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Theme

**Evaluation of soil humidity to determine the
water needs of some crops irrigated by drip and
infiltration in the Saharan regions
(Case of Ouargla)**

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Abstract: The irrigation method is fundamental for maintaining a moist bulb around the roots of the crop. The best technique is one where soil moisture around the root system can be maintained at all times, between the two extremes of water content. The first objective of this work is the determination of theoretical watering doses using formula and experimental by measuring soil humidity before and after watering. The results showed that to meet the water needs of wheat in localized irrigation, it is necessary to irrigate 4 hours every 2 days, for sunflower 2 hours every 2 days, for cotton 2 hours every 8 days and for those of alfafa 2 hours every 2 days, with respectively a dose 67.45 , 241.12mm ,156.12 mm and 49.83 mm . The second objective is the study of the effectiveness of combined irrigation using the plastic bottle. From the results, on the one hand we can only conclude that combined irrigation reduces evaporation losses. And on the other hand, sand can retain a quantity of salt from water. This work falls into the context of water saving, sustainable development, environmental protection and especially in the agricultural sector.

Keywords: Water stress; Water requirements; irrigation, Drip, combined irrigation

ملخص: الطريقة المثلى للري هي التي يمكن من خلالها الحفاظ على رطوبة التربة باستمرار حول جذور المحصول، بين الحدود القصوى والدنيا لمحتوى الماء. الهدف الأول من هذا العمل هو تحديد كميات الري النظرية باستخدام الصيغ، والتجريبية عن طريق قياس رطوبة التربة قبل وبعد الري. أظهرت النتائج أنه لتلبية احتياجات القمح المائي في الري الموضعي، من الضروري الري لمدة 4 ساعات كل يومين، أما بالنسبة لعباد الشمس فتكفي ساعتين كل يومين، وللقطن ساعتين كل 8 أيام، وبالنسبة للفصفاة ساعتين كل يومين. والجرعات كتالي 67.45ملم، 241.12ملم، 156.12ملم و49.83ملم الهدف الثاني هو دراسة فعالية الري المشترك باستخدام قارورة بلاستيكية. أظهرت النتائج من جهة أن الري المشترك يقلل من فقدان الماء بالتبخر، ومن جهة أخرى أن نشارة الخشب يمكن أن تحتفظ بكمية من الملح الموجود في الماء. يدخل هذا العمل في سياق الاقتصاد في استهلاك المياه، التنمية المستدامة، حماية البيئة، وخاصة في المجال الزراعي.

كلمات مفتاحية: الإجهاد المائي؛ احتياجات المياه؛ التنقيط؛ الري المشترك

Résumé : La méthode d'irrigation joue un rôle crucial dans le maintien d'un bulbe humide autour des racines des cultures. La meilleure technique consiste à maintenir en permanence l'humidité du sol autour des racines, entre les deux extrêmes de teneur en eau. Le premier objectif de cette étude est de déterminer les doses d'arrosage théoriques à l'aide de formules et de les vérifier expérimentalement en mesurant l'humidité du sol avant et après arrosage. Les résultats montrent qu'il est nécessaire d'irriguer le blé pendant 4 heures tous les 2 jours, le tournesol pendant 2 heures tous les 2 jours, le cotonnier pendant 2 heures tous les 8 jours et la luzerne pendant 2 heures tous les 2 jours, avec des doses respectives de 67,45 mm, 241,96 mm, 156,12 mm et 49,83 mm. Le deuxième objectif est d'évaluer l'efficacité de l'irrigation combinée en utilisant des bouteilles en plastique. Les résultats indiquent que l'irrigation combinée réduit les pertes par évaporation et que la sciure de bois peut retenir une quantité significative de sels dissous dans l'eau. Ce travail s'inscrit dans le cadre de l'économie de l'eau, du développement durable, de la protection de l'environnement et, surtout, du domaine agricole.

Mots clé : Stress hydrique ; Besoins en eau ; Goutte à Goutte ; irrigation combinée

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General Introduction

General Introduction

The climatic context of arid regions is mainly influenced by a very marked annual irregularity and interannual variability of precipitation and a heterogeneity of their distribution. Aridity is expressed not only by high temperatures in summer and by low precipitation, but above all by the importance of evaporation due to the dryness of the air [Dubief J., 1953] Added to this is the scarcity of water resources and their poor quality.

Irrigation plays a vital role in increasing and stabilizing crop yields. In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi-humid regions irrigation is often provided to certain crops in addition to rainfall.

Due to the extremely low rainfall in these areas, the water necessary for plant vegetation is provided from surface resources (watercourses, wadis, floods, etc.) and underground resources (resurgent sources, water tables, etc.). deep layers....) [Toutain G, .1979]

Developing countries (Maghreb countries in particular) are increasingly concerned by conflicts of use due to an increase in the urban population and its standard of living. Climatic conditions mean that irrigation is almost necessary in these countries, which are often faced with problems of water shortages. [Mailhol et al.,1990a]

In the Northern Sahara unfortunately no plant domesticated by man can vegetate without a supply of water [Dubief J, 1953]. And it is a paradoxical undertaking to want to cultivate in the desert which requires irrigation more than any other land elsewhere in all seasons because in addition to its hot and dry climate water is rare there.

The use of irrigation is in many cases necessary to ensure that a sufficient level of production is maintained in many arid and semi-arid regions. The practice of irrigation is even an essential aspect of agriculture in the Saharan environment. Today we know how to calculate and predict the fundamental parameters that govern it but there is no miracle recipe, in fact the solutions adopted are always compromises. Many factors must intervene which take into account natural conditions, local know-how, the level of industrial development of the country and the economic performance of the envisaged agricultural production. [DHE 1959]

Irrigation techniques are numerous but, in reality, the efficiency of irrigation is to be deplored. It is essential to practice efficient techniques that consume little water,

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particularly in the case of semi-arid and arid areas where the potential for mobilized water resources is low. Fresh water has quickly become one of the rarest resources of the 21st century. By increasing the total productivity of water and the efficiency of the multitude of irrigated systems, particularly in Africa, we can optimize the use of this highly sought-after resource. [Hafiane A.A and Hadjrioua B.,2015].

Insufficient or excessive irrigation is detrimental to crops; It is therefore necessary to determine exactly the dose of watering appropriate to their needs. It is in this context that this research has as its primary objective the theoretical determination of the irrigation regime, that is to say the dose, frequency and duration of watering of certain crops (sunflower, esparto, cotton and wheat). in an arid region (Ouargla). To do this, you will first need to calculate the water needs. The choice of crops focused on those resistant to the arid climate, which adapt to sandy soil and which gave good yields in these conditions.

The choice of the appropriate irrigation system depends on the quality of water used, culture, customs, experience, skill and ability of farmers to manage different irrigation methods. Surface irrigation was for centuries the only method of applying water to cultivated land and then modern and highly sophisticated irrigation techniques such as sprinkler irrigation and drip irrigation were introduced. been developed during this century. But water losses through evaporation, especially in arid regions, are abundant and reduce the effectiveness of these techniques. In this context, as a new technique, "drip" was combined with one of the oldest methods used since the time of the Romans throughout North Africa and the Near East, based on the frequent pouring of water in porous pottery vases buried in the ground but replacing the pottery vase with sawdust-filled plastic bottles that release water through their perforated walls into the surrounding soil. The moisture that emerges nourishes the roots of the plant.

The second objective of this study is the experimental determination of the watering doses received in the case of Drip-to-Drip irrigation and in the case of combined Drip-to-Drip irrigation and underground irrigation.

The document plan is structured as follows:

- We start with a bibliographic search on the chosen cultures. Then we will define the irrigation techniques used in this work.

General Introduction

- In the second chapter, general information will be given on the study region and the experimental site. We will also present the materials and methods used to determine the characteristics of the water and those of the soil in the irrigated area.
- The third chapter will be devoted to the theoretical determination of the irrigation regime, that is to say the duration, frequency and dose of watering. To do this, we must first determine the needs of the crops chosen for this work.
- The fourth chapter is reserved for the experimental determination of the watering doses received for the two techniques used. A comparison of the results will make it possible to define the effectiveness of the combination of Drip by Drip and underground irrigation.
- We will end with a general conclusion which will summarize all the theoretical and experimental results as well as some recommendations.



CHAPTER I
BIBLIOGRAPHIC STUDIES

Introduction

In the following we present the irrigation techniques used in this work. We also give an overview of the main characteristics of the chosen cultures.

I.1 Irrigation techniques

Irrigation is the activity that consumes the most water, it absorbs more than 85% of the water controlled by man; [Horing H M., 1973 and Plauchu., 2004] It plays an essential role in the increase and stability of crop yields. In arid and semi-arid regions, irrigation is essential for economically viable agriculture, while in semi-humid regions irrigation is often provided to certain crops in addition to rainfall.

There are currently several irrigation methods for supplying water to crops. Each method has at the same time advantages and disadvantages which must be taken into consideration when selecting the method which best adapts to local conditions.

The choice of an irrigation technique is based on a set of criteria and constraints which have been studied by [Hlavek, 1992]:

- Topography (slope of the land, relief, geometry of the plot).
- Water resource (quantity, quality, flow available).
- Nature of the soil (permeability).
- Sociological and cultural factors.
- Economic factors.
- Profitability of the operation.

Each of these criteria should not be considered in isolation. On the contrary, we must have a global vision in order to better evaluate the irrigation potential of a given site or region. To better help make the choice, a preliminary examination of the advantages and disadvantages of each of the main types of irrigation techniques is proposed.

As in this study, the two irrigation techniques used are drip and a combination of drip with subsurface irrigation, so we will only give an overview of these two techniques (drip and subsurface irrigation).

I.1.1 Underground irrigation

Subsurface irrigation can be defined as the action of supplying water to plants below the surface of the soil, maintaining an artificially high-water table, so as to maintain the best combination of water and soil. air in the root zone for maximum yields

Underground irrigation can be done using buried perforated pipes or open channels.

[Bagoshvski 1987] (Photo I.1)

Advantages

Absence of material on the surface, hence none hindering operation.

Very low investment and operating costs on plots previously equipped with underground drainage.

Does not wet the foliage or the soil, which is favorable from a phytosanitary point of view and cultural practices.

Disadvantages

Technique usable only in certain soil conditions on plots requiring underground drainage.

Incomplete and uncertain control of the water supply of crops which means that this technique is reserved for low added value production.



Photo I.1: Underground irrigation [Oulhaci D, Hafsi.M and Boudjema.S,2020]

I.1.2 Jar irrigation

Jar irrigation is a technique falling into the category of underground irrigation which consists of discharging water directly into the rhizosphere via porous or perforated receptacles which are buried in the soil at a certain depth (15 at 50 cm), and whose openings are flush with the surface.

It is one of the oldest methods used since Roman times throughout North Africa and the Near East and is based on the frequent pouring of water into porous pottery vessels buried in the ground [Bagochvski 1987].

We do not have certain information on the origin and antiquity of this method, but numerous reports attest that it was used throughout North Africa and the Near East. [FAO; 1997] It was led by the poor Indians of the Andes who, having no rights to irrigation water conveyed by canal, were authorized to draw water using jars [Knapp G, 1991]. But the pot irrigation technique has also developed along two paths. The first

CHAPTER I BIBLIOGRAPHIC STUDIES

consists of digging small wells in the middle of the plots from which the watering water poured manually onto the cultivated plants is collected, using pottery or wooden jugs. (Photo I.1) One of the best documented examples of this type of culture is that described by A. Kirkby in the Oaxaca Valley in Mexico [Kirkby, 1973]. It was chosen to illustrate here this laborious but effective method of cultivation (pot irrigation in Oaxaca. "Itinerant" wells in northern Ghana). The second, common in Roman times, consists of burying pots with porous walls, at the very foot of the plants to be irrigated. The pots are made of clay fired at low temperature which are buried up to the neck and filled with water to irrigate the plants placed nearby. The porous walls slowly diffuse water which will be absorbed by the plant roots.

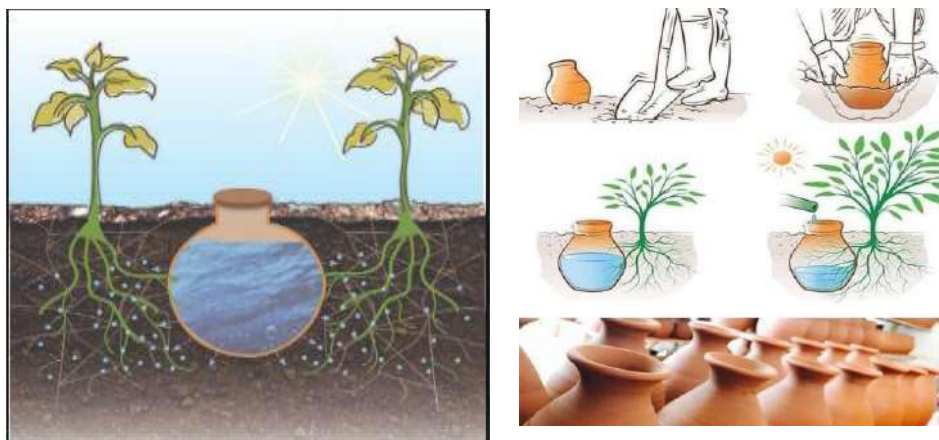


Figure I.1: Jar Irrigation

The opening of the jars is flush with the surface of the ground allowing them to be filled regularly. This ancestral technique, largely unknown, has been the subject of much scientific research since the 1960s. The jars are sometimes replaced by pots with perforated walls or by pottery pipes. (Figure N°. I.1)

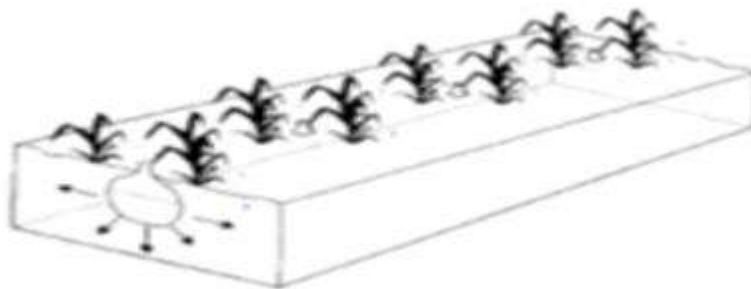


Figure I.2: Shape of soil wetting around a porous clay vase buried between two rows of crops (source FAO, 1997)

Jar irrigation has many advantages: it is simple, profitable and saves water, compared to watering, it saves water (50 to 70%), it offers stable irrigation and adapted to the

needs of the plant and it reduces the weed problem. and particularly suitable for small farms in arid areas.

On the other hand, it has disadvantages, namely: difficulty of installation, moderate flexibility, fragility of the material

I.1.3 Drip irrigation

“Drip” irrigation is one of the techniques of localized irrigation (micro irrigation) which consists of providing each plant and tree, individually, with the quantity of water they exactly need, depending on the type. of soil, the specificities of the climate and its development, without appreciable runoff. [Walker, W.R.,1989]. The water circulates in small diameter flexible pipes placed on the surface of the ground and equipped with "dripper" devices which bring the water to the base of the plants; the most widespread localized irrigation systems are drip (indicated for market gardening) and micro-jet (indicated for arboriculture). [Messahel, M., 1988]

In drip irrigation, water is delivered to the plant in low doses, thereby moistening a fraction of the soil. This helps limit losses through evaporation and percolation. It also helps reduce the development of weeds. It also uses fixed and light equipment and allows fertigation. In most cases, it requires automation through controllers associated with volumetric and/or hydraulic valves and solenoid valves.

In practice, we often use drippers of 2 l/h for market gardening and 4 l/h for perennial crops (fruit trees and vines). Depending on the type of dripper, the method of attachment to the boom can be either diversion, in-line or integrated. Currently, there is a growing trend towards integrated mode given its low manufacturing cost as well as its ease of installation in the field. In fact, you just need to unroll the ramp whereas for other modes, the drippers must be installed one by one, following the desired spacing. In derivative fixation, we can find short circuits or long circuits. These have the advantage of covering a large surface area and can be arranged in a circle to cover a larger surface area.

In certain drip irrigation projects for perennial crops, we can deliberately use a small diameter boom when the plants are small and then add a second boom when the water needs are greater.[Goldbergd Bornatb and Bar-Yousef., 1971]

Drip irrigation involves bringing water under pressure through a system of pipes, usually PVC; This water is then distributed in drops to the field by a large number of drippers distributed along the rows of the plantations. The humidified zone of the soil

is that located in the immediate vicinity of the plant roots. Therefore, this irrigation method has a high degree of water distribution efficiency (Photo I.2). Drip irrigation is also called micro-irrigation or localized irrigation. [Brouwer, C. et al., 1990.]



Photo I.4: Drip irrigation [Oulhaci D, Hafsi.M and Boudjema.S(2020)]

Advantages

- Water saving: avoids surface evaporation and runoff with an efficiency of 95%;
- Saving and improving fertilization: direct application of water and nutrients to the root system;
- Savings in energy costs compared to sprinkling;
- Possibility of using marginal water (saline and/or residual);[Moshe Sné. ,2007]
- With mini-sprinklers and low-flow drippers, the formation of surface crusts is reduced, the duration of irrigation is extended and the water can penetrate slowly into the soil [Papadopoulos I. Stylianouy.,1991]

Disadvantages

- Clogging of nozzles with physical debris, chemical elements and biological materials;
- Special equipment used to control clogging can significantly increase the unit cost of an installation;
- Limiting the volume of wetted soil could lead to water stress for the crop in the event of a malfunction of the irrigation installation;
- Installation of the system requires special attention. [Idder, Med T., 2005]

I.2 Crops

I.2.1 sunflower

The scientific name of the sunflower, *Helianthus annuus* Linnaeus, refers to the characteristic shape of its compound inflorescence, the flower head. It comes from the Greek words Helios and Anthos which mean “sun” and “flower” respectively [Evon Philippe, 2008].

The sunflower is an annual plant of the Asteraceae (Compositae) family and native to Peru.

The plant has an erect habit, with a single or slightly branched stem, with a height varying from 1 to 1.2 m, the yellow flowers are grouped in a flower head at the end of the stem. The seeds borne are oval, flat, black or gray in color [ITGC, 2013]. If the root system does not encounter any obstacles, it can explore the soil up to 2 meters [INA, 2003]

The sunflower is one of the spring crops most tolerant of dry conditions thanks to its root system which allows it to extract water from the soil better than others. The sunflower is resistant to drought, provided that water stress is avoided during flowering (critical phase).

When the sunflower is young, it grows very quickly during the day. As it grows, it turns towards the sun.

The side in the shade grows faster than the side that receives the light, its stem bends according to the movement of the sun, giving the impression that the flower is following the sun. This is linked to the auxin contained in the apical region of the plant. This hormone, responsible for cell elongation in plants, migrates towards the side opposite to that exposed to the sun. The cells are therefore larger on the shaded side than on the sunny side.

Sunflowers are mainly grown for their oilseeds, the oil content of which varies from 25 to 40% depending on the variety. [ITGC 2013] The whole plant harvested before maturity is used as fodder.

The seeds are popular for feeding parrots and other aviary birds. They are also used in the manufacture of concentrated poultry feed.

Sunflower seeds are also used in the manufacture of biofuels. [INA, 2003]

Sunflower stems have the qualities to make good insulators for buildings. Their fibers have good mechanical resistance and their porous core has good thermal resistance.

Soil type The sunflower adapts to all types of soil and grows well in sandy textured soils. The sunflower is an annual plant and is tolerant of hot and dry climates [Morizet, J., Merrien A 1990.]

Thanks to its root system which allows it to extract water from the soil better than others [Cabelguenne and Debaeke , 1998]. But it is resistant to drought, provided that water stress is avoided during flowering (critical phase). [Lecomte Vincent, 2024]

But it is resistant to drought, provided that water stress is avoided during flowering (critical phase). [Lecomte Vincent, 2024]

Sowing: Depending on the production areas and the soil and climate conditions of the year, sowing is carried out at the beginning of April. An early variety will be harvested, on average, between August 20 and 25. A mid-early variety will be harvested between August 25 and September 4. In some cases, sowing is done between February and early March.

- **Spacing and sowing density of sunflowers:** When sowing, the choice of spacing and sowing density are decisive because they determine the soil cover and consequently the nutrition of the sunflower. The goals are:
 - to avoid competition between plants;
 - to better exploit soil reserves;
 - to capture as much solar energy as possible.

The ideal spacing is 40 to 60 cm, however a sowing of 80 cm allows the use of existing equipment on the farm, particularly for hoeing [Anonymous, 2020]

Water requirements: The quantity and period of supplemental irrigation water supply are based on the needs of the crop, soil water reserves, evapotranspiration in the crop area [INA, 2003] and the vegetative state of sunflowers before flowering. Water stress in the vegetative phase causes plants to harden and behave better subsequently; significant foliage functioning long after flowering is the key to successful sunflower cultivation. [INA, 2003]

From the start of flowering to the end of seed filling, the sunflower is in a phase of maximum sensitivity to drought; it is in fact during this period that the fruit setting rate and the PMG (Thousand Grain Weight) are determined. During this phase it must consume 230 to 250 mm (Useful reserve + Rain + Irrigation) of water to ensure a yield of 30q/ha.

The optimum water requirements for sunflowers are: [INA, 2003]

- 160-180mm at the flower bud stage with a diameter of 3 cm.

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- 70mm at the stage from the beginning to the end of flowering.
- 200-230mm in grain filling phase.

Several studies have shown that the yield gain and profitability of irrigation could be significant in certain economic, climatic and hydraulic contexts [Merrien and Grandin, 1990; Unger, 1990; Goksoi et al., 2004; Demir et al., 2006].

However, the benefit of irrigating sunflowers must not be evaluated only at the scale of the plot but also at the scale of the farm or the collective of irrigators, particularly in a context of limited resources [Jacquin and al., 1993; Lorite et al., 2004; Deumier et al., 2006]. Furthermore, the insertion of sunflowers into the irrigable soil, whether or not with a view to irrigation, can meet other imperatives, particularly organizational or agronomic.



Photo I.5: Sunflower [N Gouarah and K KOUL; 2024]

I.2.2.Wheat

Wheat is a plant that belongs to the class of monocots, of the family Poaceae (graminaceae), belongs to the genus. [Layeb.L, 2018]. It is one of the first species cultivated by man. For more than 7,000 to 10,000 years, wheat has occupied the Fertile Crescent: an area covering Palestine, Syria, Iraq and a large part of Iran [Croston and Williams, 1981, Ruel, 2006]. Remains of diploid and tetraploid wheat dating back to the 7th millennium BC have been discovered on archaeological sites in the Near East (Harlan, 1975). Cereals are cultivated in Algeria over large areas of the country mainly in the high plains and high plateaus due to their strategic interest in the territory, with an average of 3.3 million hectares sown each year with durum wheat, soft wheat and barley (not including fallow), i.e. 29% of the UAA, including 62% cultivated only in wheat [DSASI, 2018]. Wheat is found mainly in the countries of the Mediterranean basin with arid and semi-arid climates. [Abeledo L.G, and al; 2008], regions characterized by increasing temperature coupled with decreasing precipitation, in addition to

desertification and drought. [Zaki.L, 2020]. In Algeria, durum wheat (*Triticum durum* Desf.) has acquired a true symbolic value over the centuries, due to its importance in agriculture and human nutrition. Wheat is a plant that belongs to the class of monocots, of the family Poaceae (graminaceae) [Feillet, 2000].

Its grain constitutes a basic product in the Algerian diet (couscous, bread, etc.), it is also considered a very large resource of proteins and carbohydrates. It also contains amino acids, lipids and vitamins. In addition, its by-products (straw) are used as livestock feed [Godon, 1985].

Soil type : Drained and deep soils [Doorenbos and Kassam, 1979], loamy, clay-limestone soils and clay-siliceous soils and with fine elements are best suited to wheat .[Soltner, 2000]) Wheat also gives good yields in sandy soils.

Temperature is the environmental characteristic that controls the development of the plant; it conditions the physiology of wheat at all times. [Latreche. F, 2018.]

Water requirements: Wheat requirements are generally between 550 to 600 mm. Wheat needs 4 to 5mm per day during the bolting, a period which sees the development of a main component for yield [Moule, 1980].

Decadal water requirements are 46 mm from the end of tillering stage to the start of bolting stage (March-April). They rise to 103 mm during the heading swelling phase. [Latreche. F,2018]

In arid zones, needs are higher given unfavorable climatic conditions. These from the 1 cm ear phase to flowering have the greatest water requirements. The critical water period is 20 days before heading to 30 to 35 days after flowering .



Photo I.6: Wheat [N Gouarah and K KOUL; 2024]

Sowing: The grain, after fertilization, the flower gives birth to a single fruit, the caryopsis or grain, which includes an embryo or germ attached to the reserves. A grain of wheat contains an edible portion has three parts. Most of the grain, called endosperm, is composed mainly of starch. Its envelope, the bran, represents nearly 15% of the weight of the grain; it is rich in nutrients and especially fiber. As for the germ, it is the embryo of the grain; it represents less than 3% of the weight of the grain. Despite its very small size, the germ is the part richest in nutrients. Its lipid content makes it easily perishable. [Layeb.L, 2018]

I.2.3 Alfafa

Alfafa is a member of the Leguminosae or Fabaceae family [Cumo, 2013]. It is also known under the name Alfalfa [Botineau, 2010].

It is also known under the name Alfalfa [Botineau, 2010]. The English name given to alfalfa « **Alfa** Alfalfa or alfalfa is a perennial herbaceous plant with an erect stem from the base, branched and angular, which can reach 60 to 70 cm in height. The alternate petiolate leaves with 3 oblong leaflets, denticulate at the top, are obtuse and a little notched at the top with a mucron towards the middle of the notch. fa » is of Arabic origin which means “best fodder”. The Italians continue to call it that. The Spanish sometimes call it Mielgas (Delgado, 2006).

Alfafa or alfalfa is a perennial herbaceous plant with an erect stem from the base, branched and angular, which can reach 60 to 70 cm in height. The alternate petiolate leaves with 3 oblong leaflets, denticulate at the top, are obtuse and a little notched at the top with a mucron towards the middle of the notch.

Soil type: Alfalfa can adapt to sandy soils as well as many types of soil, but it does not tolerate acidic (pH less than 5) or very humid soils, which are more favorable to red clover. Its preference is for healthy, deep soils which allow it to develop its taproots. It is this rooting, which can go down to a depth of 10 m, which gives it great ease of adaptation by allowing it to resist unfavorable external conditions, notably drought. Great genetic variability has also allowed it to establish itself in very contrasting environments, from the hottest to the coldest. [Marble V.L., 1993]

Climate : It resists drought particularly well [Lemaire, 2006] and adapts to sandy soils. Its greatest development is found in warm temperate zones where it finds its greatest development. [Mazoyer and al, 2002].

Sowing: It can be sown in the fall or in the spring [Djaman, Koffi, et al 2020]. It is a plant grown mainly for livestock feed or other purposes. [Rita A. and al 2017]. Its

durability gives it the ability to contribute to the sustainability of rainwater systems [Volaire and Norton, 2006]. Alfalfa, a covering plant, limits water loss through evaporation.

Alfalfa is grown pure or in association with a grass, which is most often orchard grass (Mauriès, 1994), but is also found in association with tall fescue, brome and sometimes ryegrass. A field of alfalfa is called alfalfa (Mazoyer et al, 2002).

In arid Mediterranean areas, alfalfa is often irrigated and faces salt stress. The search for cultivars better adapted to this situation is a priority [Ibriz et al, 2004].



Photo I.7: Alfafa [N Djaboreibi;2024]

I.2.4 Cotton plant

The cotton plant is a perennial plant that grows in arid tropical or subtropical climates. It is present on five continents with different varieties as well as cultural practices. The leaves of the cotton plant are webbed and measure between 12cm and 15cm long and wide and are placed in a spiral every 5cm to 8cm, along the main stem. The height is 1.3m. Its particularly developed root system (its length can sometimes reach double the height of the plant).

Soil type: It requires a loamy or clay-sandy or sandy soil in which it can sink its strong pivot roots deeply and thus develop in the best conditions.

Water requirement: It needs warmth, sun and water.(7000 à 9000 m³/ha) qui peuvent lui être fournies naturellement au travers des pluies ou de l'irrigation. [EZAN Marc et al. 1998]

Sowing: Planting of the cotton plant is at the beginning of March and the harvest will be mid-September

The first leaves appear between a week and a month after sowing. Flowering appears after a month and a half to two months and continues regularly over several weeks. The harvest is done once the cotton has reached maturity, between 6 and 9 months after sowing. [OECD/FAO, 2023].

Use: Along with the fiber, the finest cottons are generally intended for luxury products and hosiery. With down, various uses are reserved for down such as the manufacture of cellulose, varnishes, felts, fine papers, mattresses and tapestries. With the kernels of the seed which is rich in oil and protein, pressing them produces cottonseed oil (the gossypol is eliminated), a good quality edible oil, practically odorless, rich in polyunsaturated fatty acids and without cholesterol. . [<http://www.cotton.org>]. It constitutes the sixth vegetable oil in the world. [[<http://www.cotton.org>]. We can obtain from the seeds of the cotton plant a good quality edible oil, practically odorless, rich in polyunsaturated fatty acids and without cholesterol. It constitutes the sixth vegetable oil in the world. [Cretenet M and Dessauw D, 2006]



Photo I. 8: Cotton plant [GOOGL]

Conclusion of Chapter I

The choice of crops fell on sunflower, wheat, cotton and alfafa which are tolerant to dry conditions, which adapt to sandy soil and can be sown all year round. These crops often give good yields in Ouargla even when irrigated with brackish water.

There are many irrigation techniques, but in reality, the efficiency of irrigation is to be deplored. It is essential to practice other techniques that are more efficient and consume less water, particularly in the case of semi-arid and arid areas, where the potential for mobilized water resources is low. This work consists of experimenting with a combination between underground irrigation and drip irrigation. And for cultivation, we opted for the use of sunflower for experiments because it grows in sandy soil, in sunny exposure and is sown in spring around February 15. In addition, it is considered a drought-tolerant crop.



CHAPTER II
MATERIALS AND METHODS

Introduction

The water requirements of crops depend on climatic parameters and the characteristics of the soil and the water.

II.1 Presentation of the study area

The experimental site and climatic characteristics play an important role in the choice of irrigation technique, the determination of the quantity of water necessary to have a good yield and for the determination of water requirements.

II.2 Geographic location

Ouargla is located in southeastern Algeria, approximately 800 km from the capital Algiers (photo II.1) covering an area of 163,230 km². It is located at an altitude of 157 m, its latitude is 32° 45' North and 31° 45' South; the longitude is 5° 20' East and 5° 45' West.

This city, located at the bottom of a vast depression with no outlet where the water table is often at ground level, is surrounded by large expanses of sebkhas and chotts. [Halwart M. and Dam A.A., 2010]

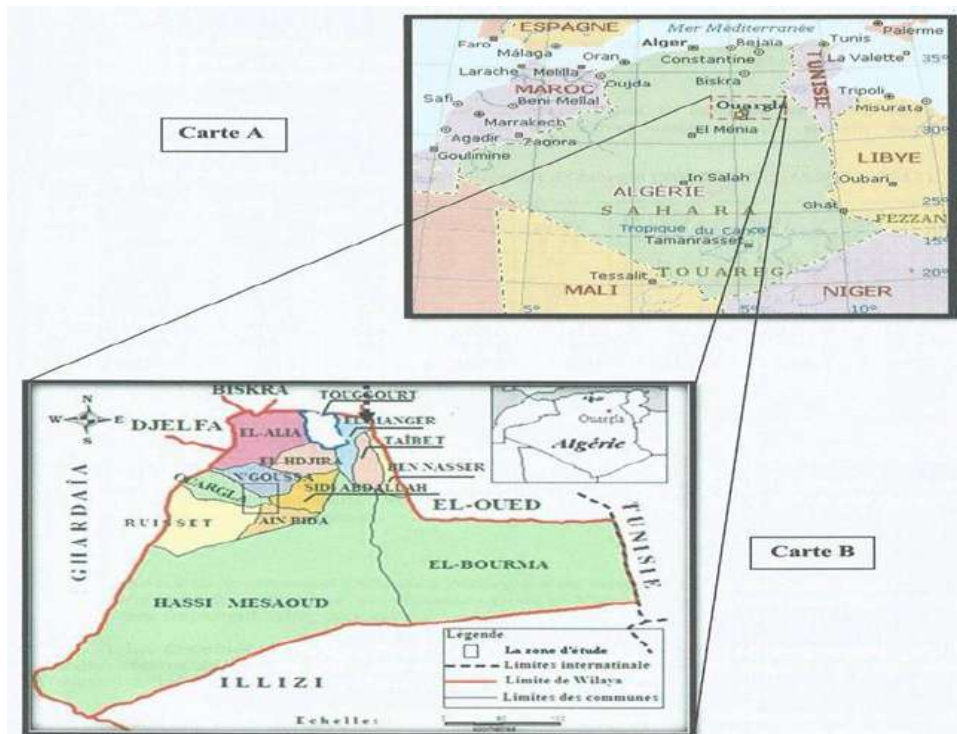


Photo N°. II.1: Geographical location of Ouargla
[<https://fr.wikipedia.org/wiki/Ouargla>]

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Ouargla is limited by wilaya the of Touggourt to the North-East, the wilaya of Djelfa to the North-West, the wilaya of Illizi and Tamanrasset to the South-East and the wilaya of Ghardaïa to the West and Tunisia to the East. (photoll.1). (NB the scales are not mentioned). The population residing throughout the basin is 254,411 inhabitants for the year [INRA of Touggourt]

II.3.Climatic study of the region

Meteorological parameters are key factors in the seasonal distribution of irrigation and evaporation and some of them are found in all formulas for determining the watering dose and in determining evaporation.

The climatic data considered mainly concern precipitation, temperatures and other climatic phenomena (wind, insolation, humidity, etc.).

The temperature being closely linked to the radiation rate, itself directly correlated to evaporation, it follows that there is a certain existing relationship between evaporation and the temperature of the evaporating surface. [Sofiane Saggai,,2008]

The relative humidity of the hydrological cycle controls soil evaporation and plant cover, it corresponds to the ratio of the partial pressure of water vapor.[Grosclaude., 1999]

The wind plays an essential role in the evaporation processes because it allows, through the mixing of ambient air, the saturated air to be replaced in the vicinity of the evaporating surface by drier air. [Sofiane Saggai,,2008]

Precipitation plays an important role in irrigation and irrigation depends on its quantities. These are the waters that fall on the earth's surface, both in liquid form (drizzle, rain, downpour) and solid form (snow, sleet, hail). Whatever the form of precipitation, the measured quantity of water falling over a certain period of time is generally expressed in millimeters (mm).

These average monthly climatic factors for an observation period of 10 years (2008-2017) are presented in the following (Table II.1):

The Ouargla region is characterized by strong insolation. The latter corresponds to the duration of illumination of the ground by the sun. The maximum is reached in the month of August with a duration of 340 hours and the minimum in the month of December with a duration of 231 hours.

The Ouargla region is characterized by significant evaporation and is very strong, especially during the hottest months. With an annual average of 225.4 mm, the

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maximum noted for the month of July (433 mm) and the minimum for the month of December (83.4 mm).

II.4. Climate synthesis

The climatic synthesis is an essential step for determining the evapotranspiration necessary for determining the irrigation dose. It consists of determining climatic indices in order to arrive at climate trends, its characteristics and describe these variations. [ALLAM. Salah., 2014] The literature on the subject is very rich in climatic indices, specific to each region. For arid zones we often resort to the use of the aridity index of De Martonne and the ombrothermal diagram of Gaussen and Bagnouls and that of Emberger which illustrates the existing relationship between temperature and precipitation for the determination of periods of drought [HAFIANE Ahmed Amine and HADJRIOUA Bilal.,2015]

Martonne aridity index

Based on essentially geographical considerations, De Martonne defined as a new climatological function the climate aridity index by the quotient $IDM = P/(T+10)$. This index makes it possible to characterize the evaporating power of the air based on the temperature; evaporation being considered as a linear function of temperature.[MEDJERAB A.,2013]

To calculate the annual aridity index we use the following formula:

$$I = \frac{P}{T+10} \quad (II.1)$$

P: Total annual precipitation in mm;

T: Average annual temperature in °C.

This index takes on values that are higher as the climate is wetter and lower as the climate is drier.

De Martonne proposed the classification of climates according to the values of the index as presented in the following (Table II.1)

Table II. 1 : Classification of climates according to the De Martonne index.[MEDJERAB A. ,2013]

De Martonne aridity index	Climate type	Potential vegetation type
0 to 5	Hyper arid	Absolute desert
5 to 10	Arid	Desert
10 to 20	Semi-arid	Steppe
20 to 30	Semi-humid	Natural meadows, forests
30 to 40	Humid	Forests
40 to 55	Humid	Forests

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We determine the annual aridity index with the average annual temperature of 23.7°C (table II.1) and the annual precipitation of 39.19 mm (table II.4), $I = 1,16$ The annual aridity index is between 0 and 5; The climate of Ouargla is therefore hyper arid.

II.5. Gausson and Bagnouls ombrothermal diagram

The Gausson and Bagnouls ombrothermal diagram is a graphical method which makes it possible to define the dry and humid periods of the year where the months are plotted on the abscissa, and on the ordinate the precipitation (**P**) and temperatures (**T**).

If the average monthly precipitation for a month is less than or equal to twice the monthly temperatures for the same month ($P \leq 2T$), the period is called dry. [Joël Charre, .,1997]

The monthly average values of precipitation and temperatures (2008-2017) are shown in Tables II.4 and II.1 respectively.

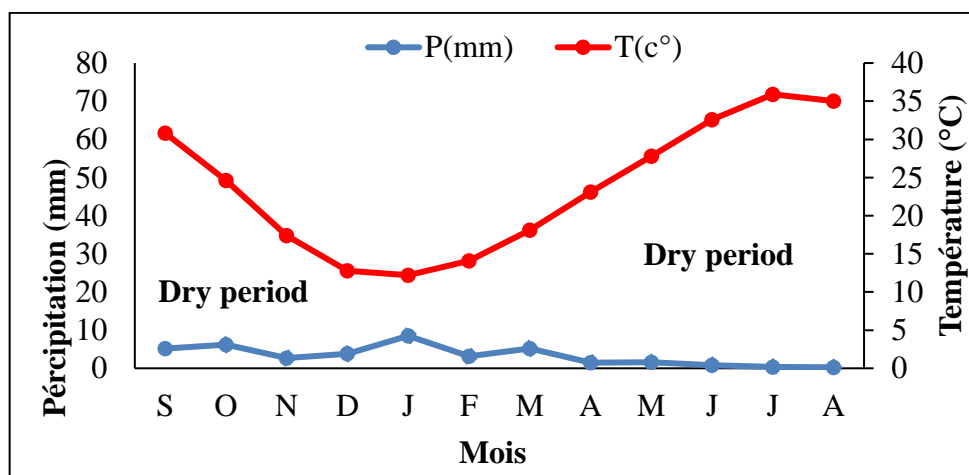


Figure II.1: Gausson ombrothermal diagram of Ouargla in the period (2008-2017)

From this diagram (Figure II.1) we notice that the study region is characterized by a dry period all year round.

II.6 Experimental site

II.6.1 Soil and water characteristics

The physical and chemical characteristics of soil and water play an important role in the choice of irrigation system and crops.

The water characteristics are summarized in Table II.2.

Table II. 2 Water characteristics

Physical and chemical parameters				
	hP	conductivity	Turbidity	Temperature
Water	7.91	4710	0.507	25

II.6.2 Soil characteristics

The physical and chemical characteristics of a soil play an important role in the choice of irrigation system and crops.

- The main physical and chemical characteristics that could be determined are:
- Granulometry.
- uniformity coefficient.
- apparent density.
- Salinity.
- Conductivity.
- hP .

The samples have been taken. The analyzes were carried out in the hydraulics laboratory at the faculty of applied sciences of Kasdi Merbah University –Ouargla-

II.6.2.1 Soil particle size analysis:

It is the determination of the percentage by weight of elements of different diameters.

a) Operating mode

The test consists of classifying the different grains which constitute the sample using a series of sieves nested one on top of the other with the dimensions of the openings decreasing from top to bottom. The analyzed material is placed in the upper sieve and the grain classification is obtained by vibration of the entire sieve column. Weighing the sieve rejects makes it possible to trace the particle size curve and determine the type of soil.

The sieving values are given in (annex 1). And the particle size curve in (annex 2).

According to the diameter of the particles, we can discern the particle size groups on the graph in appendix 2: (according to the International Association)

- Colloids <. 2μ
- Limon 2μ <. 20μ
- Fine sand 0.02 ÷ 0.2 mm
- Coarse sand0.2 ÷ 2 mm

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- Gravel > 2 mm



Photo II 2: Sieve [K Koull.;2024]



Photo II 3: Balance [N Gouarah 2024]

According to the results in Appendix 2, we deduce that the soil is composed of 20% fine sand, 78% medium sand and 2% coarse sand.

The soil of the experimental site therefore has a sandy texture, characterized by a well-aerated soil, easy to work, but difficult to store water and nutrients..

II.6.2.2 Uniformity coefficient C_u :

The uniformity coefficient characterizes the size distribution of the elements that make up the sample. It is calculated as follows:

$$C_u = \frac{D_{60}}{D_{10}}$$

Or :

D_{60} : Corresponds to the diameter which allows 60% of the sample to pass;

D_{10} : Corresponds to the diameter which allows 10% of the sample to pass.

According to the graphs of the particle size analysis, we trace the projection of the point of intersection of the curve at the percentages of 60% and 10% on the axis (x), corresponding to the diameters of the sieves, and we deduce $D_{60}=0.62$ and $D_{10}=0.2$

the uniformity coefficient is $C_u = 3.1$

Or according to the value of the uniformity coefficient, classified as follows:

CHAPTER II: MATERIALS AND METHODS

- For Cu²⁺: uniform particle size
- For Cu²⁺: spread particle size Donc le sol du site classe dans une répartition étalée

II.6.2.3 Apparent density:

The apparent density is necessary for calculating the irrigation dose. It is equal to the ratio of the mass of the dry sample to the apparent volume (i.e. it corresponds to the external envelope of the sample considered).

To determine the apparent density, samples were carefully taken using small metal cylinders (of volume V and mass M_v) from the soil.

The weight of the filled cylinder is M_r

Determination of apparent density $\frac{M_r - M_v}{V}$ in the Laboratory gave the following result:

Average apparent density: Da = 1.151 (g/cm³)

II.6.2.4 Salinity, conductivity and PH:

A) Materials used

- Electronic scale (Photo 4)
- Funnel (Photo 4)
- Beaker (Photo 4)
- Turbidimeter (Photo 6)
- Paper filter (Photo 4)
- Multi-parameter (Photo 7)
- Burette
- Distilled waters

B)Operating mode

- We weigh 5 grams of fine sand
- We put the 5g of sand in the beaker and add 100ml of distilled water.
- Place in a shaker for 20 minutes
- After stirring, pour the water into the Erlenmeyer flask using filter paper.
- After filtration, we measure using a multi-parameter

CHAPTER II: MATERIALS AND METHODS



Photo N°II.4: Electronic scale



Photo N°II.5: Erlenmeyer flask



Photo N°II.6: Turbidimeter



Photo N° II.7: Multi-parameter

The results of the measured parameters of distilled water and filtered water are shown in the table.

The results are summarized in the table II.3

Table II.3: Results of analyzes and Algerian standards

	hP	Conductivity (ms /cm)	Salinity (mg/l)	T c°
Distilled water	7.32	8	0	27.6
Filtered water	6.60	10.78	0.53	27.98

The hP is between 6.5 and 8.5 therefore admissible. The salinity of the water of 0.53psu (1g of salt per kg of water) allows us to conclude that the soil is not salty.

Conclusion of Chapter II:

The climatological study allows us to deduce that Ouargla is characterized by a hyper arid climate. The diagram characterizes the region as having a dry period all year round, hence the need for irrigation.

The particle size analysis made it possible to conclude that the soil is sandy (medium) with a spread distribution (uniformity coefficient $C_u = 3.1$) and an apparent density is 1.15. The PH is between 6.5 and 8.5 therefore admissible. The salinity of the water of 0.53psu (1g of salt per kg of water) allows us to conclude that the soil is not salty.



CHAPTER III
IRRIGATION REGIME

Introduction

Taking into account the climatic conditions of the study region, the nature of the soil, the suitability for cultivation and the volume of water available, we opted for "drip" as an irrigation technique and for "cotton, sunflower, wheat and alfafa" as crops. We determine the water needs of the crops to which we add the leaching dose.

III.1 Characteristic of the basic data

Spacing for Cotton

- Spacing between trees: $E=8\text{m}$ [<https://www.google.com>]
- Spacing between crop rows: $E_r= 1\text{m}$ [<https://www.agricultureegypt.com/Agenda/Articles>]
- Dripper spacing: $e=0.4\text{m}$ [<https://regaber.com/blog/canal>]

Spacing for the sunflower:

- Spacing between crops: $E = 1\text{m}$ [<https://www.terresinovia.fr/-/tournesol>]
- Spacing between Sunflower rows: $E_r= 0.5\text{ m}$ [<https://regaber.com/blog/canal-de-l-aragon>].
- Dripper spacing $e = 0.5\text{m}$ [<https://agronomie.info/>]

Spacing for wheat

- Distance between crops:
- Spacing between rows: $E_r = 2\text{m}$
- Dripper spacing $e = 0.2$

Spacing for the alfafa

- Distance between crops:
- Spacing between rows: $E_r = 2$
- Dripper spacing: $e = 0.2$

III.2 Soil characteristics:

- Apparent density of the soil $d_a = 1.15\text{ g/m}^3$ (Determined in the laboratory)
- Weight retention capacity $H_{pr} = 21\%$ [D Oulhaci.,2003.]
- Humidity at the wilting point by weight $H_{pf} = 7\%$ [D Oulhaci.,2003.]

III.3 Vegetative period:

The growing period, i.e. the distribution of land use relative to the crop cycles selected, is constant in this study (to be able to make a comparison between the theoretical values and the experimental values). The growing period begins in February (start of field experiments). The end of the sunflower growing season is the end of June, that

CHAPTER III: IRRIGATION REGIME

of cotton at the end of August and that of esparto at the end of July.

III.4 Climate data:

In this study, we opted to use as climatic data (temperatures, precipitation, percentage of lighting duration) necessary for determining water needs, those provided by the Climwat software (our results will be used for a comparison with water requirements provided by agrometeorological models).

Table III 1: Climatic factors provided by the Ouargla Climwat model

Months	T min	T max	H	Vent	I	Ray.	P
	°C	°C	%	km/day	hours	MJ/m ² /days	Mm
January	4,4	17,2	62	181	6,8	11,8	7
February	6,7	20	57	199	8	15,3	5
March	9,4	23,3	43	181	8,9	19,3	8
April	13,9	28,9	50	216	9,4	22,5	1
Mau	17,8	32,8	42	216	9,6	24,1	1
June	23,3	39,4	36	207	9,5	24,3	0
July	25,5	42,8	39	173	11,2	26,5	0
August	25	41,7	41	181	10,3	24,1	0
September	22,2	37,2	50	190	9	20,2	4
October	16,1	30,5	58	207	8,1	16,2	3
November	10	23,3	77	181	7	12,4	6
December	6,1	18,3	73	181	6,7	11	5
Average	15	29,6	52	193	8,7	19	40

T min: Minimum monthly temperature in °C. T max: Maximum monthly temperature in °C. H: Air humidity in %. Wind: Average wind speed in km/day. I: Insolation in hours per month Ray: Average solar radiation in mj/m²/day P: Monthly precipitation in mm/month.

III.5. Irrigation water requirements:

The water balance of a given crop is the difference between, on the one hand, the water requirements of the crops and on the other hand, the sum of the actual inputs.

$$B = Kc \cdot ETP - (Pe + X RFU) \text{ (mm/month)} \quad \text{(III.1)}$$

ETM = Kc. ETP corresponds to the maximum consumption of the plant. But physiological or more often economic reasons can lead to considering a certain rationing of the plant.

CHAPTER III: IRRIGATION REGIME

Kc is the specific crop coefficient of a given crop which takes different values depending on the vegetative stage of the crop. In this study, we use the crop coefficients provided by the cropwat model summarized in Table III.2.

Tableau III.2: Crop coefficients provided by the cropwat model

Months	February	Mar	April	May	June	July	August
Sunflower	0.35	0.83	1.8	1.6	0.6		
Cotton	0.35	0.37	0.97	1.23	1.23	1.01	0.96
Alfafa	0.75	0.4	0.4	0.4	0.4	0.54	
Wheat	0.7	0.72	0.82	0.92	1.26	1.12	

ETP: Evapotranspiration represents the quantity of water lost in the form of vapor from a surface covered with vegetation. This quantity is generally expressed per unit of area and per unit of time, in m³/ha/day, in m³/ha/month or in m³/ha/year. Of course, evapotranspiration can also be written in mm/days per month or per year [M Ducrocq., 1990] The method most used in Algeria to determine Evapotranspiration is that of H.Blanney and W .Criddle (1945):

$$\text{ETP} = 0.457 P (17.8 + t) \text{ (mm/month)} \quad \text{(III.2)}$$

With

- P: the percentage of lighting duration during the period considered as a function of latitude in%. The latitude of Ouargla is 32° 45' North and 31° 45' South. We read the P values in the table in the appendix (Annex 4).
- t: monthly average temperature in C.

We determine the ETP using this formula and summarize the values in Table III.2

Table III.3: Monthly ETP estimated by the Blanney – Criddle method

Months	Tmoy °C	P%	ETP(mm)	Mois	Tmoy °C	P%	ETP(mm)
January	10.8	7.2	94.10	August	33.35	9.8	229.08
February	13.35	7	99.64	September	29.7	9.3	201.87
March	16.35	8.4	131.09	October	23.2	7.9	148.02
April	21.4	8.8	157.64	November	16.65	7.1	111.77
May	25.3	9.6	189.08	December	12.2	7.1	97.34
June	31.35	9.6	215.63	Average	22.316	8.45	158.60
July	34.15	9.6	227.91	year	267.8	101.4	1903.234

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ETP values vary from month to month. ETP takes a minimum value in January of 94.10 mm/month and a maximum value of 229.08 mm/month in August, the average monthly ETP is 158.60 mm/month with the annual total of around 1903.23 mm

III.6. Effective rain (Pe):

Effective rain represents only a portion of the total precipitation that actually fell. In practice, given the extreme difficulty of evaluating the share of effective rainfall contained in total precipitation, we proceed by approximations. [CHARRE, Joël., 1997] The method proposed by the I.R.A.T (Institut de Recherches Agronomiques Tropical) integrates the following parameters:

- ❖ $P < 20 \text{ mm} \quad R = 0 \rightarrow Pe = P$
- ❖ $P > 20 \text{ mm} \quad R = 0,15 (P - 20) \rightarrow Pe = P - R$
 - P: Rain measured in (mm).
 - R: Runoff in (mm).
 - Pe: Effective rain in (mm).

We determine R according to the precipitation P and we calculate the effective rain Pe. In this study we use the rainfall and effective rainfall provided by the cropwat model summarized in Table III4

Table III4: Effective rain in mm provided by the cropwat model for the Ouargla

Months	M	A	M	J	J	A	S	O	N	D	J	F	Year
P (mm)	3.1	1.8	1.6	0.8	0.4	0.6	3.9	4.1	1.2	4.2	9.4	3.2	34.3
Pe(mm)	3.1	1.8	1.6	0.8	0.4	0.6	3.9	4.1	1.2	4.2	9.4	3.2	34.3

Runoff is still zero since precipitation is less than 20mm. This table shows that the annual contribution of effective rainfall is of the order of 34.3 mm distributed irregularly during the year, the maximum value is recorded in the month of January which reaches 9.4 mm, and minimum value of the order of 0.4 mm recorded in July

*X : Usable percentage of the initial reserve, taking into account the rooting depth reached. (we take X=1)

Readily Usable Reserve (RFU):

The easily usable reserve (RFU) by plants, for a soil depth (Z) and surface area equal to 1 ha is determined by the relationship:

$$\mathbf{RFU=y. RU (m^3/ha).} \quad \text{(III.3)}$$

Y=2/3 sandy soil [Gchpée.2016]

RU is the Useful Reserve in (m³ /ha) is determined by the formula:

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$$RU = 10^4 \times h \times da \times (H_{pr} - H_{pf}). \quad (III .4)$$

With:

Z: rooting depth in m;

da: apparent density of the soil (1.15g/m³)

H_{pr}: weight retention capacity (21%) [https://kiaai.ae/sites/default/files/book_files/]

H_{pf}: humidity at wilting point by weight (7%) [<ps://ar.stuklopechat.com>]

Fraction the following:

In arid and semi-arid zones, the irrigation of salty soils requires a higher water supply than the crops need [V Valles, F Bourgeat, M Guiresse, 1988.] which can allow the leaching of salts. To evaluate the sivant fraction, we must know both the salinity of the irrigation water and the tolerance of the crop with respect to soil salinity. Generally, we use the formula of [JD Rhoades., 1971.] ,[V Valles, F Bourgeat, M Guiresse., 1988.] the Rhodes formula is presented as follows:

$$FL = \frac{CE_i}{5CE_e + CE_i} \quad (III. 5)$$

With :

CE_i: Electrical conductivity of irrigation water (mS/cm)

CE_e: electrical conductivity of saturated extract averaged over the root zone (mS/cm).

The application of the Rhoades formula requires the determination of the salinity of the irrigation water, as well as the average salinity in the soil profile [RHOADES JD., 1971.]

The leaching dose can be estimated for sandy soils at 15% of the water requirements B_n

We determine the needs for each crop which we summarize in tables III.4 to III.7

Table III.5: Sunflower water requirements

Sunflower					
Months	Feb	Mrch	Apr	May	Jun
Coef Kc	0.35	0.83	1.8	1.6	0.6
ETP (mm)	99.64	131.09	157.64	189.08	215.63
ETM (mm)	34.87	108.80	283.67	302.54	129.37
Pe (mm)	3.2	3.1	1.6	1.8	0.8
Z(mm)	200	310	450	550	600
RFU	21.44	33.24	48.251	58.97	96.6
B (mm)	10.23	72.46	233.71	241.96	64.42

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Table III.6: Water requirements of cotton

Cotton							
Mois	Feb	March	April	May	Jun	Jul	Augst
Coef Kc	0.35	0.37	0.97	1.23	1.23	1.01	0.96
ETP (mm)	99.64	131.09	157.64	189.08	215.63	227.19	229.08
ETM(mm)	34.87	48.50	152.91	232.57	265.22	230.19	219.91
Pe (mm)	3.2	3.1	1.8	1.6	0.8	0.4	0.6
Z(mm)	500	650	750	950	1010	1200	1300
RFU	53.61	69.69	80.41	101.86	108.29	128.67	139.39
B (mm)	-----	58.29	70.69	85.62	156.12	101.72	79.92

Table III.7: Water requirements of wheat

Wheat						
Months	Feb	March	April	May	Jun	Jul
CoefKc	0.7	0.72	0.82	0.92	1.26	1.12
ETP(mm/mois)	99.64_	313.095	157.64	189.08	215.63	229.08
ETM(mm/mois)	69.75	94.38	129.27	173.96	271.69	256.57
Pe(mm)	3.2	3.1	1.8	1.6	0.8	0.4
Z(m)	450	730	1130	1250	1660	1760
RFU	48.251	78.27	121.16	134.03	177.99	188.71
B(mm)	8.33	13.01	34.68	38.32	41.14	67.45

Table III.8: Water requirements of alfafa

Alfafa						
Months	Feb	March	April	May	Jun	Jul
Coef Kc	0.75	0.4	0.4	0.4	0.4	0.54
ETP (mm)	99.64	131.09	157.64	189.08	215.63	123.07
ETM (mm)	74.73	52.43	63.05	75.63	86.25	123.07
Pe (mm)	3.2	3.1	1.8	1.6	0.8	0.4
Z(m)	190	250	360	470	553	683
RFU	20.37	26.80	38.60	50.39	59.29	73.23
B (mm)	16.28	22.53	22.65	23.63	25.35	49.83

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We summarize the total requirements of the four (4) crops, to which we add the leaching dose DL and we determine the monthly requirements B in mm. We report all the results in Table III.9.

Table III.9: Water requirements of all crops

Months	F	M	A	M	J	J	A	Total
Sunflower	10.23	72.46	233.71	241.96	64.42			622.78
Cotton		58.29	70.69	85.62	156.12	101.72	79.92	552.36
Wheat	8.33	13.01	34.68	38.32	41.14	67.45		203.23
Alfafa	16.28	22.53	22.65	23.63	25.35	49.83		160.07
Monthly	34.84	166.29	361.73	389.53	287.31	219	79.92	1538.62
DL (mm)	5.22	24.94	54.25	58.42	43.09	32.85	10.93	229.7
B (mm)	40.06	191.23	415.98	447.42	330.04	251.85	90.85	1767.43

Kc → cultural coefficient

ETP → Evapotranspiration

ETM → Maximum evapotranspiration

Pe → Effective rain

Z → Root depth

RFU → Easily Usable Reserve

B → Water needs

DL → Leaching dose

III.6.1 Crop needs for localized irrigation

Watering obeys laws, from the point of view of doses, frequencies and durations which are determined for the dimensioning of the network.

The total daily water requirements for traditional irrigation are equal to 556.3 mm and correspond to the month of July, with:

For the:

- Wheat at least from July 67.45 mm, So: aperture = 2.17 mm./ day.
- Cotton tree at least from June B= 156.12mm, So: ajour= 5.20 mm / day.
- Sunflower at least May and 241.96 mm, So: aperture = 7.80 mm / day.
- Alfafa less than July 49.83mm, So: aperture = 1.60mm / day

But it is preferable to size the network with the maximum needs, that is to say:

Cutting-edge ETM. For the month of June or July we have:

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Wheat ETM = 271.96 mm for the month of June

Cotton ETM = 265.22 mm for the month of June

ETM of Sunflower = 302.54 mm for the month of May

ETM of Alfafa = 123.07 mm for the month of July

We determine the corresponding daily requirement a (mm/d) as follows:

Mainly with localized irrigation for row crops where only part of the surface occupied by the plants is irrigated.

Therefore: the figures for water requirements determined by the methods where the entire surface area is considered to be irrigated must be multiplied by a reduction coefficient “ K_r ” depending on the coverage rate “ Cr ”.

Therefore, in localized irrigation, the daily needs are reduced as follows:

$$B_r = ETM_{point} * K_r \tag{III.6}$$

The K_r coefficient given by several formulas like:

The Keller and Karmeli formula is (1974):

$$K_r = \frac{C_s}{0.85} \tag{III.7}$$

The Freeman and Garzoli formula is:

$$K_r = C_s + 0,5 (1 - C_s) \tag{III.8}$$

The Decroix formula is (CTGREF):

$$K_r = 0,1 + C_s \tag{III.9}$$

In our case we consider a coverage rate equal to 100% for sunflower, wheat and esparto and 70% for cotton. We summarize the values of the coefficients K_r in table III.10.

Table III.10: Coefficient K_r

Crops	Cs	Coefficient K_r		
		Keller et Karmeli	Freeman et Garzoli	Decroix
Wheat	1	1.17	1	1.1
Cotton plant	0.7	0.82	0.7	0.8
Sunflower	1	1.17	1	1.1
Alfafa	1	1.17	1	1.1

We choose the Decroix method:

$K_r = 1.1$ for wheat

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Kr=0.8 for cotton

Kr= 1.1 for sunflower

Kr= 1.1 for alfafa

We determine for localized irrigation the monthly needs BI and the daily needs al. The values are shown in Table III.10

III.6. 2 Pratical dose:

The practical dose is determined by the formula: [Ollier CH .Poiree M ., 1971]

$$dp = 2/3x h x P(H_{pr}- H_{pf}) \quad (III.10)$$

* Pest the fraction of the surface to be humidified. The optimum of P depends on many variables: Nature of cultivation:

- Flow rate and dripper spacing
- Nature of the soil watered
- Rainfall in the region.

It is between 0.20 and 1.

The table in (appendix 5) taken from the American study “trickle irrigation design” by J.Keller and D.Karmeli gives the P values according to:

- Spacing between ramps
- Dripper flow
- Optimal spacing of drippers determined by soil texture (G coarse texture soil, M medium texture, F fine texture).

For closely spaced crops, it may be necessary to moisten a large part of the soil ($0.80 < P < 1$) to ensure certain nourishment for each plant.

For wheat r we have:

- Spacing between rows: $E_r = 2m$.
- Dripper spacing $e = 0.2m$
- We have the choice between different drippers with varying flow rates $q = (1,2,4,6,8)$ l/h. $q=1l/h$

So

$$P= 15\%$$

For the sunflower:

- Spacing between lines $E_r=0.5 m$
- Spacing of drippers $e= 0.5m$

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- We have the choice between different drippers with varying flow rates $q = (1,2,4,6,8)$ l/h. $q=1$ l/h

So

$$P = 38\%$$

For cotton:

- Spacing between lines $E_r=1$ m
- Dripper spacing $e=0.4$ m
- We have the choice between different drippers with varying flow rates $q = (1,2,4,6,8)$ l/h. $q=1$ l/h

So

$$P= 45\%$$

For the alfafa:

- Spacing between lines $E_r=2$ m
- Dripper spacing $e=0.2$ m
- We have the choice between different drippers with varying flow rates $q = (1,2,4,6,8)$ l/h. $q=1$ l/h

So

$$P= 15\%$$

Even on this P fraction of the soil, humidification is not perfectly uniform. We notice:

- d_{min} the dose received in the least well-watered areas
- average the average dose.

The uniformity coefficient C_u is defined as follows:

$$C_u = \frac{d_{min}}{d_{moy}} . \quad (III.11)$$

It is generally taken equal to 90%

On the other hand, a fraction delivered, often estimated at 15%, will be lost by evaporation, lee, deep percolation.

The yield R is therefore 85%.

The net dose d_n actually consumed by the plants is therefore only a fraction of the actual practical dose.

$$d_n = d_p * c_u * R \quad (III.12)$$

III.7 Watering frequency

The frequency or spacing between two waterings depends on the (reduced) needs of the crop in net dose supplemental water applied to each watering;

$$T = \frac{dn}{al} \quad (III.13)$$

We round the number of days to Tc and correct the net dose to get the real dose.

$$dr = al * Tc \quad (III.14)$$

This real dose dr is lower than the practical dose dp

To meet the water needs of wheat in localized irrigation, it is necessary to irrigate 4 hours every 2 days, for sunflower 2 hours every 2 days, for cotton 2 hours every 8 days and for alfafa 2 hours every 2 days.

Table III.11: Determination of all watering doses and times

	B(mm/m)	a(mm/d)	Kr	Br(mm/m)	al (mm/d)	P (%)
Wheat	67.45	2.17	1.1	298.85	9.69	15
Cotton	156.12	5.20	0.8	124.89	4.1	45
Sunflower	241.96	7.77	1.1	332.79	10.73	38
Alfafa	49.83	1.60	1.1	135.37	4.36	15

Table III.12 (continued): Determination of all watering doses and times

	Hpr-Hpf (%)	dp mm)	dn(mm)	T (days)	Tc(days)	Dr
Wheat	14	24.64	18.84	1.94	2	19.92
Cotton	14	42.42	32.45	7.91	8	32.8
Sunflower	14	19.50	14.91	1.38	2	21.46
Alfafa	14	9.56	7.38	1.84	2	8.72

III.8. Watering duration:

If watering all at once, the watering duration in hours is calculated as follows:

$$\Theta = \frac{V}{q} \quad (III.15)$$

spacing:

❖ for wheat E =2 m,

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❖ for the Cotton Plant E=1m;

❖ for Sunflower E=0.5m

for Alfafa E= 2m

With

Among the choice between different drippers with flow rates varying q = (1,2,4,6 et 8) l/h, we opted for 2l/h.

V: is Volume to be supplied by the dripper:

$$V = G * d_{rl} \quad (III.16)$$

dr: real dose =mm for palm and= for sunflower, and

for okra =mm, for melon =mm

G is the surface served by a dripper.

$$G = E * e \quad (III.17)$$

- **For Wheat**

We have

➤ E= Spacing between lines 2m

➤ e= Spacing between drippers is 0. 2m

$$G = 2*0.2 = 0.4 \text{ m}^2$$

$$V = 0.4\text{m}^2 * 19.92 * 10^{-3} \text{ m} = 7.96 * 10^{-3} \text{ m}^3 = 7.96 \text{ liters}$$

q is the flow rate provided by the dripper 1l/h

$$\Theta = \frac{7.96}{1} = 7.96 \text{ hours}$$

That's to say $\frac{7.96 \text{ heures}}{(20*24) \text{ heures}} = 0.16$ or 16% of the total duration of the period T= 2d

- **For the sunflower**

We have

➤ E= Spacing between ramps = 0.5m

➤ e = Spacing between drippers is 0.5.m

$$G = 0.5*0.5 = 0.25\text{m}^2.$$

$$V = 0.25\text{m}^2 * 21.46 * 10^{-3} \text{ m} = 5.36 * 10^{-3} \text{ m}^3 = 5.36 \text{ liters}$$

q is the flow rate provided by the dripper 1 l/h

$$\Theta = \frac{5.36}{1} = 5. \text{hours}$$

That's to say $\frac{5.36 \text{ heures}}{(2*24) \text{ heures}} = 0.11$ i.e. 11% of the total duration of the period T= 2d

- **For the cotton plant**

We have

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- E= Spacing between ramps = 1m
- e = Spacing between drippers is 0.4m

$$G = 1 * 0.4 = 0.4 \text{m}^2.$$

$$V = 0.4 \text{m}^2 * 32.8 * 10^{-3} = 13.12 * 10^{-3} = 13.12 \text{ liters}$$

q is the flow rate provided by the dripper 1l/h

$$\Theta = \frac{13.12}{1} = 13.12 \text{ hours}$$

That's to say $\frac{13.12 \text{heures}}{(8*24) \text{heures}} = 0.068$ so 6.83% of the total duration of the period

, T=8days

- **For Alfafa**

We have

- E= Spacing between ramps = 2m
- e = Spacing between drippers is 0.2m

$$G = 0.2 * 2 = 0.4 \text{m}^2$$

$$V = 0.4 \text{m}^2 * 8.72 = 3.48 * 10^{-3} = 3.48 \text{ liters}$$

q is the flow rate provided by the dripper 1 l/h

$$\Theta = \frac{3.48}{1} = 3.48 \text{ hours}$$

That's to say $\frac{3.48 \text{ heures}}{(2*24) \text{heures}} = 0.072$ or 7.2% of the total duration of the period T= 2days

Table III.13: Watering parameters

	a_i (mm/d)	Dr	T(days)	E(m)	e(m)	G(m²)
Wheat	2.17	19.92	1.94	2	0.2	0.4
Cotton plant	5.20	45.06	2.16	1	0.4	0.4
Sunflower	7.77	21.46	1.38	0.5	0.5	0.25
Alfafa	1.60	8.72	1.84	2	0.2	0.4
	V(m³)	Q(l/h)	Θ(h)	Θ%		Θ'(h/day)
Wheat	7.96	1	7.96	16	0.16	3.98
Cotton plant	13.12	1	13.12	25	0.25	1.64
Sunflower	5.36	1	5.36	11	0.11	2.68
Alfafa	3.48	1	3.48	7.2	0.072	1.74

So, we water:

- every 2 days for 4 hours wheat; with a daily watering dose $d=19.92\text{mm}$
- every 2 days during sunflower 2 h; with a watering dose $d=21.46\text{mm}$
- every 8 days for 2 hours the cotton plant; with a watering dose $d=32.45\text{mm}$
- ❖ every 2 days 2 hours alfafa during; with a watering dose $d=8.72\text{ mm}$:

III.9. Practical provisions

For wheat, alfafa and sunflowers, we therefore irrigate for 6.45% of the watering period and 93.55% of this period the soil will not receive water. And for cotton 26.66%/73.55%. But in reality, it is better to keep the soil constantly very close to the retention point and, to do this, “water a little every day”.

To do this, we divide the total duration Θ of 7.96 hours for wheat, 23.4 for sunflower, 13.12 hours for cotton and 3,480 hours for esparto by the time T equal to 2 days for wheat, esparto and sunflower. and 8 days for the cotton plant times a daily duration:

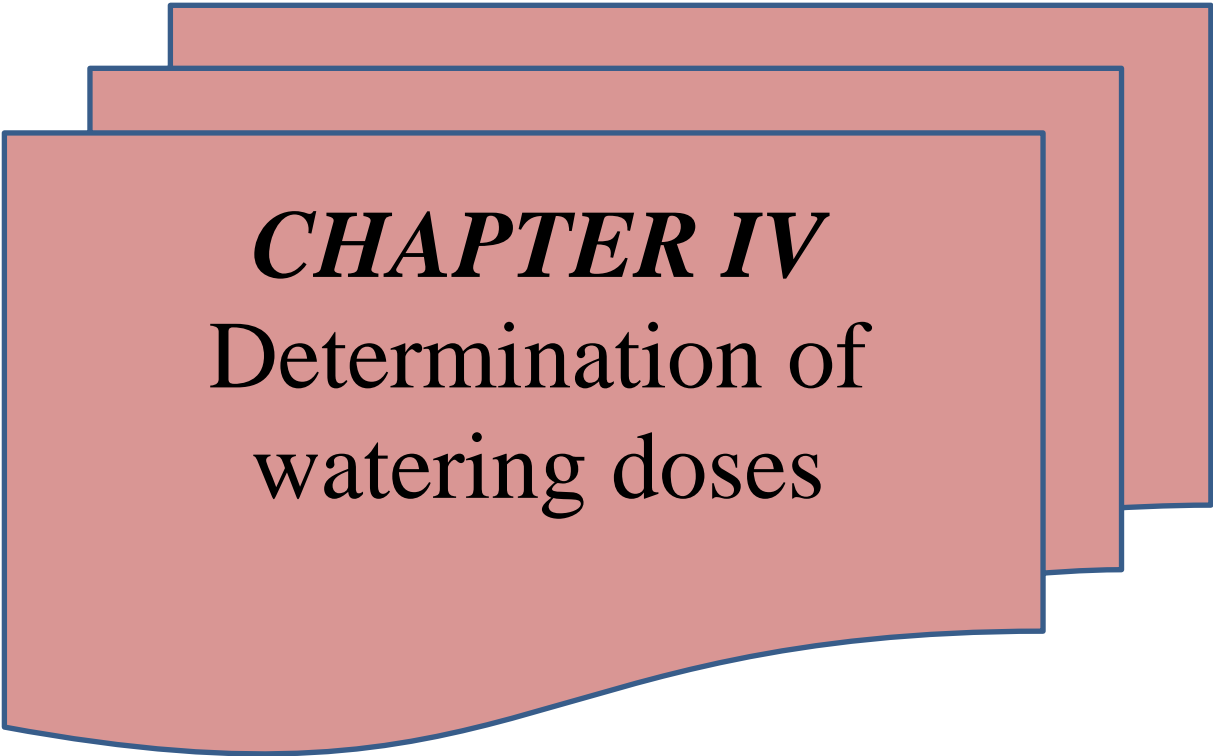
- For wheat $\Theta'=7.96/ 2= 3.98\text{ hours/d}$. That is to say almost the total duration of the day.
- For sunflower $\Theta'= 5.36/ 2 = 2.68\text{ hours/day}$. That is to say only 2 hours and 6 minutes per day.
- For the Cotton Plant $\Theta'=13.12/ 8= 1.64\text{ hours /d}$. That is to say only 2 hours during the day;
- For the Alfafa $\Theta'= 3.48/ 2 = 1.74\text{ hours/day}$. That is to say almost 2 hours of the total duration of the day.

We therefore irrigate every day for 4 hours the wheat, 2 hours and 6 minutes the sunflower, 2 hours the cotton plant and 2 hours the alfafa a watering dose of 19.92 mm, 21.46mm, 32.45mm and 8.72 mm respectively for the wheat, sunflower and cotton and falfa.

Conclusion of Chapter III

The objective of this chapter is to determine the irrigation regime. We first determined the maximum potential evapotranspiration for each crop. We obtained for wheat 271.96 mm in June, for sunflower 302.54 mm in May, for cotton 265.22 mm in June and for alfalfa 123.07 mm in July. Evapotranspiration made it possible to determine the monthly water needs: 313.09mm, 215.63mm, 229mm and 215.63 mm for respectively wheat, sunflower, cotton and alfalfa.

Concerning the irrigation regime, we obtained a watering duration equal to 9.96mm, 10.73mm, 4.1mm and 4.36mm and a watering time of 4h and 38min, 2h and 6mn, 2h and 4mn and 2h and 14 min for wheat, sunflower, cotton and alfalfa respectively. The best frequency is daily irrigation so as not to moisten the soil one period and dry it out another period.



CHAPTER IV
Determination of
watering doses

CHAPTER IV: Determination of watering doses

Introduction

The aim of this work is to determine on the one hand the dose of watering received in the soil experimentally by measuring the humidity of the soil before and after watering. And on the other hand, the estimation of the fluctuation in soil salinity caused by irrigation by measuring the conductivity before and after watering.

We irrigate by two methods:

- Using the bottle
- Drip by drip

IV.1. Equipment used:

The material used in this work is:

- Sunflower seeds (Photo.IV.1)
- Drip pipes 16 mm in diameter (photo. IV.2)
- Geotextile fabric (photo. IV.3)
- Several one (1.5) liter plastic bottles.
- Drippers
- Pipes (40 and 60) photo.IV.4 and.IV.5)
- Reducer (40/60) (photo IV6)
- The valves (photo. IV.7)
- Water tank (photo. IV.8.)
- A humidity meter (photo IV.9a)

The material used is simple. We therefore only give an overview of the soil moisture sensors used for the determination of soil moisture in % and electrical conductivity: SM100 (photo. IV.8a) and SMEC300 (photo. IV.8b).

The meter initially displays the firmware level, then enters sensor reading mode. The initial mode display is the mode that was active when the meter was turned off.

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Photo IV.1: Sun-flower seeds



Photo IV.2: Geotextile fabric



Photo IV3: Pipes 40



Photo IV4: Pipes 60



Photo IV5 : Reducer



Photo IV.6: The valves

[N Gouarah and K Koul; 2024]

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Photo IV.7: water tank



Photo IV.8 : drip pipes



Photo IV.9. a: Soil moisture sensor (SOIL SENSOR READER SM100).



Photo IV.10. b: Soil moisture sensor (SOIL SENSOR READER SMEC300).

[N Gouarah and K Koul; 2024]

IV.2. Standard spectrum:

For the SM100 and SMEC300, the volumetric water content of mineral soil is displayed on the first line. For the SMEC300, the EC is on the second line.

The adapter has a 2.5mm stereo pin which can then be connected to the meter.

To calibrate the sensor, one needs a container large enough that the sensor can be submerged up to the midpoint of the sensor casting.

For the test of this study, the sunflower was sown on 13/02/24 (photo IV.9), a week after 02/21/24 the first leaves appeared. 07/04/24 the foliage is dense (photo IV.10).

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Photo IV.11: Appearance of first

[N Gouarah and K Koul; 2024]

Photo. IV .12: Experimental protocol leaves (21/02/24)

The irrigation techniques used are:

-The drip

-A combination of drip irrigation with jar irrigation.

IV.3 Types of irrigation

IV.3.1. Drip by Drip

A drip irrigation pipe is connected to a 60cm diameter water pipe, which contains controls for each drip irrigation pipe. We irrigate for 4 hours' Time

IV.3.2. Combined irrigation

Drip irrigation is combined with one of the oldest methods used since Roman times throughout North Africa and the Near East based on the frequent pouring of water into porous pottery vessels buried in the ground [Saskatchewan, SLIMANI. A. Contribution] The vases are replaced by full one (1.5) liter capacity plastic bottles which release water through their perforated walls into the surrounding soil. (Photo IV. 13). [Ouargla meteorological station] The humidity that emerges nourishes the roots of the plant.

To ensure porosity and to allow the bottles to hold together, they are filled with sawdust (photo IV11). Sawdust will also filter water used for irrigation and reduce salinity.

CHAPTER IV: Determination of watering doses

We pierce the bottles with holes of 2 mm in diameter spaced 2 cm apart in the four directions (photo IV. 14) (we therefore have 16 holes in height and 13 holes on the periphery), then we wrap the bottles in geotextile fabric (photo IV. 15) to standardize the humidity of the soil around the bottles on the one hand and to prevent the penetration of roots inside the bottles on the other hand.



Photo IV.13: Sawdust bottle



Photo IV.14: Drilling the bottle

[N Gouarah and K Koul; 2024]

We dig small, shallow pits in the ground and place the bottles there. The ground is then gently tamped around the necks of the bottles so that their edges barely exceed the surface of the ground. The water comes to the bottles by means of a pipe fed from a nearby tap (Photo III.14); at the end of the pipe or at the entrance to the bottle we place a dripper with a flow rate of 0.22L/S



Photo N° IV.15: Bottle wrapped in a geotextile fabric



Photo IV .16 Watering place

[N Gouarah and K Koul; 2024]

CHAPTER IV: Determination of watering doses

First, we study the circulation of water in the bottle and in the ground. To do this, we carry out an isolated experimental setup by placing plastic bottles filled with sawdust on a table.

Then, we pierce the plug and attach a three-way connector (head outputs). The bottle is connected to the reservoir by a transparent tube. The feed rate is equal to 0.22l/s. Water comes out of the last hole 1.58 minutes later.



Photo IV.17: the filled bottle Measurement methodology [Gouarah N and KOUL K; 2024]

The following formula is usually used to determine the water reserve received in the soil in millimeters (mm).

$$R = W_{fin} - W_{in} \quad (IV.1)$$

That is to say the difference between the quantity of water contained in the soil after watering (W_{fin}) and the quantity of water contained in the soil before watering (W_{in}) [Fareh B and Aidouni D, 2015]

$$R = P (H_{end} - H_{in}) \quad (IV.2)$$

H_{end} is the final humidity, i.e. after watering in (%)

H_{in} is the minimum humidity, i.e. initial watering in (%)

The results are summarized in Annex IV.1 for combined irrigation and Table IV.2 for Drip by Drip.

CHAPTER IV: Determination of watering doses

Table IV.1 shows the results of the watering doses received by irrigating with Drip by Drip and using combined irrigation.

Table IV.1: Irrigation dose for sunflower plants Bottle irrigation method and Drip by Drip

Dates	Drip by Drip	combined irrigation
18/02/24	8.9	7.16
20/02/24	14.6	8.06
22/02/24	14.25	8.65
25/02/24	15.86	10.4
27/02/24	15	8.83
29/02/24	18.17	10.92
03/03/24	15.56	12.6
05/03/24	16.69	13.6
07/03/24	18.9	11.4
10/03/24	16.66	12.7
12/03/24	17.96	12.32
14/03/24	18	12
17/03/24	17.33	10.83
19/03/24	17.73	12.6
21/03/24	16	13

The results in Table IV.1 show that the watering dose received in the soil in the case of combined irrigation is greater than that received by irrigating by Drip by Drip for the same water supply time.

To determine whether sawdust absorbs a quantity of salt from brackish water, the electrical conductivity is measured before and after irrigation.

The results are summarized in Annex IV.3 for combined irrigation and Table IV.4 for Drip by Drip

Table IV.2 shows the results of increasing electrical conductivity by irrigating with Drip by Drip and using combined irrigation.

. The results in Table IV.2 show that the increase in electrical conductivity in the soil after irrigation is greater in the case of drip irrigation.

CHAPTER IV: Determination of watering doses

Table IV.2: Increased electrical conductivity for soil Bottle irrigation method and Drip by Drip

Dates	Drip by Drip	combined irrigation
18/02/24	0.05	0.08
20/02/24	0.05	0.02
22/02/24	0.11	0.02
25/02/24	0.06	0.03
27/02/24	0.09	0.09
29/02/24	0.16	0.02
03/03/24	0.16	0.04
05/03/24	0.22	0.07
07/03/24	0.21	0.03
10/03/24	0.26	0.04
12/03/24	0.12	0.04
14/03/24	0.42	0.02
17/03/24	0.37	0.03
19/03/24	0.25	0.01
21/03/24	0.23	0.099

The results in Table IV.2 show that the increase in electrical conductivity in the soil after irrigation is greater in the case of drip irrigation

Conclusion of Chapter IV

The results show on the one hand that the dose of watering received in the soil in the case of combined irrigation is greater than that received by irrigating by Drip by Drip for the same water supply time. We can therefore conclude that combined irrigation reduces evaporation losses.

And on the other hand, we see that the increase in electrical conductivity in the soil after irrigation is greater in the case of drip irrigation. We can therefore conclude that sawdust can retain a quantity of salt from water.



GENERAL CONCLUSION

In the bibliographic study we were interested in the irrigation techniques most used in general and those opted for in this work in particular. The study of irrigation techniques led to the choice of the most economical procedure with several advantages, which is localized irrigation. This method delivers water and fertilizer directly to plant roots, and prevents water loss through evaporation, runoff and underground infiltration. It seems that drip irrigation is most suitable.

As crops, in this modest study, we opted for the cultivation of sunflower, because this plant tolerates the dry conditions of the Saharan regions and adapts to sandy soils and purified water.

Examination of climatic data shows that the study area is defined by an arid climate characterized by a hot summer and a cool winter with a dry period extending throughout the year, significant evaporation is accentuated by hot winds. In summer (Sirocco) and significant sunstroke. All these parameters cause water stress for crops, which therefore requires irrigation. The particle size analysis made it possible to conclude that the soil is sandy (medium) with a spread distribution (uniformity coefficient $C_u = 3.1$) and an apparent density is 1.15. The pH is between 6.5 and 8.5 therefore admissible. The salinity of the water of 0.53psu (1g of salt per kg of water) allows us to conclude that the soil is not salty.

The second stage of this work consists of determining the irrigation regime which is the set of doses, frequencies and durations of watering that must be applied to cultivated plants during their entire vegetation period, in the aim of compensating for the water deficit in the active layer of the soil.

For this, we first determined the monthly evapotranspiration which is 256.57 mm, 302.54 mm, 230.19 mm and 123.07 mm respectively for wheat, sunflower, cotton and Alfalfa. This allowed the determination of monthly water requirements equal to 67.45 mm for wheat, 241.96 mm for sunflower, 156.12 mm for cotton and 49.83 mm for Alfalfa.

When using both methods of drip irrigation and spot irrigation with a plastic bottle filled with sawdust. We see that this method conserves soil moisture, which helps saturate the plant with water. At the same time, it is noted that this method helps to filter the salinity of the water, which leads to the conclusion that this experiment is the best irrigation method due to its ability to maintain soil moisture and absorb excess salt.



RECOMMENDATIONS

RECOMMENDATIONS

At the dawn of the climate changes expected for this half century, investments must be planned with full knowledge of the facts and studies must be focused on the control of general irrigation and particularly localized irrigation, which is a simple technique that can be adapted at low flow rates and easily accepted by farmers.

Good irrigation practices with brackish water for the control of agronomic risks consist of the combination of several preventive or corrective measures including the selection of an adequate irrigation method, the appropriate choice of irrigated crops which have an adequate salt tolerance, proper soil management practice (preparation, amendments, etc.), sufficient leaching and drainage of the soil to drain water and carry away excess salts, and proper use of fertilizers.

In order to complete this study and to closely identify the laws which govern the determination of irrigation doses and evapotranspiration, it is recommended for the future to improve this irrigation method which uses a quantity of water necessary for the plant and prevent the water table from rising.

It is necessary to continue experiments with several other combinations of watering doses and frequencies to arrive at a water and environmental technical-economic methodology that adapts to local conditions.



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ANNEXS

ANNEXS

Annex 1: Results of particle size analysis

Ø (mm)	refusal (g)	cumulative refusals (g)	cumulative refusals (%)	cumulative sieve (%)
5	0	0	0.00	100.00
2.5	0.01	0.01	0.0016	100.00
1.25	0.65	0.66	0.0125	99.99
0.63	12.65	13.31	2.21	97.79
0.315	518	531.31	88.55	11.5
0.16	25	556.31	92.72	7.28
0.08	29.5	585.81	97.64	2.36
0	585.81			
	600			

ANNEXS

Annex 2: Particle size curve

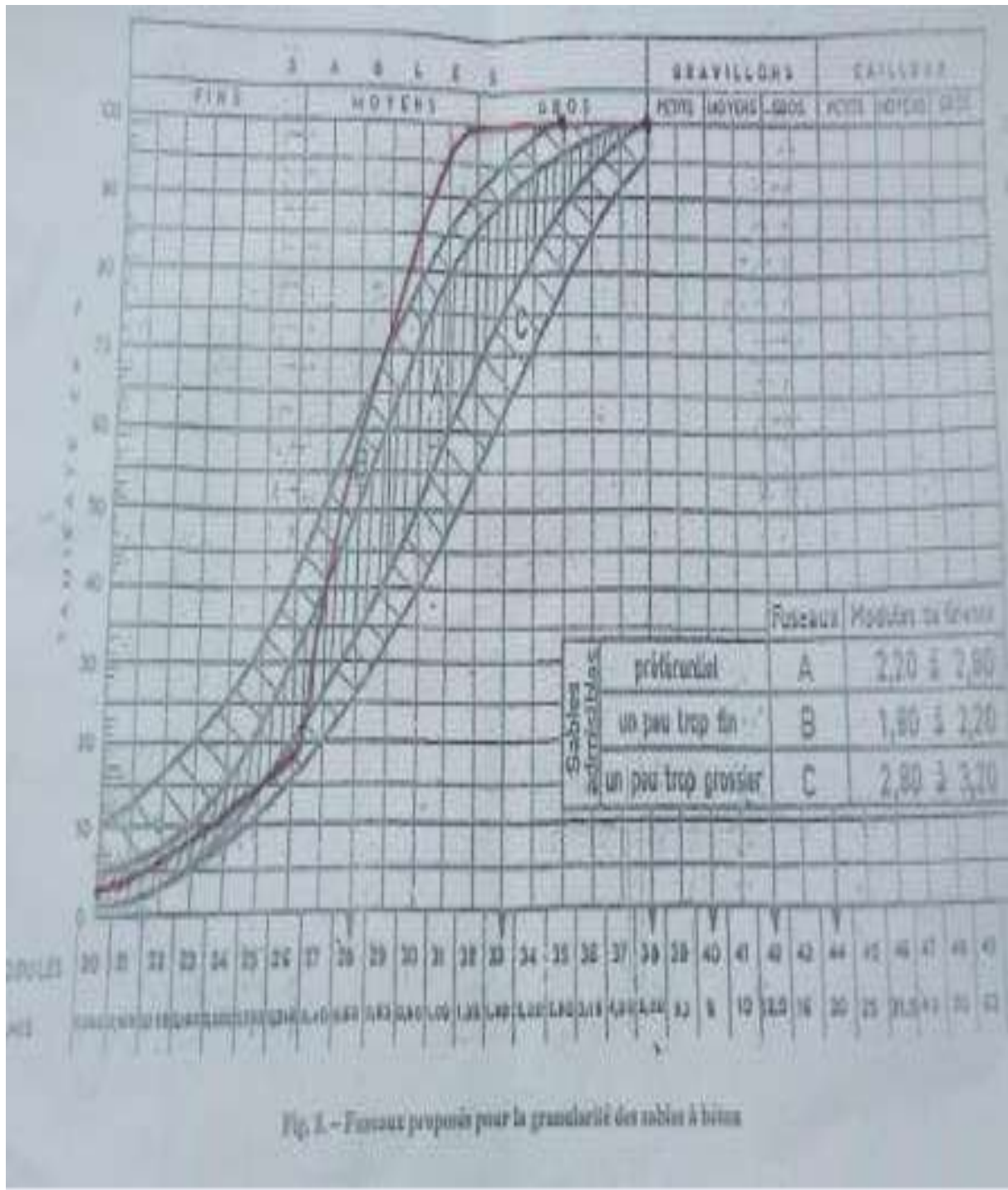


Fig. 3. - Faisceaux proposés pour la granulométrie des sables à béton

ANNEXS

Annex 3: Sunflower crop coefficient

Besoins en eau d'irrigation par semaine

	Avril			Mai			Juin			Juillet			Août			Septembre		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Coefficient cultural Kc	-	-	0,5	0,5	0,8	0,8	1,05	1,05	1,05	1,05	1,05	0,6	0,6	-	-	-	-	-
Besoins totaux (Kc x ETP) en mm	-	-	18	21	36	49	57	67	72	74	71	46	39	-	-	-	-	-
Irrigation (en mm)	-	-	-	-	-	5	22	56	71	74	70	-	18	-	-	-	-	-

Pour une RU de 160 mm et une profondeur d'enracinement de 100 à 150 cm

Annex 5: Fraction P of the soil to be humidified

		Fraction P du sol à humidifier														
Débit des goutteurs		≤ 1,5 l/h			2 l/h			4 l/h			5 l/h			≥ 12 l/h		
Espace- ment des goutteurs	m	G	M	F	G	M	F	G	M	F	G	M	F	G	M	F
		0,2	0,5	0,9	0,3	0,7	1	0,6	1	1,3	1	1,3	1,7	1,3	1,6	2
Ecarte- ment entre rampes																
0,8 m		.38	.88	1	.50	1	1	1	1	1	1	1	1	1	1	1
1		.33	.70	1	.40	.80	1	.80	1	1	1	1	1	1	1	1
1,2		.25	.58	.92	.33	.67	1	.67	1	1	1	1	1	1	1	1
1,5		.20	.47	.73	.26	.53	.80	.53	.80	1	.80	1	1	1	1	1
2		.15	.35	.55	.20	.40	.60	.40	.60	.80	.60	.80	1	.80	1	1
2,5		.17	.28	.44	.16	.32	.48	.32	.48	.64	.48	.64	.80	.64	.80	1
3		.10	.23	.37	.13	.26	.40	.26	.40	.53	.40	.53	.67	.53	.67	.80
3,5		.09	.20	.31	.11	.23	.34	.23	.34	.46	.34	.46	.57	.46	.57	.68
4		.08	.18	.28	.10	.20	.30	.20	.30	.40	.30	.40	.50	.40	.50	.60
4,5		.07	.16	.24	.09	.18	.26	.12	.26	.36	.26	.36	.44	.36	.44	.53
5		.06	.14	.22	.08	.16	.24	.16	.24	.32	.24	.32	.40	.32	.40	.48
6		.05	.12	.18	.07	.14	.20	.14	.20	.27	.20	.27	.34	.27	.34	.40

ANNEXS

Annex 6

Determination of irrigation dose for sunflower plants Bottle irrigation method

Irrigation dates	Humidity (%°)		Watering doses	Average watering doses
	Before irrigation	After irrigation		
2024/02/18	8	15	7	7.16
	9	16	7	
	8	15.5	7.5	
20/02/2024	13.5	17	13	14.6
	8	16	16	
	9	16.4	14.8	
22/02/2024	15.7	11.3	16.8	14.25
	7.3	12.4	15.3	
	8.5	12.05	10.65	
25/02/2024	13	18.3	21.2	15.86
	15.1	19.5	17.6	
	15.8	18	8.8	
27/02/2024	15	19	20	15
	14	17	15	
	16	18	10	
29/02/2024	13.5	16.8	19.8	18.17
	15.08	17.1	12.12	
	15.07	18.3	22.61	
03/03/2024	11.4	13.1	11.9	15.56
	11.13	14.09	20.72	
	13.06	15.07	14.07	
05/03/2024	16.8	17.08	2.24	16.69
	17.3	20.08	22.24	
	15.1	18.3	25.6	
07/03/2024	14.1	16.3	19.8	18.9
	14.5	16.5	18	

	15	17.1	18.9	
10/03/2024	14	16.1	21	16.66
	13.5	15.3	18	
	13.7	14.8	11	
12/03/2024	13.9	15.1	13.2	17.96
	14.1	16	20.9	
	14.8	16.6	19.8	
14/03/2024	14.3	15.8	18	18
	15.2	16.4	14.4	
	14.4	16.2	21.6	
17/03/2024	14.9	16.4	19.5	17.33
	15.1	17	24.7	
	14.8	15.4	7.8	
19/03/2024	13.7	15.1	19.6	17.73
	14.3	15.6	18.2	
	15.1	16.2	15.4	
21/03/2024	14	15.8	27	16
	14.9	15.5	9	
	15.3	16.1	12	

ANNEXS

Determination of the irrigation dose for sunflower plants

Irrigation dates	Humidity %		Watering doses	Average watering doses
	Before irrigation	After irrigation		
18-02-2024	8.9	13.7	4.8	8.9
	11.4	14.3	2.9	
	12	15.6	3.6	
20-02-2024	11.6	15.7	8.2	8.06
	11.2	14.8	7.2	
	10.3	14.7	8.8	
22-02-2024	8.9	14	15.3	8.65
	9	10.03	3.09	
	8.5	11.02	7.56	
25-02-2024	10	11.9	7.6	10.4
	9.2	12.9	14.8	
	10.1	12.3	8.8	
27-02-2024	13.2	14.9	8.5	8.83
	14.7	16.4	8.5	
	13	14.9	9.5	
29-02-2024	9.74	11	7.56	10.92
	10.4	13.4	18	
	12.6	13.8	7.2	
03-03-2024	11.7	13	9.1	12.6
	12.3	13.7	9.8	
	14	16.7	18.9	
05-03-2024	11.8	13.9	16.8	13.6
	12.6	14.5	15.2	
	12.2	13.3	8.8	
07-03-2024	13.3	15.2	17.1	11.4
	14.3	15	6.3	

	14.9	16.1	10.8	
10-03-2024	13.03	14.08	10.5	12.7
	14.06	15.3	12.4	
	14.18	15.7	15.2	
12-03-2024	13.18	14.8	17.82	12.32
	14.08	15.03	10.45	
	14.01	14.8	8.69	
14-03-2024	14.8	15.2	4.8	12
	15.1	16.1	12	
	15.93	17.53	19.2	
17-03-2024	13.8	14.8	13	10.83
	14.7	15.1	5.2	
	15	16.1	14.3	
19-03-2024	14.1	15	12.6	12.6
	14.6	15.3	9.8	
	14.9	16	15.4	
21-03-2024	16	16.9	13.5	13
	15.7	16.8	16.5	
	14.9	15.5	9	

ANNEXS

Electrical conductivity results before and after irrigation method Drip by Drip:

Dates	Before	After
18/02/2024	0.06	0.11
20/02/2024	0.11	0.16
22/02/2024	0.01	0.12
25/02/2024	0.05	0.11
27/02/2024	0.03	0.12
29/02/2024	0.01	0.17
03/03/2024	0.06	0.22
05/03/2024	0.11	0.33
07/03/2024	0.1	0.31
10/03/2024	0.15	0.41
12/03/2024	0.23	0.35
14/03/2024	0.17	0.59
17/03/2024	0.65	1.02
19/03/2024	0.80	1.05
21/03/2024	0.86	1.09

ANNEXS

Electrical conductivity results before and after drip irrigation

Dates	Before	After
18/02/2024	0.1	0.09
20/02/2024	.018	.02
22/02/2024	0.15	0.17
25/02/2024	0.20	0.23
27/02/2024	0.10	0.19
29/02/2024	0.23	0.25
03/03/2024	0.31	0.35
05/03/2024	.039	.046
07/03/2024	.057	.060
10/03/2024	0.71	0.75
12/03/2024	.077	.081
14/03/2024	.089	.091
17/03/2024	0.91	0.94
19/03/2024	0.86	0.87
21/03/2024	0.01	1

ANNEXS

Zone : Ouargla
Unité : Ouargla

Ministre des ressources en eau
Algérie des eaux
Laboratoire de contrôle de la qualité des eaux

Bulletin D'analyses

Code de l'échantillon : 1706
Nature de l'échantillon : EAU POTABLE
Lieu de prélèvement : FORAGE AIN MATTMOURA
Commune : OGX

Date et Heure de prélèvement : 17/04/2024
Prélèvement effectué par : PRELEVEUR ADE
Date d'analyse : 17/04/2024
Analyse effectuée par : Laboratoire Central

Paramètre Organique	Unité	Résultat	N.A (E.I)	Minéralisation Global	Unité	Résultat	N.A (E.I)
Couleur	mg/plaine	00	15	Calcium Ca ²⁺	mg/l	252.5	200
Odeur à 25 C°	Taux dilution	Néant	04	Magnésium Mg ²⁺	mg/l	155.55	150
Saveur à 25 C°	Taux dilution	Néant	04	Dureté Totale (TH)	CaCO3 mg/l	1270	500
Chlore résiduel libre	mg/l	brute	>0.1	Sodium Na ⁺	mg/l	465	200
Paramètre Physique-Chimique	Unité	Résultat	N.A (E.I)	Potassium K ⁺	mg/l	33	12
Concentration en ions hydrogène	Unité PH	7.91	≥5.5 ets 9	Chlorures Cl ⁻	mg/l	979.77	500
Conductivité à 25C°	µs/cm	4710	2800	Sulfate SO ₄ ²⁻	mg/l	840	400
Température	C°	/	25	Nitrate NO ₃ ⁻	mg/l	7.5	50
Turbidité	NTU	0.507	5	Bicarbonate HCO ₃ ⁻	mg/l	120.83	-
Oxygène dissous	mg/l	/	-	Titre alcalimétrique complet (TAC)	mg/l CaCO3	99.04	-
TDS	mg/l	2355					
Résidu sec 105 C°	mg/l	3986	-				
Paramètres de Pollution	Unité		N.A (E.I)	Paramètre Indésirables	Unité	Résultat	N.A (E.I)
Ammonium NH ₄ ⁺	mg/l	0.120	0.5	Fer	mg/l	00	0.3
Nitrite NO ₂	mg/l	<0.005	0.2	Manganèse	mg/l	/	0.05
Phosphore (p)	mg/l	<0.005	5	Aluminium	mg/l	/	0.2
Oxydabilité	mg/l	/	5				
Paramètre bactériologiques	Unité	Résultat	N.A (E.I)	Paramètre Ioniques	Unité	Résultat	N.A (E.I)
Coliformes totaux	/	00	/	Fluorures(F)	mg/l	/	1.5
Escherichia-coli	n/100ml	00	00	Cyanures (CN)	µg/l	/	70
Entérocoques	n/100ml	00	00	Bromes (Br)	mg/l	/	
Bactéries Sulfito-réductrices	n/20ml	/	00	Sulfure d'hydrogénée (H ₂ S)	mg/l	/	

Observation

N.A Norme Algérienne relative au décret exécutif N° 14-96

E.T : Eau Traitée

Visa du Chef Laboratoire

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