant kernels can be developed, which then lead to inflorescence and fruits (grains);
- If there is enough water left for supplemental irrigation, apply a third irrigation before the grain starts to mature (stage 3) when the fruit (grain) is developing and after flowering. This can help to prevent shriveling of the grain. Grains need to have around 10% of water content when ripe for an optimal storage.

**Some adapted cultural practices**

There are some general practices that are important for improving the efficiency of supplemental irrigation. These practices should be applied **additionally** to supplemental irrigation.
Crop variety

Use more water efficient varieties. They should comply with the following criteria:

- **rapid vegetative development**: a variety grows rapidly, so that it can develop early fruits and needs less water in total;
- **high harvest index**: choose a variety that produces a large amount of yield compared with the total biomass produced;
- **fitting the crop cycle with the rainy season**: means to plant early, in order to align plant growth with the wet months.

Generally, it is recommended to use drought-resistant varieties. The following varieties are drought resistant:

- **Bread wheat**: Merchouch8, Kanz, Arrihane, Achtar, Amira
- **Durum wheat**: Marzak, Oum Rabia, Ascad 65, Yasmine

Sowing date

It is recommended to sow early in November in dry areas. By that, autumn rainfall can be fully utilized and the soil will be covered when the heat months begin. By this, the maximum available water can be capitalized and crop losses minimized.

Seeding rate

The optimal seeding rate is at 300 seeds/m² when applying supplemental irrigation.

Nitrogen application

Early application of N-fertilizer is recommended, so that it can be utilized with the soil moisture after planting. The rate of fertilization and the time of application depend on the soil and the climatic conditions of the region, the amount of water for supplemental irrigation and the yield that wants to be achieved.

In Tadla, 80kg/ha Nitrogen fertilizer could increase the yield by up to 50% for early planting (early November) and 30% for late planting (late December to early January). More than 80kg/ha did not show any increase in yield.

**FURTHER READING:**


Stages of plant growth: [https://en.wikipedia.org/wiki/BBCH-scale](https://en.wikipedia.org/wiki/BBCH-scale) [15](cereals)

**SOURCE(S):**
Country: Italy

Country: Lebanon

Links: