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Test on irrigation Scheduling method use on Production Parameters of a *Quinoa* Crop (Chenopodium Willd) in saline conditions in the Region of Biskra

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Safia

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Dedication

To my father and mother, who were my shadows during all the years of study and who made sure throughout my life to encourage me, give me all the help, and protect me. They inspired me to work hard and guided me whenever I faced any difficulties. I love you.

To my brothers and sister, I wish you a future full of joy, happiness, success, and serenity. I express to you through this work my feelings of fraternity and love.

To all members of my family.

Last but not least, I want to thank me

For believing in me

For doing all this hard work

For having no days off

For never quitting

I want to thank me for just being me at all times.

LIST OF ABBREVIATIONS

%	Percent.
EC	lectrical Conductivity.
Cm	Centimeter.
ET°	Reference Potential Evapotranspiration.
ETM	Maximum Evapotranspiration.
ETP	Potential evapotranspiration.
ETPs	Potential evapotranspiration in green houses.
ETR	Actual evapotranspiration.
ETR	Actual evapotranspiration.
FAO	Food and Agriculture Organization of the United Nations.
G	Gram.
Ha	Hectare.
I.T.D.A.S	Technical institute for the development of Saharan agriculture.
INRAA	National Institute of Agronomic Research; Adrar station.
INRF	National Institute of Forestry Research.
ITGC	Technical Institute of Field Crops.
Kc	Cultural Coefficient.
Kg	kilogram.
L	Liter.
Km	Kilo metre
M	Meter.
M^2	Square meter.
Mm	Millimeter.
N°	Number.
C°	The Celsius Temperature scale.
pH	Hydrogen potential.

ds/m	decisiemens per metre.
RFU	Easily Usable Reserve.
RU	Useful Reserve.
Tn	Tons.
meq/l	Milliequivalents per liter.

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Introduction

Quinoa, scientifically known as Chenopodium quinoa Willd., is a type of pseudo-cerealthat has its origins in the Andes region. It was regarded as a fundamental food source for communities that existed between 3000 and 5000 years ago. The technological advancement of quinoa washighly developed and primarily disseminated throughout the empire of the Incas. Upon the arrival of the Spanish, this culture was supplanted by cereals, known for their remarkable ability to thrive in challenging soil and weather circumstances **(FAO, 2016).**

The introduction of this crop into dry and semi-arid regions primarily lacking water aims to secureits production as an alternative crop and enhance food security in these areas. It is a viable alternative in areas limited by climate change and soil salinization. **(ITDAS 2015),** These constraints affect the conditions under which crops can grow and influence the nutritional quality of the grains. Soil and water salinity is ubiquitous, with about one billion hectares affected world widein 2021 **(FAO, 2021)**

Quinoa (Chenopodium quinoa Willd.) is interesting crop for production under drought conditions It is well adapted to produce in unfavorable soil and climatic conditions (Garcia et al., 2003 cited by**(Geerts et *al*., 2008)).** Quinoa appears to be a hardy crop with interesting agronomic and physiological traits. It can grow under different stress conditions, such as soil salinity and acidity, and also, under certain conditions, tolerate episodes of drought and frost due to its genetic variety.

The evapotranspiration (ET) determines the amount of water required for the normal growth of the crop. It represents the most basic data in estimating the amount of water used in agriculture. In recent years, several works on estimating crop evapotranspiration have been published **(Sheng-Feng Kuo et a*l*, 2011).** Quantifying ET for specific crops and regions is required for litigation of water right applications and disputes, design of irrigation systems, for basin water balance estimates, for irrigation water management **(Allen et *al*., 2021)**

Irrigation scheduling is a procedure used to determine the time and depth of water application for each irrigation event also, for an efficient water management it is necessary to know the water requirement of irrigated crops during their respective yield cycles. (Conceição, 2002). According to **FAO (1996),** the objectives of irrigation management are to maximize net return, minimize irrigation costs, maximize yield, optimally distribute a limited water supply and therefore minimize ground water pollution.

The need for such sustainable water management practices is particularly critical considering the steady increase of global population and the limitations on availability of natural resources, particularly in vulnerable agricultural areas where water scarcity is of great importance (**Pereira et *al.*, 2021).** Over the past 70 years, more information programs and computer assistance have been proposed for scheduling and irrigation gestures, based on methods of culture evaporation and water reserve (**Best and James, 1988 ; Jensen et al. 1971**).

To optimize water and energy use, researchers are actually investigating irrigation scheduling methods. These methods aim to determine the precise amount of water needed to bring soil moisture to optimal levels, preventing both under watering and over watering.

This justifies our interest in studying the effect of a scheduling method adopted by a program ASAD -ITDAS for estimating quinoa water requirements and irrigation management in the experimental station of ITDAS - Ain Ben Naoui biskra region. This evaluation includes a comparison of morphological characteristics and yield between two plots (scheduling and non-scheduling).

This dissertation is divided into four chapters :

The first two chapters are dedicated to a comprehensive literature review pertaining to the topic of study. They consist :

- Chapter I : General information on Quinoa crop.
- Chapter II : Water requirements for crops and Irrigation scheduling

The third Chapter pertains to the materials and methodology used in this study.

The fourth and last Chapter of the report focuses on elucidating the collected results and conducting a comprehensive discussion.

This task is finalized by a comprehensive debate along with a broad conclusion.

Chapter I

General information on Quinoa crop

I.1. History and origin

Quinoa, also known as Chenopodium quinoa Willd., is an indigenous plant from the Andean mountains, cultivated by impoverished rural communities in Bolivia, Peru, and Ecuador. It is a significant source of organic exports in industrialized nations like Europe, North America, and Japan. Quinoa's success is attributed to its high nutritional value, as its seeds are abundant in proteins and contain a balance daminoacid combination **(Tapia et *al.*, 1979; Risi and Galwey 1984; Coulter and Lorenz, 1990)**. Cultivated for over 5,000 years in South America, *quinoa* served as a staple food for pre-Columbian civilizations, but did not attract Spanish conquerors due to its saponin content and lack of gluten in its flour.

During the 1970s, developed nations seeking a more nutritious diet became aware of the nutritional benefits of *quinoa*. As a result, quinoa is now widely available in most supermarkets, especially those that specialize in organic and fair trade products. **(Mujica, 1992)**.

Due to its tolerance to abiotic variables such as drought, UV radiation, frost, and soil salinity, this plant has been considered as a potential option for growing experiments at orbital stations. **(Tapia et al., 1979; FAO., 2001; Bruno and Whitehead.,2003).**

The genetic material of this species, along with other related local species (Chenopodium pallidicaule Aellen, Chenopodium quinoa ssp. Melanospermum Hunz.), has been kept by a spontaneous in situ conservation system, thanks to the efforts of these generations of farmers. **(Tapia, 2002).**

Figure 1: Geographic distribution of traditional *quinoa* cultivation in South America (the density of points reflects the relative importance of the crop) (from National Research Council 1989).

I.2. Economic importance of quinoa cultivation

I.2.1. In the world

The global cultivation of quinoa spansan estimated 99,313 hectares, with a total production of 78,025 tons in 2010. Bolivia and Peru are the primary producers (Fig. 01). Bolivia has the largest *quinoa*-producing area, covering roughly 63,010 hectares and producing over 36,106 tons. In comparison, Peruproduces over 41,000 tons on an area of approximately 35,313 hectares, resulting in a higher yield per hectare in Peru. **(FAO STAT, 2010).**

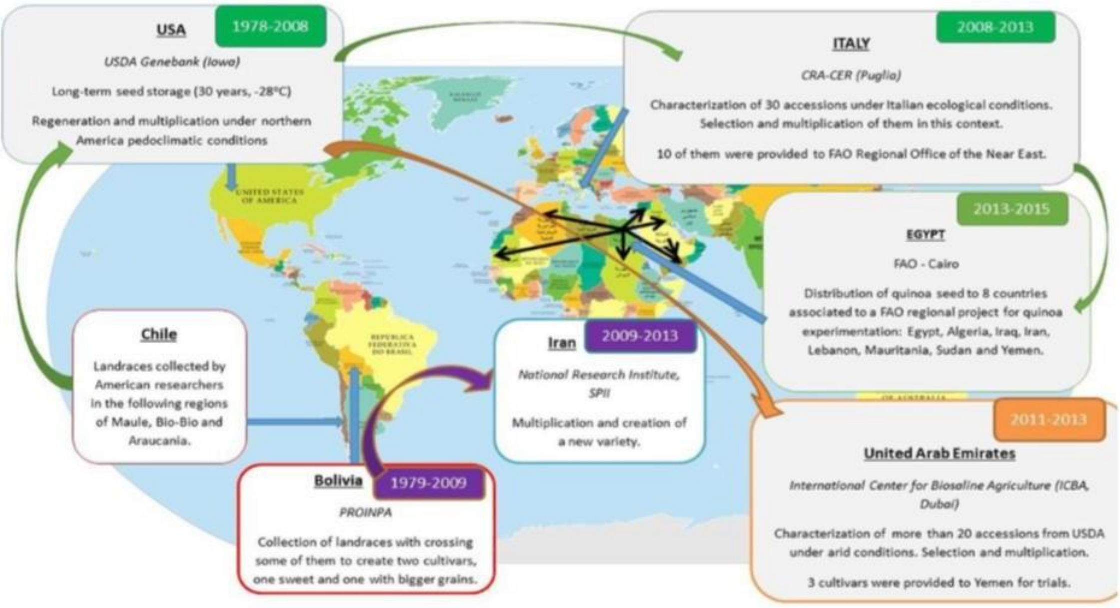


Figure 2: Movement of *quinoa* in the world (Bazile, 2014)

I.2.2. Quinoa cultivation in Algeria

Quinoa cultivation was introduced in Algeria in 2014. The cultivation is conducted experimentally at eight sites owned by four institutions, each with distinct agro-ecological characteristics. The ITDAS, located in Biskra and El-oued, the INRAA, located in Adrar and Ghilizane, the ITGC, located in Sétif, Tiaret, and Guelma, and the INRF, located in Algiers.

The FAO and Algeria signed an agreement for the project (TCP/RAB/3403) titled "Technical assistance for the introduction of quinoaand appropriation/institutionalization of its production in Algeria, Egypt, Iraq, Laban, Mauritania, Sudan, and Yemen."

The goal of monitoring is to identify the crop cycle and optimize water and fertilizer inputs based on the crop's developmental stages, in order to achieve bettere conomic efficiency.

The cultivated accessions exhibited variation in their development cycle, with distinct early and late variations.

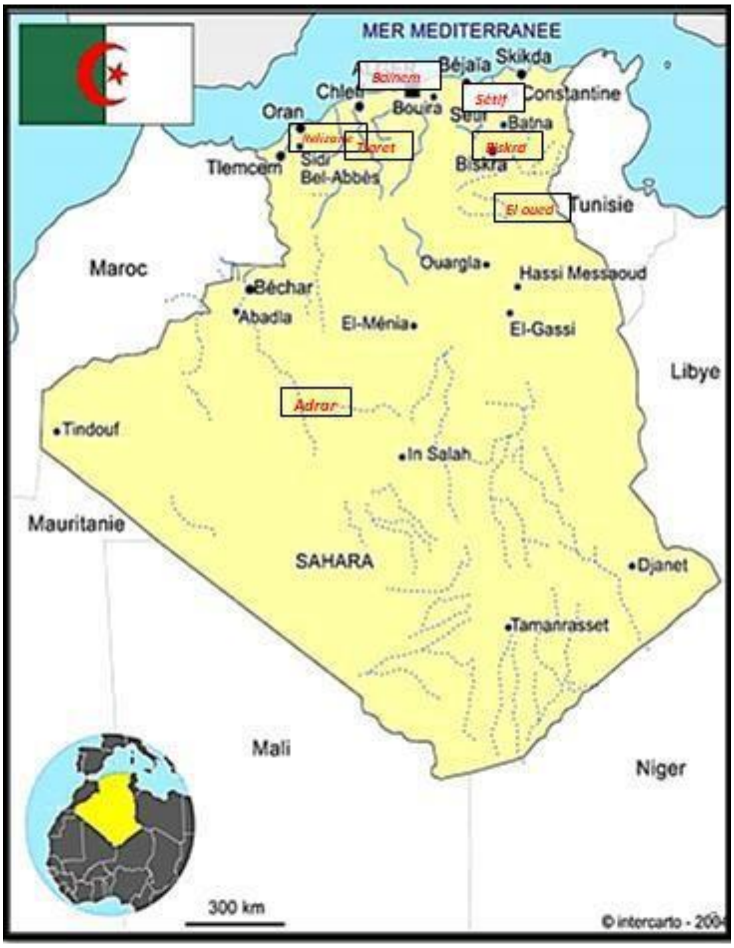


Figure 3: Location of *quinoa* introduction trial sites in Algeria (FAO, 2010)

I.3. *Quinoa* classification

Quinoa, scientifically known as Chenopodium *quinoa*, belongs to the Chenopodiaceae family, which also include spinach and beets. It is classified under the genus Chenopodium, which encompasses over 250 species. There are an estimated 1,800 distinct types of quinoa that have been identified. It is commonly referred to as a "pseudocereal." **(Foucault, 2014).**

- **Cronquist classification (1981)**

Kingdom : **Plantae**

- Sub-embr : **Tracheobionta**
- Division : **Magnoliophyta**
- Class : **Magnoliopsida**
- Group : **Thalamiflorae**
- Subclass : **Dicotyledonae**

- Order : **Caryophyllale**
- Family : **Chenopodiaceae**
- Genus : **Chenopodium**
- Species : **Chenopodium quinoa.**
- Binomial name : **Chenopodium quinoa Willd**

I.4. Description of plant morphology

The morphology of *quinoa* differs accordingto the genotypes and the agroecological zones in which it is cultivated. Differences of considerable magnitude can beobserved in the color of plants and grains, the kind of inflorescence, and the ability to adjust to different climatic conditions.

➢ The plant

Quinoa plants grow upright, reaching height sranging from 0.60 to 3.00 m, influenced by factors like quinoa type, genetic variations, soil fertility, and environmental conditions. **(Vidal Apaza et *al*., 2013 in Malti 2019).**

Figure 04: Cultivation of the plant quinoa (ITDAS, 2019)

➢ The roots

The germination of quinoa is remarkably rapid, starting within a few hours when the soil has enough moisture, as there is no time for seed dormancy. The radicle first elongates and then extends to form a taproot, which has the ability to penetrate up to a depth of 30 cm. Secondary and tertiary roots grow from the main taproot, and these roots further produce rootlets that can also under go branching.

The root system is highly resilient and capable of supporting plants that are over 2 meters tall. However, there have been occasional instances of plant subsidence due to factors like wind, severe humidity, or the weight of the plants. Panicles **(Gandarillas, 1979 ; Mujica et *al*., 2001).**

The depth of a plant's roots is strongly correlated with its height. The study conducted by Pacheco and Morlonin 1978 documented plants that were 1.70 meters tall with roots of 1.50 meters, as well as other plants that were 90 centimeters tall with roots measuring 80 centimeters. *Quinoa*'s tolerance to drought and stability can beat tributed to its remarkable rotating, energetic, deep, well-branched, and fibrous root structure. **(Herbillon, 2015).**

Figure 5: Root system of *quinoa* (Gandarillas, 1979)

- **The stem**

The stem of a plant has a cylindrical shape at the base and become sangular as it extends towards the branches. It can have unique or multiple ramifications. The stem's diameter can range from 1 to 8 cm and its height between 50 cm and 2 m. These measurements are influenced by the plant's variety and its growing environment, including seed density and fertilization. **(Mujica et *al*., 2001).**

The changeable coloration ranges from green to red, frequently exhibiting streaks and pigmented armpits that may appear green or purple. **(VIDAL APAZA et *al* ,2013)**

Figure6: The stem of the *quinoa* plant (ITDAS, 2019)

➢ Leaves

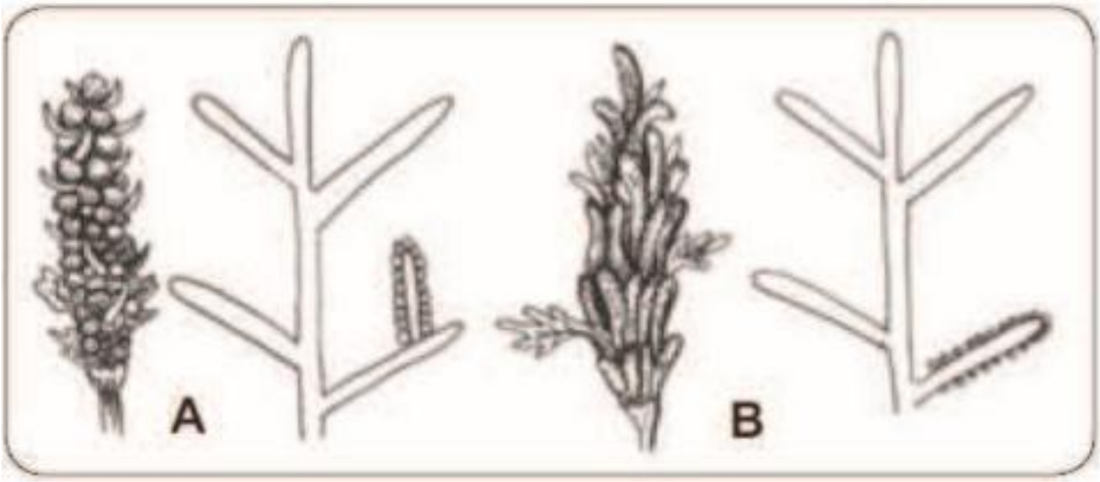
The leaves of quinoa exhibit diverse colors, ranging from green to red, and possess a simple structure. They are rich in nutrients and can beused as a vegetable. It is recommended to harvest them prior to the flowering stage. **(JAEL CALLA, 2012).**

Figure 7: the leaves of the *quinoa* plant (FAO,2013)

➢ Inflorescence

The panicleis a conventional structure consisting of a central axis and secondary branches, as well as tertiary branches and pedicels that support the glomeruli. The primary axis is more developedthan the secondary axis, and it can have either a relaxed (amarantiform) or compact (glomerulate) structure, with inter mediate forms existing between the two.

The panicle's length and diameter vary based on genotype, *quinoa* type, growth location, and soil fertility. It can range from 30 to 80 cm and 5 to 30 cm in diameter. The number of glomeruli per panicle can range from 80 to 120, and the number of seeds per panicle can range from 100 to 3,000 a single flower can yield up to 500 grams of seeds through the production of enormous panicles. **(Vidal Apaza et al., 2015).**



A) glomerular **B)**amaranthiform (Tapia and Fries, 2007)

Figure 8: The inflorescence of the *quinoa* plant (FAO,2013)

- **Seed**

An achene is a *quinoa* grain that forms compact, flattened discs around 2mm in diameter. The seeds are coated with saponin, a bird repellent, and do not require cultivation. This is why it is promoted as an example of "organic farming."

According to **Moore (2017),** these grains are gluten-free and contain all the necessary proteins for human nutrition.

Quinoa grains are colorful and have a diameter of 2 to 3 millimeters, with hues like white, red, yellow, black, pink, and purple. **(Chaherli and Saleh, 2015 in Hadj hammou 2019).**

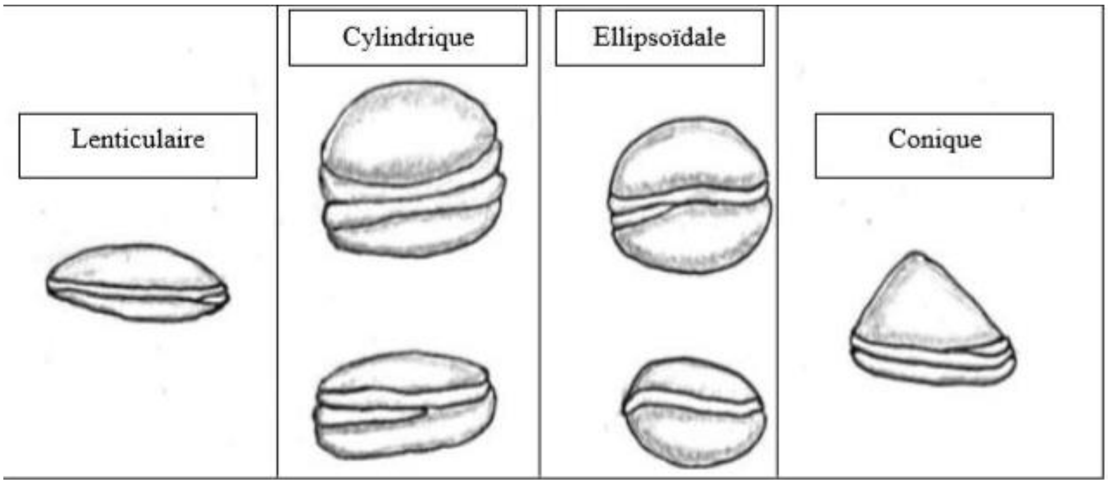


Figure 9: grain shapes

Figure 10: Quinoa fruit (FAO, 2013)

- **Flower**

Quinoa has hermaphroditic flowers in clustered inflorescences, which are false spikes(panicle) and are terminal and variable in length during the reproductive stage of the quinoa cycle.

There are two primary categories : glomeriform and amaranthiform. According to Gandarillas (1968), the glomeriform type is the original form and the second type is derived from it through mutation. The flowers are apetalous and small. (03 mm maximum) **(TAPIA and al.1979), (IZQUIERDO et al.2001).**

Figure 11: the flower of the *quinoa* plant (FAO,2013)

I.5. The phenological stages of quinoa

Germination of grains takes ten hours, with cotyledons visible in the field around the 7th day. Root grow this linked to above-ground growth. **(Del Castillo et al., 2008)**.

Mujica and **Canahua (1989)** delineated a development scale consisting of 12 phases, with each phase having a specified duration measured in average days.

- **Lifted Stage**

The process of seedling appearance and cotyledonary leaf unfolding occurs 7 to 10 days after sowing.

- **Two true leaves**

The first two true leaves appear 15-20 days after sowing, with rapid root growth and arhomboidal shape. They are highly susceptible to insect attacks.

- **Four true leaves**

The second set of genuine leaves emerges 25-30 days after seeds are planted, with cotyledonary leaves remaining green and demonstrating resilience to low temperatures and water scarcity.

- **Six true leaves**

The emergence of the third set of genuine leaves takes place between 35 and 45 days following planting, coinciding with the withering of the cotyledon leaves.

The vegetative apex is effectively shielded by the mature leaves, especially during periods of stress such as heat, water scarcity, or high salinity.

- **Branching**

The eight-leaf stage, 45-50 days after planting, reveals axillary buds up to the third node in branches. Discolored cotyledonary leaves descend, creating a stem mark, and the inflorescence is concealed by the foliage.

- **Start of panicle formation**

The inflorescence emerges at the plant's top 55-60 dayslater, surrounded by small leaves. The initial leaves turn yellow, losing their photosynthesis ability, while the stem elongates and increases in diameter. This process occurs simultaneously with the initial leaves.

- **Panicle**

The inflorescence, consisting of glomeruli, is visible above leaves and flower buds emerge 65-70 days after seeds are planted.

- **Start of flowering**

After 75 to 80 days, the first flowers appear. The plant starts to feel cold and dry more easily.

- **Flowering**

The opening of 50% of the flowers of the inflorescence occurs around the 90th or 100th day. It must pay attention to when the flowers close at midday, as this is when the plant i smost vulnerable to frost, which can lead to the falling of lower, withered leaves.

- **Milky grain**

Milky grain occurs 100-130 days after sowing, resulting from the whitish liquid produced when pressure isapplied to the fruit, and a water deficit can significantly decrease yield.

- **Pasty grain**

The fruits turn pasty and white within 130 to 160 days after sowing.

- **Physiological maturity**

The grain reaches maturity after a period of 160 to 180 days, during which it becomes more resistant to pressure. At this stage, the water content of the grain is less than 15%. Throughout the grain filling stage, the majority of the leaves have under gone yellowing and shedding, resulting in nearly completede foliationupon maturity.

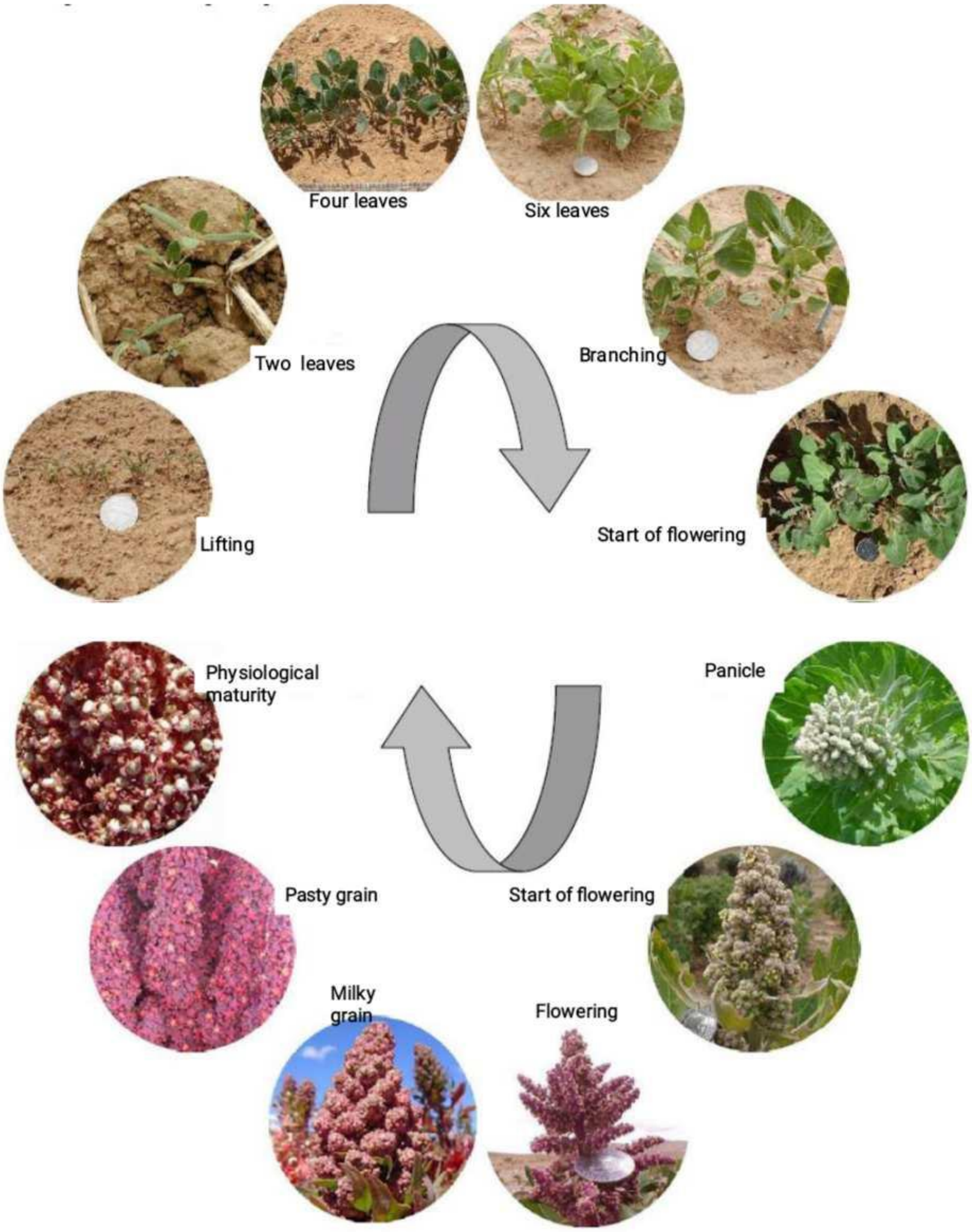


Figure 12 : The phenological stages of *Quinoa* cultivation (Lebonvallet, 2008)

Chapter II

Water requirements for crops and scheduling irrigation

II.1. Water requirements

The water requirements of a crop are the water lost after irrigation, as defined by **FAO (1975)**. They compensate for water lost through evapotranspiration by a healthy crop, assuming it is cultivated on a large plot without soil fertility or moisture limitations and can achieveits maximum production potential under the given conditions.

Crop water requirements are determined by its maximum evapotranspiration, which is influenced by the meteorological requirement known as prospective evapotranspiration (ETP) or reference (ET0).

II.2. Crop evapotranspiration

In agronomy and hydrology, this term combines two concepts : water evaporation (E) and plant transpiration (T).

Evaporation is the process by which water transforms from a liquid to a gas, escaping into the atmosphere from various surfaces like lakes, rivers, highways, exposed soils, and moist plants. Evaporation is initiated by the motion of water molecules **(Bouhlassa, 2006)**.

Transpiration refers to the process in which water received by the roots travels upwards towards the leaves and is released as water vapor through the stomata. During this process, a tiny amount of water is retained to keep the cells hydrated, while the remaining water is utilized for the production of organic matter.

Evapotranspiration refers to the amount of water vapor that is released into the atmosphere by the combined processes of transpiration from plants and evaporation from various sources such as the ground, open water surfaces, and surfaces that intercept rain **(FAO, 1975)**.

II.3. Different types of evapotranspiration

II.3.1. Potential evapotranspiration (ETP) or reference (ET0)

This parameter is utilized in many stages of study pertaining to the utilization of water for irrigation purposes. It is seen as a persistent climatic occurrence that spans both space and time. The significance of water quantities for crops is determined by Evapotranspiration (ETP), which is a function of the water shortage experienced by the plants **(Dubost, 1992)**.

Potential evapotranspiration is defined as the maximum amount of water that can be evaporated and transpired by a short grass that covers the ground entirely, is well-watered, in an active development phase, and is placed within a suitably large area. **(Perrier,1977)**.

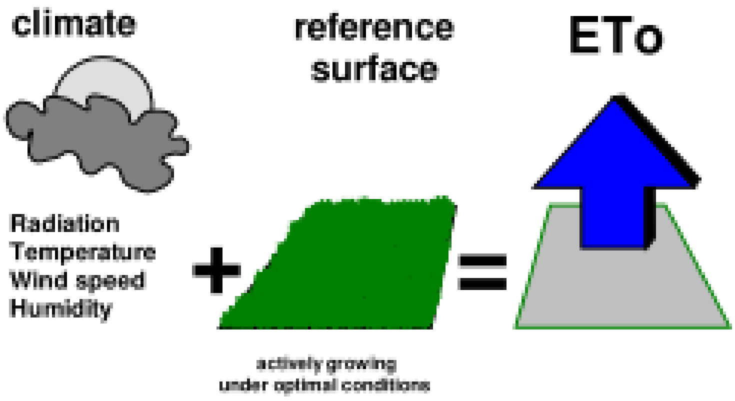


Figure 1.
Reference evapotranspiration (ETo)

Figure 13: Reference evapotranspiration (ET0) (Allen et *al.*, 1998)

Allen et *al.* (1998) assert that the ET0 isinfluenced by daily and seasonal fluctuations in solar radiation and temperature.

- The average daily evapotranspiration (ETP) values in the Mediterranean semi-arid zone range from less than 1 mm per day in winter to 8–10 mm per day in summer. The evaporation pattern is more consistent than the rainfall pattern, allowing for reasonable predictions of crop water requirements year-round.
- The ETP, being a property of the climate, can be determined using climatic factors.

II.3.2. Maximum crop evapotranspiration (ETc)

"Optimal agronomic conditions" refer to a crop's optimal growth conditions, including disease absence, stress, and water and nutrient deficiencies, which are applicable across various stages of crop development.

ETc = Kc * ET0

The cultural coefficient (Kc) determines the relationship between ET0 and a specific culture, considering physical and physiological differences between the reference surface and the provided culture.

The crop coefficient Kc measures a crop's unique evapotranspiration (ETC) and reference evapotranspiration (ET0), influenced by factors like height, cycle length, and growth rate that affect its evapotranspiration.

According to **Allen et *al.* (1998)**, the crop coefficient is largely affected by several factors such as:

- aerodynamic factors linked to the height and density of vegetation;
- biological factors linked to leaf growth and senescence;
- physical factors linked mainly to soil evaporation;
- physiological factors linked to the response of stomata to vapor pressure saturating;
- agronomic factors linked to cultural practices (irrigation system, frequency of rain and irrigation, etc.).

Crop-specific Kc values are commonly provided, accounting for different growth stages.

For each crop, there are four well-defined vegetative stages **(Figure 14)**:

- **Initial stage:** planting, sowing (wheat or barley), dormancy, etc.;
- **Growth or development stage:** the crop is developing its vegetative potential;
- **Flowering and fruiting stage:** this is a critical phase during the vegetative cycle of the plant. There must be a maximum of water to have good fruit size;
- **Ripening stage and harvest:** The following figure represents the curve of different phases of the crop coefficient according to the stages of development of the crop.

Kc is a measure of crop height, surface resistance, and albedo. Crop height affects aerodynamics and roughness, while surface resistance is determined by leaf area, soil cover, and moisture. Albedo is influenced by soil cover and moisture.

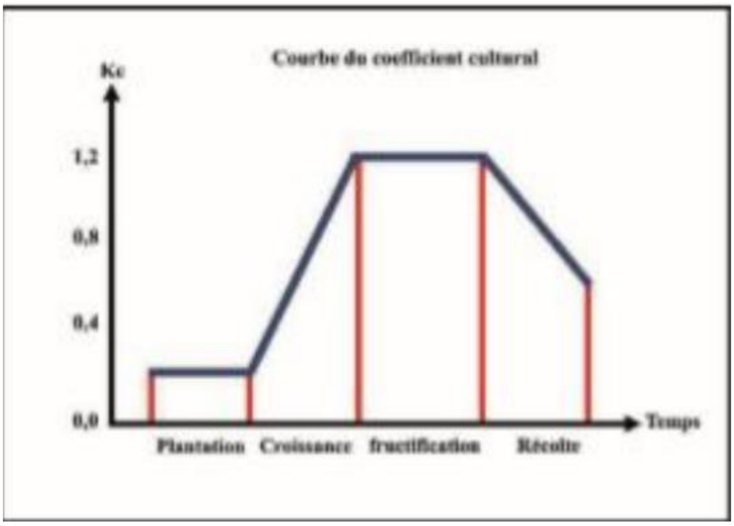


Figure 14 : Variation curve of the crop coefficient Kc (Allen et *al*., 1998).

II.3.3. Potential evapotranspiration in greenhouses (ETPs)

The evapotranspiration of plants in a greenhouse is influenced by the amount of solar radiation it receives, with air turbulence having less significance. Research shows a strong correlation between a well-nourished plant's water in take and the amount of solar energy it receives. This relationship is expressed by the following equation **(Skhiri, 2019)**:

$$ETPs = \frac{a \times RGs}{L + b}$$

- a and b : experimental coefficients of the regression equation ;
- ETPs : reference potential evapotranspiration in greenhouses (mm J-1);
- RGs : global solar radiation under greenhouse (cal cm-2);
- L : latent heat of vaporization of water (cal cm-3).

The maximum evapotranspiration rate (ETCs) is the maximum rate at which a crop can lose water through evaporation and transpiration in a well-watered greenhouse, based on the number of full-time equivalent employees (FTEs), It is estimated using the estimation method **(FAO, 1989)** as follows :

ETCs = Kc × ETPs

Hence Kc: represents the cultural coefficient

II.3.4. Actual evapotranspiration (ETR)

This represents the amount of evapotranspiration that occurs in a crop when there is not enough water available. Practically, accurately determining real evapotranspiration (ETR) is crucial for various fields such as agronomy, hydrology, and meteorology. These disciplines are concerned with managing water resources and under standing the relationship between water consumption and plant production **(Bouchet and Robelin, 1969)**. The relationship between ETR (Ecosystem Thermal Regulation) and meteorological conditions, as well as the regulating properties of plant cover (**Katerji and Perrier in 1983)**.

Greenhouse crop Actual evapotranspiration (ETRs) refers to the preciseamount of water that a plant consumes while cultivated in a greenhouse. The actual transpiration rate of a plant depends on the soil's water availability and the plant's physiological and pathological condition. It can either be equal to or lower than the potential evapotranspiration (ETP).

It depends on several factors :

- The nature of the plant
- The physiological and pathological state of the plant

- The stage of vegetative development.

II.3.5. Conditional factors of evapotranspiration

Evapotranspiration strongly depends on the intervention of three factors, climatic, geographical, biological and pedological **(Allen et *al*., 1998):**

Factors like temperature, wind, and insolation can be quantified, but root depth and plant cover height are less understood and infrequently used. (2005), evapotranspiration was found to be strongly correlated with solar radiation and Earth's surface energy balance **(in Mjejra, 2016)**.

➢ **Climatic factors (evaporating power of the climate):**

- air temperature,
- the temperature of the earth's surface,
- wind speed and turbulence,
- the duration of insolation or solar radiation,
- the relative humidity of the air,
- atmospheric pressure.

➢ **Geographic factors (mainly topography):**

- the state of the evaporating surface,
- altitude,
- effect of the site,
- proximity to the sea,
- orography (exposure of slopes to the sun, winds, slopes)

➢ **Biological factors (vegetation cover):**

- plant species (phenological stage of the crop considered),
- height of the plant cover,
- stomatal resistance,
- the depth of the roots,
- need water or not.

➢ **Pedological factors (soils):**

- the water retention capacity of the soil,
- the useful reserve in the ground,
- soil humidity,
- The texture of the soil.

II.4. Methods for estimating potential evapotranspiration (ETP) or reference (ET0)

It is difficult to quantify evapotranspiration (ETP) on soil covered in vegetation. Estimating ETP can be done using the oretical and empirical methods, but they are frequently crop- or region-specific. The most popular approach for calculating reference evapotranspiration (ET0) in any climate or location is the Penman-Monteith method, which was derived from the Penman 48 formula.

II.5. Direct method of estimating ETP

II .5.1. Evaporation Pans

II.5.1.1. Pan evaporation

The US Weather Bureau uses a cylindrical Pan called a bac, whose water has a thickness of 17.5–20 cm. It has a 15cm support for ventilation, is simple to install, and is immune to the effects of solar radiation and air temperature.

According to Skhiri (2019), the measurement of ETO using the class-I evaporation method is done using the following formula :

$$ET0 = Kbac \times Ebac \left(\frac{mm}{j}\right)$$

ETo: evaporation potential referral;

Kbac: conversion coefficient (varieties of 0,7 to 0,8);

Ebac: Evaporation of the Pan.

The coefficient of Pan (Kbac) is determined by a table involving wind speed, relative humidity, and bac distance. Pans are cheap and easy to build, but they are not very good at measuring direct radiation and heat transfer.**(Doorenbos, 1980)**

Photo 1: Pan evaporation Installed on site (Skhiri, 2019)

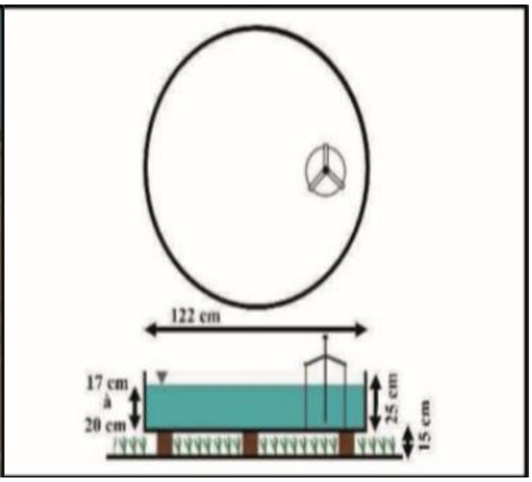


Figure 15 : Schematic diagram of a Class A ferry (Skhiri, 2019)

II.5.1.2. Colorado Evaporation Pan

The Pans edgeis 10 cm above ground level, yet they are less susceptible to changes in temperature and solar radiation. Debris and rainfall can introduce inaccuracies in measurements. The parallelepiped "colorado" tank isburied 50 cm below the surface and has a 100 cm side square, 60 cm depth, and 50 cm buried area. **(ANRH, 2002)**.

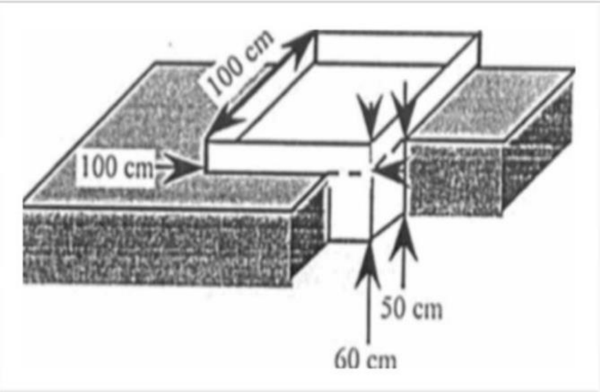


Figure 16 : Colorado Evaporation Pan (ANRH, 2002).

II.5.2. Evaporometers

II.5.2.1. Wild Evaporometer

A U-shaped glass tube of 25 cm in length and 1.5 cm in diameter is filled with pure water. A circular filter paper with a diameter of 30 mm and a thickness of 0.5 mm is used to seal the lower opening, enabling the calculation of the rate of evaporation. **(Remenieras, 1963).**

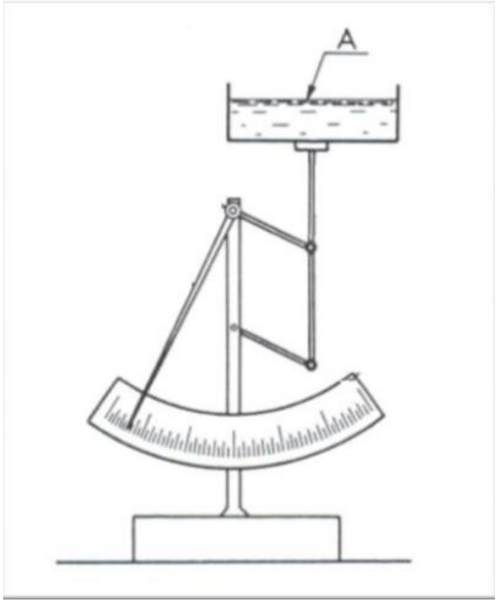


Figure 17: Wild Evaporpmeter (ANRH, 2002).

II.5.2.2. Piche Evaporometer

The device consists of a glass tube filled with water for daily measurements. Additionally, it includes a buvard-shaped pastille with two surfaces, one wet and one dry, which allows for direct reading of evaporated water. **(Charles, 1975).**

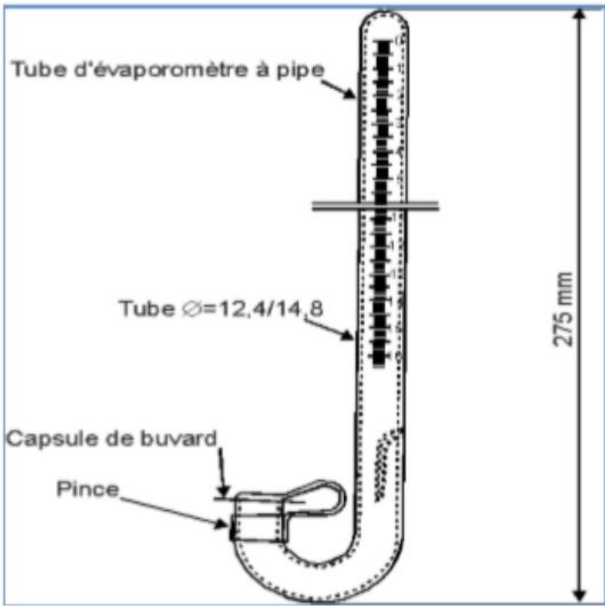


Figure 18: Piche Evaporometer (Skhiri, 2019)

II.6. Irrigation management by scheduling

II.6.1. Definition of scheduling

Irrigation management involves programming watering, defining optimal watering dates and doses, and distributing irrigation through out the crop cycle while maintaining acceptable stress levels. **(Leopold. and Pierre, 2000, cited by Borni and Saad, 2007).**

The irrigation method aims to minimize water stress through out the crop cycle by considering soil, rain, and plant age-specificneeds.

The control can be based either on an indicator parameter alone:

- Climate: soil and plant.
- Either by monitoring the water balance in the soil.

II.6.2. Objective of scheduling

The objective of irrigation management is to reduce water stress during the entire crop cycle, there by optimizing agricultural yield without any limitations. To meet crop needs during periods of water restriction, it is necessary to decrease irrigation and maintain appropriate stress levels through out the crop cycle.

II.7. Estimation of scheduling: Software program

The model is user-friendly and requires minimal explicit parameters, primarily climate, soil, agricultural techniques, and crop characteristics, which can be easily derived from experimental research. **(Steduto et al., 2009, Vanuytrecht et al., 2014)**.

AquaCrop offers conservative and non-conservative parameters that remain unchanged under favorable conditions and time but can bemodified for stressful conditions by modulating their stress responses. **(Steduto et al., 2009; Raes et al., 2009).**

The parameters for crop growth and decline include vegetation cover, transpiration coefficient, biomass WP, and soil water reserve depletion thresholds. These parameters are universally applicable and not specific to a specific cultivar **(Steduto et al., 2012).**

Non-conservative parameters, such as plantingdensity and phenological parameters, requiread justment based on environmental conditions. Other parameters, influenced by climate, technical route, or soil properties, requireoperator correction or model estimation **(Raes et al., 2009, 2011).**

The Reasons

Simulation models are widely used globally to analyse crop responses to environmental stresses, test management practices, and identify promising irrigation strategies, particularly in arid environments, relating herbaceous species development to water efficiency **(Lobell and Ortiz-Monasterio, 2006 ; Heng et al).**

Modeling for agricultural production began in the 1960s to forecast regional evolution, with models like WOFOST being developed since then**.(Diepen Van, 1989)**, EPIC **(Williams, 1989),** DSSAT **(Jones et al., 2003)**, and CropSyst**(Stöckle et al., 2003)**have been validated and compared**(Touré et al. ., 1995; Todorovic et al., 2009)**with the aim of a better under standing of the response of crops to climate and management scenarios, knowing that each model has its own strengths and weaknesses**(Fraisse et al., 2006; Resop et al., 2012).**

These software are mainly used by scientists and some users in advanced fields of highly commercial agriculture **(Toumi et al., 2016).** It is to over come these complications that, in 2009, the United Nations Food and Agriculture Organization (FAO) developed the AquaCrop model (Steduto et al., 2009 ; Raes et al., 2009) based on the algorithm of response of crop yield to water **(Doorenbos and Kassam, 1979).**

The new model simulates herbaceous crop growth and production under various water productivity regimes, including rainfed, total irrigation, supplemental irrigation, and deficit irrigation.

Sinceits launch, it has been tested under various environmental conditions and for various crops like corn, sunflower, and sugar beet. **(Stricevic et al., 2011), barley (Abrha et al., 2012),** winter wheat **(Iqbal et al., 2014)**...The article on AquaCrop only mentions wheat grown in the east of the country, which is often limited by a water deficit.**(Guendouz et al., 2014)**. The tool's ability to predict herbaceous species production and yields make sithighly valuable for agricultural development.

The proposed solution couldaid the agricultural sector's cereal intensification program by designing additional irrigation management scenarios to enhance national cereal yields.

Chapter III

Materials and Methods

III.1. Objectives

The primary objective of this study is to evaluate a scheduling irrigation method for a quinoa crop using an ACSAD-ITDAS program. The study aims to compare the water quantities and irrigation frequencies applied to two plots: one managed using the scheduling method (pilot plot) and the other managed conventionally (non-pilot plot). The evaluation will focus on vegetative growth, soil moisture evolution, and electrical conductivity (EC), pH, and yield.

Key Objectives of Sustainable Irrigation

- Sustainable Management Irrigation for Enhanced Water Economy
- Preservation of the “water” resource; non-renewable through the use of irrigation programs
- Enhancement of water resources by improving crop productivity.

III.2. Choice of the experiment site

The trial was set up at the experimental site, located at the Ain Benoui seed demonstration and production farm in Biskra, part of the Technical Institute for the Development of Saharan Agronomy (ITDAS). GPS address RM43+MR7, El Hadjeb.

This site is located 10 km to the South - West of the town of Biskra. It is limited to the north by national road No. 31Biskra - Tolga, to the east by Oued Ain Ben Noui, to the south by an old track, and by Oued Oumache to the west.

Photo 2: Positioning of the experimental site

Photo 3: General view of the experimental plot ***Quinoa* crop irrigation management (Original photo 2024)**

III.3. Climatic data

The climatic characteristics during the cultivation period are presented in the following table:

Table 01: climatic data during the cultivation period

Climatic parameters	November	December	January	February	March	April
Average temperature (C°)	19.4	14.4	13.9	15.6	19.0	22.0
Precipitation (mm)	0.25	6.6	5.03	8.63	2.54	9.14
Relative humidity (%)	41.6	47.4	44.3	43.3	32.7	32.2
Average wind speed (km/h)	9.6	10.1	9.9	9.6	9.5	8.8

III.4. Materials

III.4.1. Plant material

- **Species:** *Quinoa*
- **Variety:** Giza1
- **The color:** White,yellow,brown

III.4.2. Experimental device

The experimental device used is to prepare 2 blocks: a scheduling and a non-scheduling plot. In each block, there are 3 elementary plots with an irrigation network: a drip system and volumetric meter in both blocks According to the following measurements:

- Size of the plot: 40 m2 (08m x 05m).
- Dimensions of the elementary plot: 4m x 5m
- Number of lines per plot: 05 lines
- Spacing between lines: 40 cm.
- Spacing between two pockets: 20 cm
- Number of grains per pocket: 2-4 grains
- Sowing depth: 1 to 2 cm.

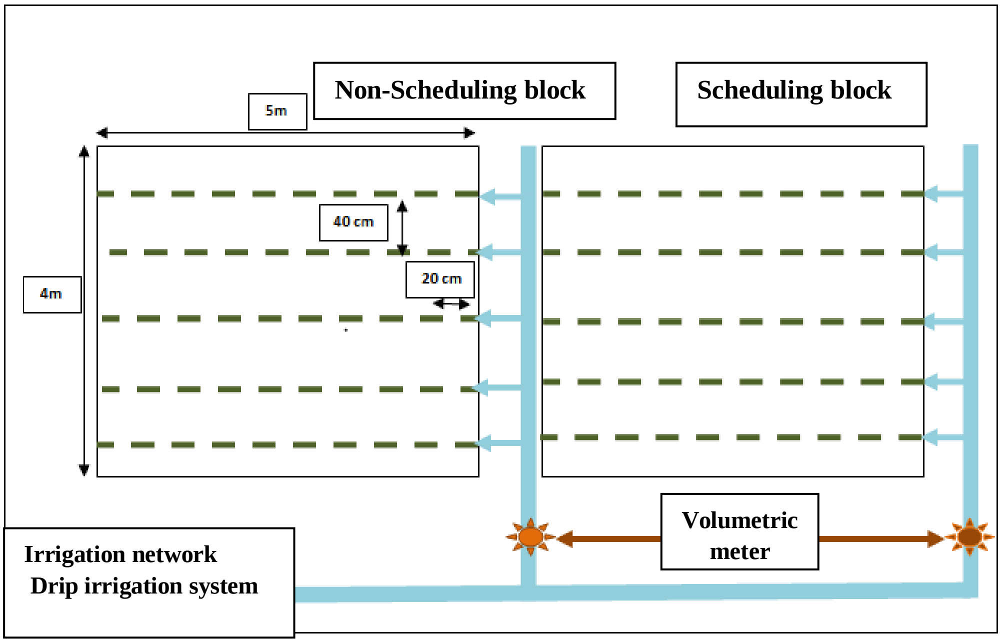


Figure 19: Diagram of the experimental device

III.4.3. Soil and water analyses

III.4.3.1. Soil analyses

The analyses were carried out before sowing the *Quinoa* crop on October 22, 2023, at depths of 30 cm and 60 cm. The soil has a sandy texture.

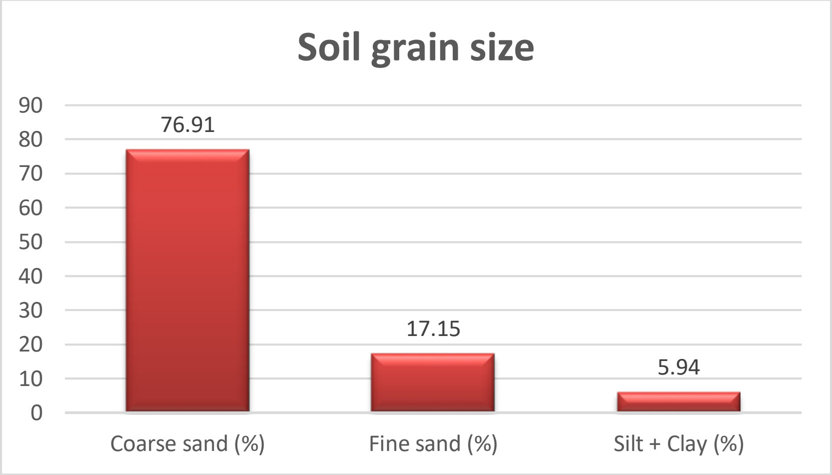


Figure 20: Soil grain size

Texture of the ground is **Sandy soil.**

III.4.3.2. Physico-chemical analyses of the soil

The analyses reveal that the soil has EC values of **03.24 ds/m** (30 cm) and **03.36ds/m** (60 cm); therefore, it has a very high salinity. The same remark is also noted for salts such as Sodium Na+ **14.42**meq/l at (30 cm) from **07.59**meq/l at (60 cm) and chlorides; Cl- **09.22**meq/l at (30 cm) and **13.29**meq/l at (60 cm). As for bicarbonates; HCO3-; **01.20**meq/l at (30 cm) and **01.30**meq/l at (60 cm), their concentrations are slightly moderate.

The pH is slightly alkaline **07.57** at (30 cm) and **07.53** at (60 cm).

Table 02: Physico-chemical analysis of the Soil (October 22, 2023)

Sample	Deep	EC (ds/m)	Ph	Relative humidity (%)
Ground	0-30	03.24	07.57	22.37
	30-60	03.36	07.53	22.74

III.4.3.3. Analyses of irrigation water

According to the guidelines adopted by (FAO-1985) for the interpretation of irrigation water quality, borehole water has a salinity greater than 3 dS/m **(05.57)**, therefore it has a high salinity degree with a very severe restriction on agricultural use. The same remark is also noted for Sodium ; Na+ **(35.83)** and chlorides; Cl-**(26.46)**.

As for bicarbonates ; HCO3- ; **(05.20)**, their concentration is slightly moderate.

Table 03 : chemical analysis of irrigation water

Source	**Ph**	**EC (ds/m)**	***Cations méq/l***				***Anions méq/l***		
Borehole water	**07.58**	**05.57**	Na^{+}	Ca^{++}	Mg^{++}	K^{+}	$CO3^{--}$	$HCO3^{-}$	Cl^{-}
			35.83	**10.40**	**21.60**	**00.20**	**02.00**	**05.20**	**26.46**

III.4.4. Crop works

III.4.4.1. plowing

The plowing was carried out on November 21, 2023; at a depth of 25 to 30 cm. The leveling, preparation and staking of the plots took place on November 25, 2023.

III.4.4.2. Installation of the irrigation network and volumetric meters

The installation of the irrigation and pre-irrigation network was carried out on November 27, 2023.

Photo 4: Irrigation network (Original photo 2023)

III.4.4.3. Fertilization

- Background manure: 3qx/ha of N.P.K (15.15.15).
- Maintenance manure: 100 U/ha of 46% Urea (divided into two contributions).

Photo 5: Spreading maintenance manure (Original photo 2024)

III.4.4.4. Sowing

Sowing was carried out manually on **November 29, 2023**; at a rate of 2 to 4 seeds per hole**(Or 04 kg/ha)**.

III.4.4.5. Phytosanitary Protection

- Just after the lifting on **December 12, 2023** ; young quinoa shoots were attacked by ants. The damage caused was sosevere. A treatment based on KARATOP was applied at a rate of 50 g per hole (gite).

Photo 6: Ant treatment (Original photo 2023)

- The quinoa crop was attacked by the moth at the branching stage, causing significant damage.
- At the early panicle stage, the crop was also attacked by the Mildew, causing minor damage. A curative treatment with a REVOLT fungicide at a dose of 100 ml/hl of water was applied.

Photo 7: Damage fromMoths and DownyMildew (Original photo 2024)

III.4.4.6. Indentification of staddiums

Table 04 : indentification of *quinoa* phenological stages (ITDAS, 2019)

The stages	Indentification
Lifting stage	Is reached when the cotyledonary leaves emerge, we note the date when emergence has been reached by 90% of the lants emerged from the parcel
Two true leaves	On note the date when the stage been reached by 50 % of lants of the plot
Four true leaves	Appearance of the 2nd pair of true leaves on note the date when the stage been reached by 50% of plants of the plot
Six true leaves	The appearance of 3rd pair of true leaves we note the date when the stage has been reached by 50% of the plants of the plot
Branching	From stage of leaves. Cotyledonary leaves yellowed and falls off leaving a scar on the stem. Note the date when stage was reached by 50% of plants of plot.
Panicle	The inflorence is now clearly visible above the leaves, and the compposition of glomeruli and flower buds. We note the date when the stage has been reached by 50% of the plants of the plot.
Flowering	The opening of 50% of the flowers of the inflorescence. We note the date when the stage has been reached by 50% of the plants of the plot.
Milky grain	The existence of a whitish liquid on the fruit.

	We note the date when the stage has been reached by 50% of the plants of the plot.
Pasty grain	The inside of the fruit becomes a pastyconsistency. We note the date when the stage has been reached by 50% of theplants of the plot.
Physiological maturity	We note the date when the stage has been reached by 90% of the plants of the plot.

III.4.4.7. Parameters studied

To achieve the objective of our test we took in to consideration the following parameters :

a. Germination rate

The germination test is performed under appropriate conditions. The germination rate is determined by watering 100 seedswith irrigation water under normal conditions for 6 days

The germination rate is calculated using the method of **Duran and Jin (1986)** through the following formula :

$$G\% = 100 * (T/N)$$

G% : Germination percentage.
T : Number of germinated seeds.
N : Total number of seeds germinated.

Table 05: Germination test

Variety	Germination rate
Giza1	94 %

Photo 8: The germination of *quinoa* grain (Original photo 2023)

b. Relative humidity (%)

Soil moisture was measured at depths of 30cm and 60cm after 24 hours of irrigation. It was measured during three (03) periods of the crop cycle, namely: before sowing, Six leaves and at the flowering period. Soil moisture is calculated according to the following relationship:

Hp (%) = [Wet weight - Dry weight / Dry weight] × 100

c. pH

Soil pH was also measured at depths of 30 cm and 60 cm and for the same periods as for humidity. The 1/2.5 soil solution is measured using a pH meter.

d. Salinity EC (ds/m)

The salinity of the 1/5 soil solution is measured using a conductivity meter at depths of 30 cm and 60 cm.

e. Plant height

Plant height (cm) was measured from the stem to the tip of the panicles ;03 elementary measurement plots were carried out on each block.

f. Number of branches

We count all the true leaves which have taken their final forms and which are clearly visible, 3 elementary plots per block.

g. Number of panicles

We measure the average number of panicles, 03 elementary plots for each block.

h. Root length

We measure the average root length, 03 elementary plots for each block.

III.4.4.8. Statistical analysis

In order to determine the significance of the treatments applied on the different parameters studied ; we carried out analyses of variance and comparison of meansusing ANOVA and XLSTAT software (2014).

III.4.4.9. Irrigation scheduling

Given that integral irrigation scheduling is a necessity in arid areas, and in order to properly manage our natural resources (water and soil), the adoption of an irrigation management program is essential.

- **NP**: Irrigation management without scheduling (irrigation according to the state of the soil like farmers), (non-scheduling plot) Measuring the amount of water consumed between one stage and another.
- **PP**: Irrigation with scheduling (Irrigation following the scheduling program (FAO /ACSAD /ITDAS) (scheduling plot)

Program used:

The program used in the experiment resides in irrigation management software designed by FAO-ACSAD and improved by ITDAS

Temps d'irrig/parcelle (S)
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00

Date de Semis		Espèce	Variété
Jours	Mois		
29	11	quinoa	Giza 01

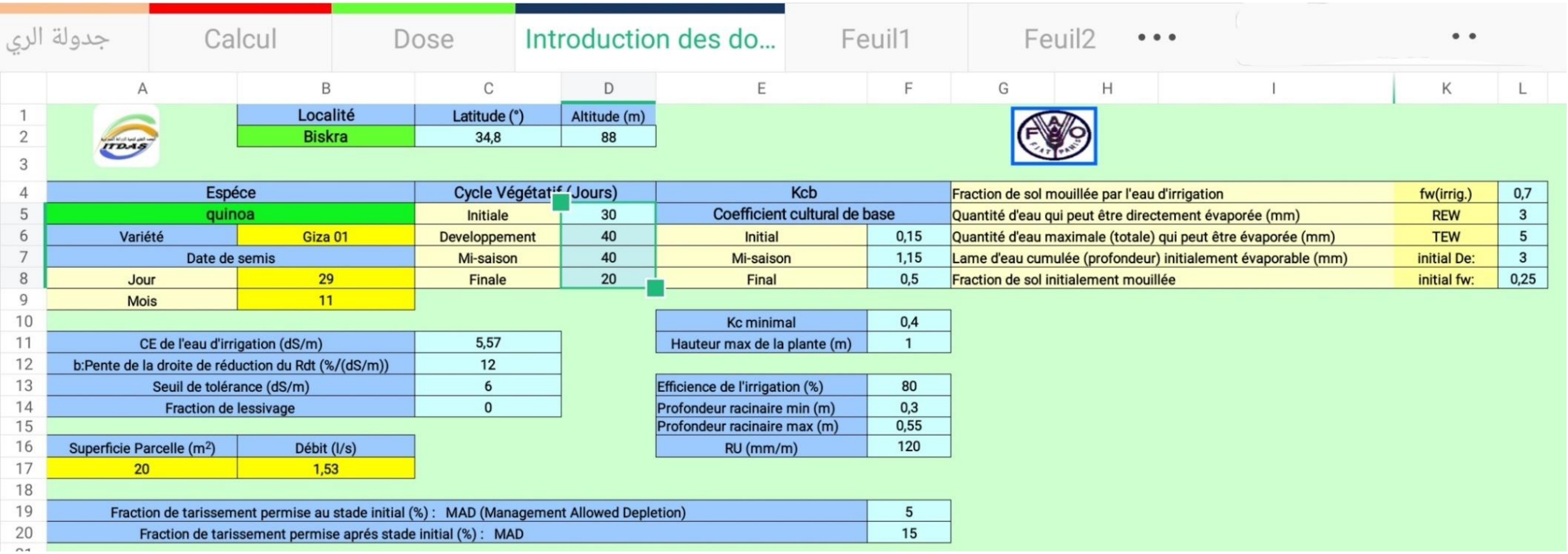
Besoins en eau de la plante (m^3/ha)	3851.6
Besoins en eau de la plante (mm)	385.2
Nombre irrigation	52

Figure 21: FAO-ACSAD-ITDAS irrigation software interface (Original photo 2023)

This software consists of :

a. Data entry

We fill in all the data related to the climat data, the plant (name,varities ,phelological stages, kc) and the region, irrigation system…



Localité	Latitude (°)	Altitude (m)
Biskra	34,8	88

Espéce		Cycle Végétatif (Jours)	
quinoa		Initiale	30
Variété	Giza 01	Developpement	40
Date de semis		Mi-saison	40
Jour	29	Finale	20
Mois	11		

Kcb	
Coefficient cultural de base	
Initial	0,15
Mi-saison	1,15
Final	0,5

Fraction de sol mouillée par l'eau d'irrigation	fw(irrig.)	0,7
Quantité d'eau qui peut être directement évaporée (mm)	REW	3
Quantité d'eau maximale (totale) qui peut être évaporée (mm)	TEW	5
Lame d'eau cumulée (profondeur) initialement évaporable (mm)	initial De:	3
Fraction de sol initialement mouillée	initial fw:	0,25

Kc minimal	0,4
Hauteur max de la plante (m)	1

CE de l'eau d'irrigation (dS/m)	5,57
b:Pente de la droite de réduction du Rdt (%/(dS/m))	12
Seuil de tolérance (dS/m)	6
Fraction de lessivage	0

Efficience de l'irrigation (%)	80
Profondeur racinaire min (m)	0,3
Profondeur racinaire max (m)	0,55
RU (mm/m)	120

Superficie Parcelle (m²)	Débit (l/s)
20	1,53

Fraction de tarissement permise au stade initial (%) : MAD (Management Allowed Depletion)	5
Fraction de tarissement permise aprés stade initial (%) : MAD	15

Figure 22: Data entry interface for FAO-ACSAD-ITDAS irrigation software (Original photo 2023)

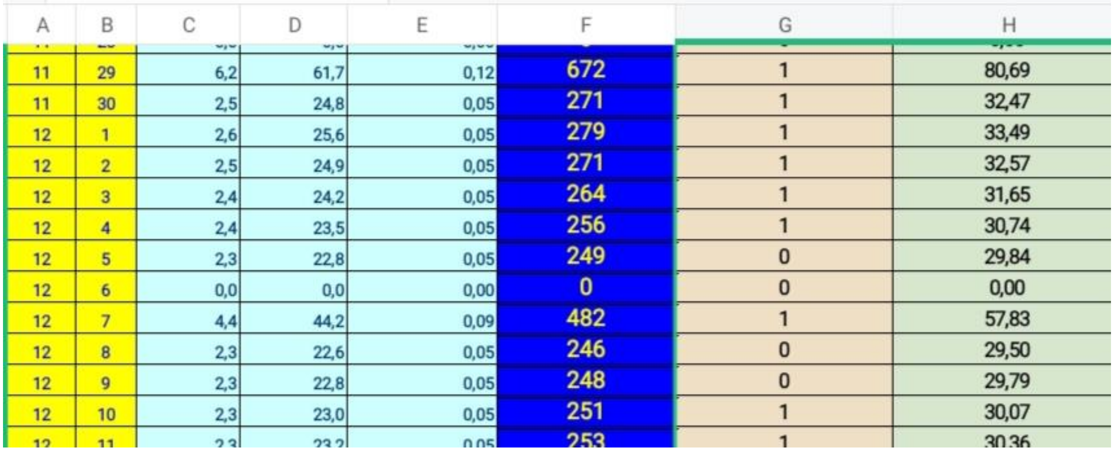
b. Irrigation amounts of water (dose)

It gives the amount of watering each day in several different units, but it starts from the day of planting, meaning all previous days before the date of planting are not counted, remaining 0.

B	C	D	E	F	G	H
Jour	Dose (mm)	D/ha (m³)	D/Parcelle (m³)	Tps d'irrig/ha (mn)	Tps d'irrig/parcel (mn)	Temps d'irrig/parcelle (S)
1	0,0	0,0	0,00	0	0	0,00
2	0,0	0,0	0,00	0	0	0,00
3	0,0	0,0	0,00	0	0	0,00
4	0,0	0,0	0,00	0	0	0,00
5	0,0	0,0	0,00	0	0	0,00
6	0,0	0,0	0,00	0	0	0,00
7	0,0	0,0	0,00	0	0	0,00
8	0,0	0,0	0,00	0	0	0,00
9	0,0	0,0	0,00	0	0	0,00
10	0,0	0,0	0,00	0	0	0,00
11	0,0	0,0	0,00	0	0	0,00
12	0,0	0,0	0,00	0	0	0,00
13	0,0	0,0	0,00	0	0	0,00

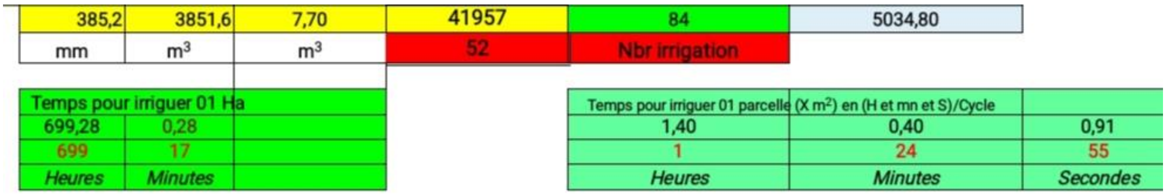
Figure 23: Schedule irrigation for FAO-ACSAD-ITDAS irrigation software (Original photo 2023)

Starting from the date of planting the plant 29 November 2023, The program begins by giving irrigation amounts



A	B	C	D	E	F	G	H
11	29	6,2	61,7	0,12	672	1	80,69
11	30	2,5	24,8	0,05	271	1	32,47
12	1	2,6	25,6	0,05	279	1	33,49
12	2	2,5	24,9	0,05	271	1	32,57
12	3	2,4	24,2	0,05	264	1	31,65
12	4	2,4	23,5	0,05	256	1	30,74
12	5	2,3	22,8	0,05	249	0	29,84
12	6	0,0	0,0	0,00	0	0	0,00
12	7	4,4	44,2	0,09	482	1	57,83
12	8	2,3	22,6	0,05	246	0	29,50
12	9	2,3	22,8	0,05	248	0	29,79
12	10	2,3	23,0	0,05	251	1	30,07
12	11	2,3	23,2	0,05	253	1	30,36

Figure 24: Schedule irrigation for FAO-ACSAD-ITDAS irrigation software (Original photo 2023)



385,2	3851,6	7,70	41957	84	5034,80
mm	m³	m³	52	Nbr irrigation	

Temps pour irriguer 01 Ha		
699,28	0,28	
699	17	
Heures	Minutes	

Temps pour irriguer 01 parcelle (X m²) en (H et mn et S)/Cycle		
1,40	0,40	0,91
1	24	55
Heures	Minutes	Secondes

Figure 25 : The total amount of irrigation and number of irrigation (Original photo 2023)

c.Interpolation of climate data

- Calculation of Etc and ET0 :

ETc calculator assesses ETc from meteorological data by means of the FAO Penman-Monteith equation.

معامل الاجهاد الملحي Kss	1
مجموع Etcss (مم)	338,63
مجموع ماء الري المكافئ (مم) cum irr	308,13
صافي مجموع ماء الري المكافئ+الغسيل(مم)	308,13
مجموع Etc (مم)	338,63
مجموع ماء الري المكافئ+الغسيل(مضاف)(مم)	385,16

شهر	يوم	ري+غسيل (مضاف) (مم)	ري+غسيل صافي(مم)	صافي الاحتياجات المائية(مم)	Etcss (مم/يوم)	ETc (مم/يوم)	Eto (مم/يوم)
1	1	0	0	0	0,00	0,00	1,8565233
1	2	0	0	0	0,00	0,00	1,8557861
1	3	0	0	0	0,00	0,00	1,8551843
1	4	0	0	0	0,00	0,00	1,8547131
1	5	0	0	0	0,00	0,00	1,8543676
1	6	0	0	0	0,00	0,00	1,8541427
1	7	0	0	0	0,00	0,00	1,8444734
1	8	0	0	0	0,00	0,00	1,8349245
1	9	0	0	0	0,00	0,00	1,8254922
1	10	0	0	0	0,00	0,00	1,8161729
1	11	0	0	0	0,00	0,00	1,8069625

Figure 26: Interpolation of climate data for FAO-ACSAD-ITDAS irrigation software (Original photo 2023)

Chapter IV

Results and Discussions

IV.1. Effect of irrigation management on the physico-chemical characteristics of the soil

IV.1.1. Effect of irrigation management on soil moisture

Carefully considering soil moisture is the key to success in any crop. However, its contribution with the right quantities of water and at the right time would guarantee better ionic and cationic exchanges in the soil. Humidity measurements were taken at a depth of 30cm during three periods, namely : Before sowing, 24 hours after irrigation, at the six-leaf stage and at the flowering period.

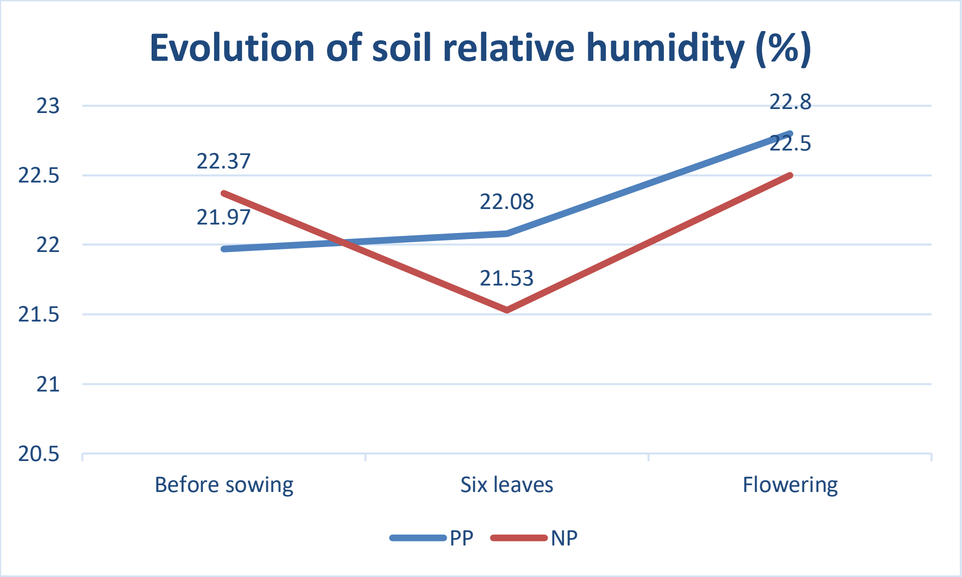


Figure27 : Evolution of soil humidity according to treatments

According to the results of the soil analyses, the plots expressed responses differently depending on the irrigation mode adopted (NP) and (PP).

At the six-leaf and flowering stages, the scheduling plot (PP) presented a better humidity level compared to the non-scheduling plot (NP) ; 22.8% against 22.5%. (An increase in soil reserve of 0.3%)

The quantities of irrigation water provided at these stages are:

- Six-leaf stage : **282.2 m3/ha** (PP) versus **633.1 m3/ha** (NP), a difference of **350.9 m3/ha**
- Flowering stage : **414.8 m3/ha** (PP) compared to **302.5 m3/ha** (NP), a difference of **-112.3 m3/ha** (less irrigation during the reproduction period)

Statistical analysis (ANOVA) revealed no significant differences between treatments.

The Student –Newman-Keuls test showed that (NP) and (PP) formed a homogeneous group (A) at the Before sowing and flowering stages and heterogeneous at the Six leaves stage (A) and (B).

Table 06: Analysis of variance (Change in soil moisture)

Modality	Estimated Averages	Difference	Lower Bound (95%)	Upper Bound (95%)	Groups	
Before sowing						
NP	**22.370**	**0.294**	**21.554**	**23.186**	**A**	
Pp	**21.973**	**0.294**	**21.157**	**22.789**	**A**	
Six leaves						
PP	**22.080**	**0.078**	**21.864**	**22.296**	**A**	
NP	**21.537**	**0.078**	**21.321**	**21.753**		**B**
Flowering						
PP	**22.733**	**0.262**	**22.005**	**23.462**	**A**	
NP	**22.500**	**0.262**	**21.771**	**23.229**	**A**	

IV.1.2. Effect of irrigation management on soil pH

pH is considered one of the main variables in soil because it controls many chemical processes that take place in that soil. The pH analysis results also revealed a fluctuation from before the establishment of the crop until flowering.

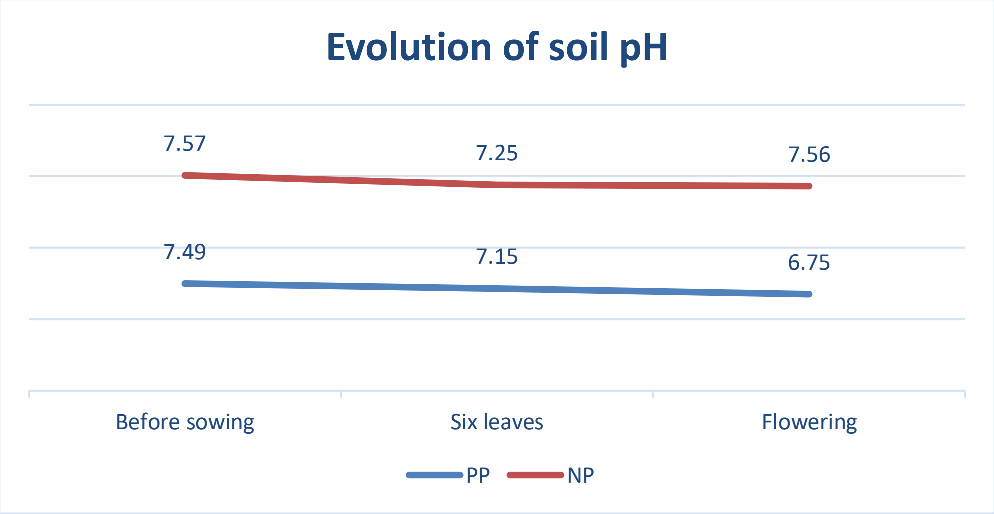


Figure 28: Evolution of pH in the soil according to treatments

For the scheduling plot (PP); the Ph followed a decreasing curve marking neutrality, from 7.49 before sowing to 6.75 at flowering.

For the non-scheduling plot (NP); the analysis results showed no variation in pH during these three stages and stabilized at a value of 7.56.

Statistical analyses (ANOVA) revealed no difference between the two treatments.

The Student –Newman-Keuls test showed that (NP) and (PP) formed a homogeneous group (A) at the Before sowing and Six leaves stages and heterogeneous at the flowering stage (A) and (B).

Table 07 : Analysis of variance (Change in soil moisture)

Modality	Estimated averages	Difference	Lower Bound (95%)	Upper Bound (95%)	Groups	
Beforesowing						
NP	**7.570**	**0.138**	**7.186**	**7.954**	**A**	
PP	**7.497**	**0.138**	**7.113**	**7.880**	**A**	
Six leaves						
NP	**7.250**	**0.059**	**7.085**	**7.415**	**A**	
PP	**7.153**	**0.059**	**6.989**	**7.318**	**A**	
Flowering						
NP	**7.560**	**0.147**	**7.152**	**7.968**	**A**	
PP	**6.750**	**0.147**	**6.342**	**7.158**		**B**

IV.1.3. Effect of irrigation management on soil salinity

Measurements for soil salinity were taken during the periods from before sowing until flowering.

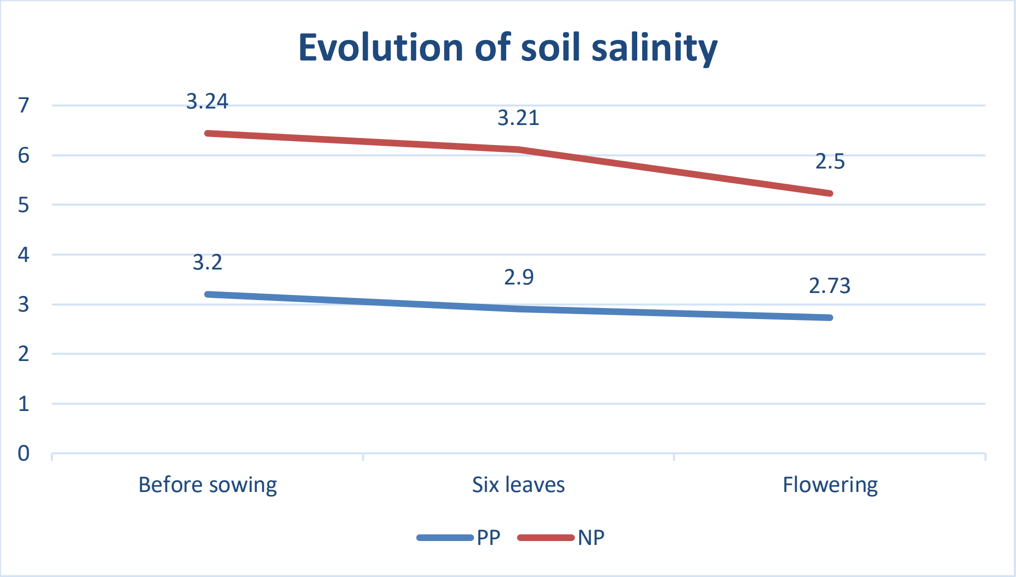


Figure 29 : Evolution of soil salinity according to treatments

The results obtained during the experiment ; revealed a progressive decrease in soil salinity for the two treatments from the pre-sowing stage until flowering, going from:

- **3.2 ds/m** to **2.73 ds/m** for the scheduling plot
- **3.24 ds/m** to **2.5 ds/m** for the non-scheduling plot
- The minimum value is noted in the scheduling plot with**2.5 ds/m**
- The maximum value is noted in the non-scheduling plot with **3.24 ds/m**

In generalthe salinity of the soil stabilizes at around **(2.5 - 2.7 ds/m)** for the two treatments and allows a measurement of the power of the soil to retain and exchange cations. This is a relative indicator of one's fertility potential. These results are consistent with those of Abdullah **M. Algosaibi 2017** on the effect of irrigation intervals on the growth and yield of quinoa and its components.

Statistical analyses (ANOVA) revealed no difference between the two treatments at the Six Leaf and Flowering stages and a significant difference for the Before Sowing treatments. The Student –Newman-Keuls test showed that (NP) and (PP) formed a homogeneous group (A) at the Before sowing stages and a heterogeneous group at the Six leaves and flowering stages (A) and (B).

Table 08 : Analysis of variance (Change in soil moisture)

Modality	Estimated Averages	Difference	Lower Bound (95%)	Upper Bound (95%)	Groups	
Before sowing						
NP	3.240	0.097	2.970	3.510	A	
PP	3.207	0.097	2.937	3.476	A	
Six leaves						
NP	3.210	0.027	3.135	3.285	A	
PP	2.907	0.027	2.832	2.981		B
Flowering						
PP	2.717	0.017	2.669	2.764	A	
NP	2.500	0.017	2.453	2.547		B

IV.2. Effect of irrigation management on the appearance of growth stages

The analytical study of the effect of irrigation management on the appearance of plant growth stages brought out the following :

- The duration from sowing to emergence is identical for the three treatments and is**11 days**.
- The duration of the growing cycle for treatment with the scheduling plot is**120 days**, which is the shortest **(early)**
- The duration of the growing cycle for the treatment of the non-scheduling plot is**142 days,** which and is the longest **(late)**.

These results are similar to those of the work of **MUJICA and CANAHUA (1989)**

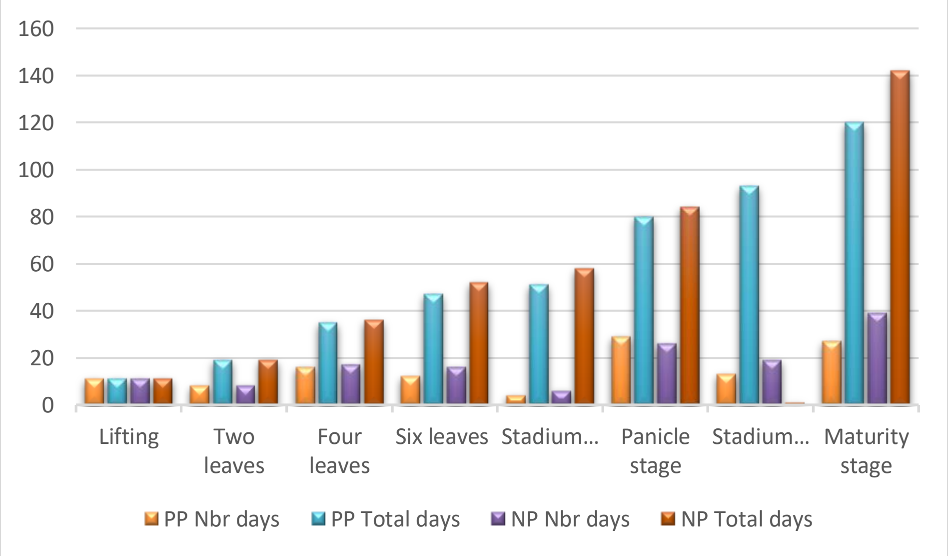


Figure 30: Appearance of phenological stages according to treatments (days)

TOTAL OF WATER CONSUMTION

- THE overall water consumption during the growing cycle for the scheduling plot is **3851.6 m3/ha** compared to **4267.3 m3/ha** for the non-scheduling plot; that is a gain of approximately **09%** in water.
- For the scheduling plot :

-The maximum water consumption is noted during the flowering - maturing phase, with a quantity of **1385.8 m3/ha.**

-The minimum water consumption is noted during the six leaf – branching phase, with a quantity of **101.1 m3/ha.**

- For the non-scheduling plot :

-The maximum water consumption is noted during the Branching - panicle phase, with a quantity of **936.4 m3/ha.**

-The minimum water consumption is noted during the Sowing –Rising phase, with a quantity of **297.1 m3/ha.**

***Quinoa* phenological stages (photo original 2024)**

Lifting

Two leaves

Four leaves

Six leaves

Branching

Start of panicle

Panicle

Flowering

IV.3. Effect of irrigation management on the morphological characteristics of the plant

IV.3.1 Average plant height (cm)

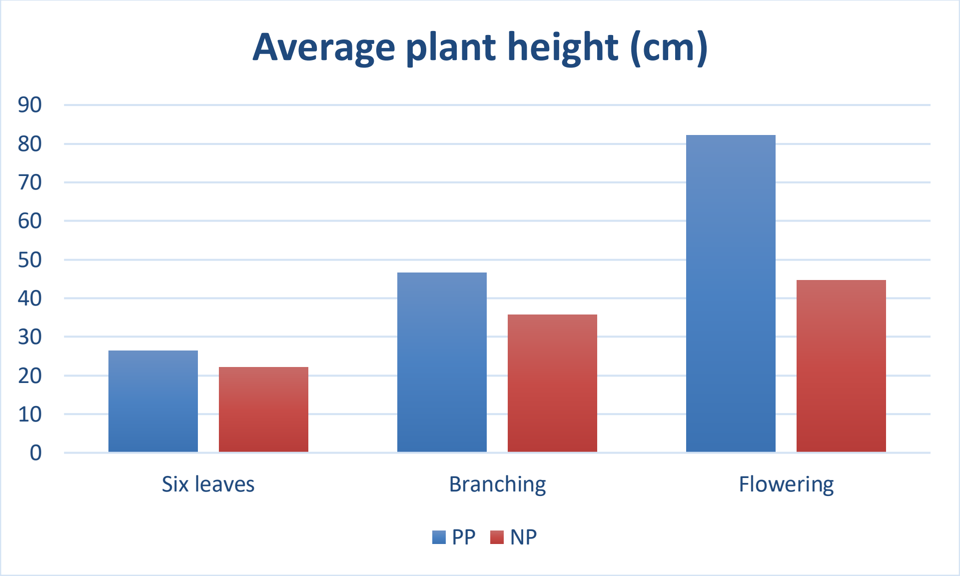


Figure 31: Average plant height according to treatments

- At the Six-leaf stage, the maximum height of the plant is noted in the scheduling plot at **27.1 cm** and the minimum in the non-scheduling plot at **17.1 cm**.

At the Branching stage, the maximum height of the plant is noted in the scheduling plot at **50.2 cm** and the minimum in the non-scheduling plot at **33.4 cm**.

At the Flowering stage, the maximum height of the plant is noted in the scheduling plot at **84.3 cm** and the minimum in the non-scheduling plot at **63.3 cm**.

Biometric analyses revealed that the application of reasoned irrigation ; had a positive influence on the height aspect of the plant. According to **BAZILE, 2015**, the type of variety and the conditions of the growing environment greatly influence the height of the plant in quinoa.

These results are consistent with those of **NEBIE 2018 and COULIBALY 2022**. On the other hand ; statistical analysis (ANOVA) showed that :

- There was no difference between the two treatments at the Six-leaf stage ; Tests of statistical analyses for comparison of means (Newman-Keuls / analysis of differences between modalities with a 95% confidence interval); identified a homogeneous group (A).

- Existence of significant differences between treatments at the Branching and flowering stages and formation of heterogeneous groups (A) and (B).

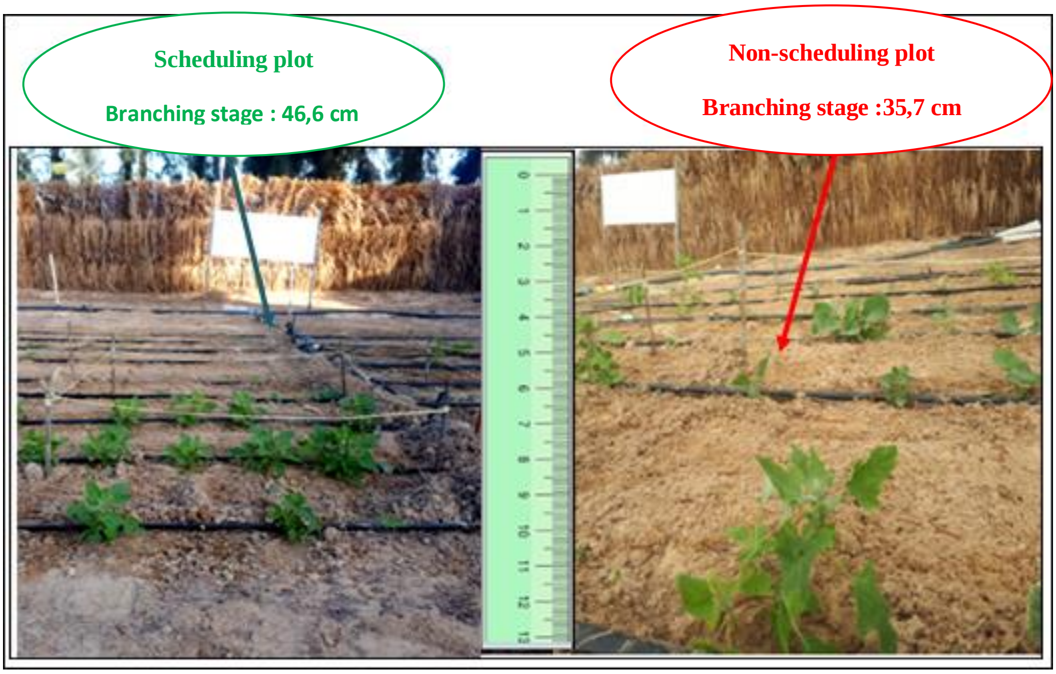


Photo 9: Plant height (cm) at the Branching stage (original photo 2024)

Table09: Analysis of variance (Plant height in cm)

Modality	Estimated Averages	Difference	Lowerbound (95%)	Upperbound (95%)	Groups	
Six leaves						
PP	**26.400**	**1.791**	**21.427**	**31.373**	**A**	
NP	**22.100**	**1.791**	**17.127**	**27.073**	**A**	
Branching						
PP	**46.600**	**1.608**	**42.135**	**51.065**	**A**	
NP	**35.700**	**1.608**	**31.235**	**40.165**		**B**
Flowering						
PP	**82.267**	**0.823**	**79.981**	**84.552**	**A**	
NP	**63.867**	**0.823**	**61.581**	**66.152**		**B**

IV.3.2. Average root length (cm)

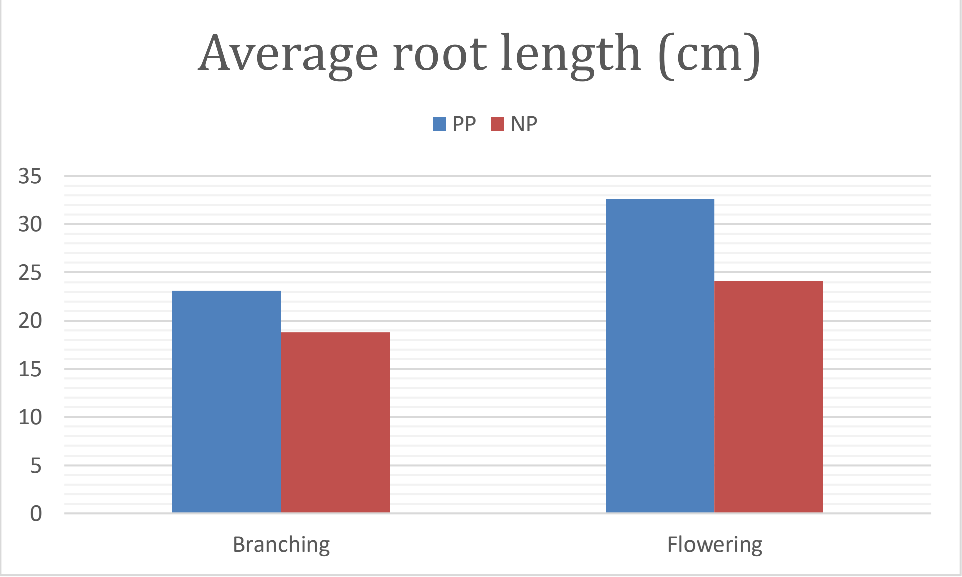


Figure 32: Average root length according to treatments

At the Branching stage, the maximum length of the root is noted in the scheduling plot at **24.1 cm** and the minimum in the non-scheduling plot at **18.4 cm**. That's an average difference of **4.3 cm**.

At the Flowering stage, the maximum length of the root is noted in the scheduling plot at **33.7 cm** and the minimum in the non-scheduling plot at **23.5 cm**. An average difference of **8.5 cm.**

Biometric measurements showed that irrigation control induced a remarkable increase in root length. This influence on length allows the plant to have good root anchorage in the soil.

Statistical analyses (ANOVA) showed significant differences between the two treatments and during the two Branching and Flowering stages.

For the Pearson test for comparison of means; the analyses showed the existence of two heterogeneous groups (A) and (B) between the treatments carried out.

Table10: Analysis of variance (Root length in cm)

Modality	Estimated Averages	Difference	Lower bound	Upper Bound (95%)	Groups	
			Branching			
PP	**23.133**	**0.384**	**22.066**	**24.201**	**A**	
NP	**18.833**	**0.384**	**17.766**	**19.901**		**B**
			Flowering			
PP	**32.633**	**0.590**	**30.996**	**34.271**	**A**	
NP	**24.133**	**0.590**	**22.496**	**25.771**		**B**

IV.3.3. Number of branches per plant

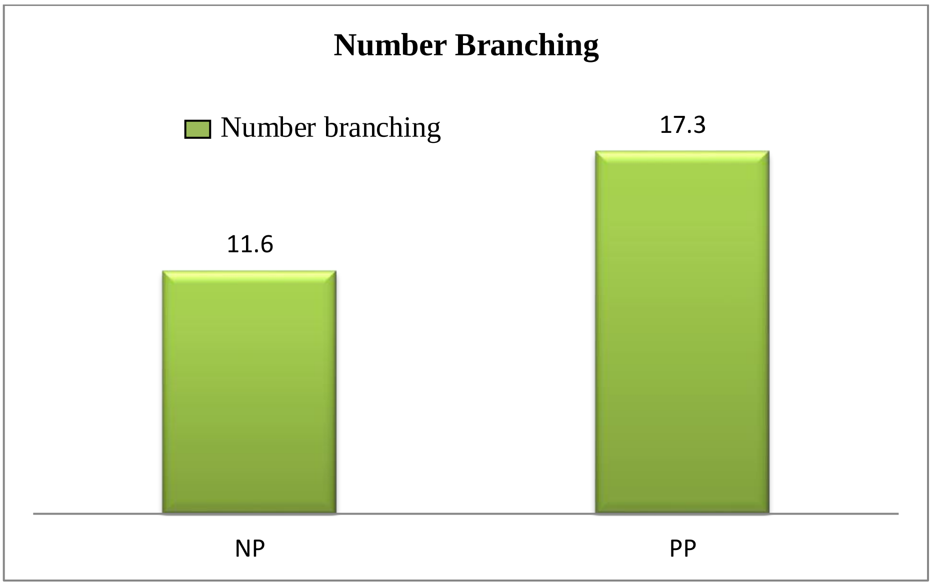


Figure 33: Number of branches per plant according to treatments

The Branching stage is reached in **51days** for the scheduling plot and **58 days** for the non-scheduling plot. That is a gap of **7 days**.

The maximum number of branches per plant is noted in the scheduling plot with **19 branches** and the minimum in the non-scheduling plot with **13**. That is an average difference of **06 branches per plant**.

At this stage, the scheduling plot had a water consumption of **101.1 m3/ha** compared to **628.7 m3/ha** for the non-scheduling plot, a difference of **527.6 m3/ha.**

Statistical analyses (ANOVA) showed a significant difference between the two treatments. The means comparison test revealed two heterogeneous groups (A) and (B).

Table11: Analysis of variance (number of branches per plant)

Modality	Average	Standard error	Lower bound (95%)	Upper bound (95%)	Groups	
PP	**17.333**	**1.054**	**14.407**	**20.260**	**A**	
NP	**11.667**	**1.054**	**8.740**	**14.593**		**B**

IV.3.4. 1000 Grain weights (PMG)

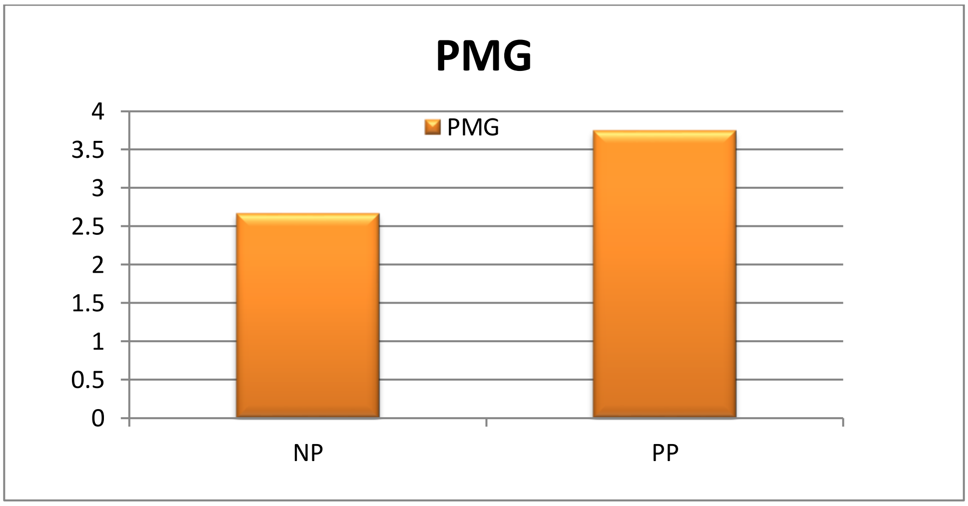


Figure 34: PMG (g) according to treatments

The maximum PMG is noted in the scheduling plot with **3.86 g** and the minimum in the non-scheduling plot with **2.48 g**. That's an average difference of **1.38 g**.

Statistical analyses (ANOVA) showed a significant difference between the two treatments. The means comparison test (S-N-K) revealed two heterogeneous groups (A) and (B).

Table12: Analysis of variance (PMG)

Modality	Average	Standard error	Upper bound (95%)	Lower bound (95%)	Groups	
PP	**3.757**	**0.096**	**3.490**	**4.023**	**A**	
NP	**2.677**	**0.096**	**2.410**	**2.943**		**B**

IV.3.5. Grain yield

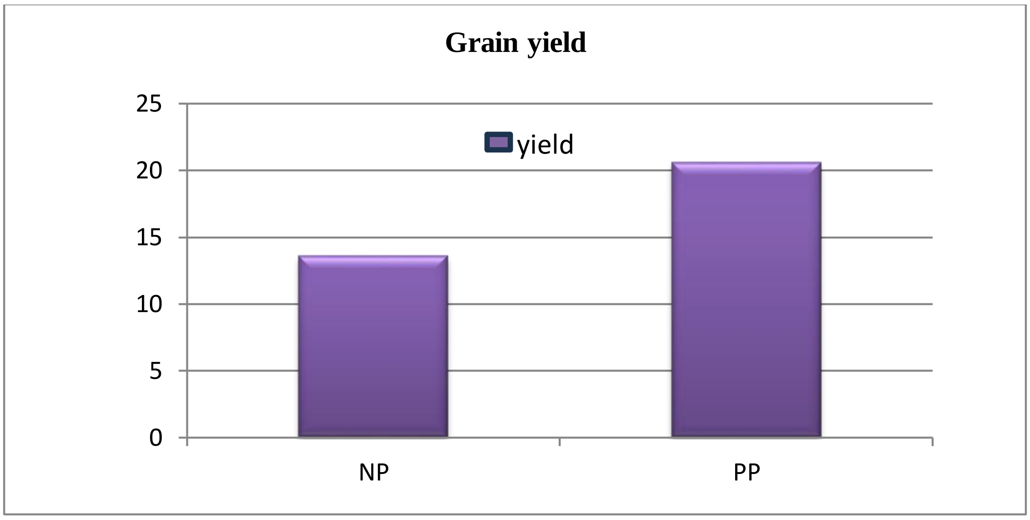


Figure 35: Grain yield (q/ha) according to treatments

The maximum grain yield is noted in the scheduling plot with **22.2 q/ha** and the minimum in the non-scheduling plot with **12.2 q/ha**. That is an average difference of **10 q/ha**.

At this stage of maturity, the scheduling plot had a water consumption of **3851.6 m3/ha** compared to **4267.3 m3/ha** for the non-scheduling plot, a difference of**415.7 m3/ha**

These results are consistent with those of **ABDULLAH M. 2017** on the effect of irrigation intervals on the growth and yield of *quinoa* and its components.

Statistical analyses (ANOVA) showed a significant difference between the two treatments. The means comparison test (S-N-K) revealed two heterogeneous groups (A) and (B).

Table13: Analysis of variance (grain yield)

Modality	Average	Standard error	Upperbound (95%)	Lowerbound (95%)	Groups	
PP	**20.633**	**0.760**	**18.523**	**22.744**	**A**	
NP	**13.633**	**0.760**	**11.523**	**15.744**		**B**

IV .4. Influence of management irrigation on water productivity

The results of the experiment showed the following :

- The scheduling plot gave an average grain yield of **20.6 q/ha** for a water consumption of **3851.6 m3/ha**, or **186.97 m3** to produce**one (01) quintal of *quinoa***.

- The non-scheduling plot gave an average grain yield of **13.6 q/ha** for a water consumption of **4267.3 m3/ha**, or **313.77 m3** to produce **one (01) quintal of quinoa**.

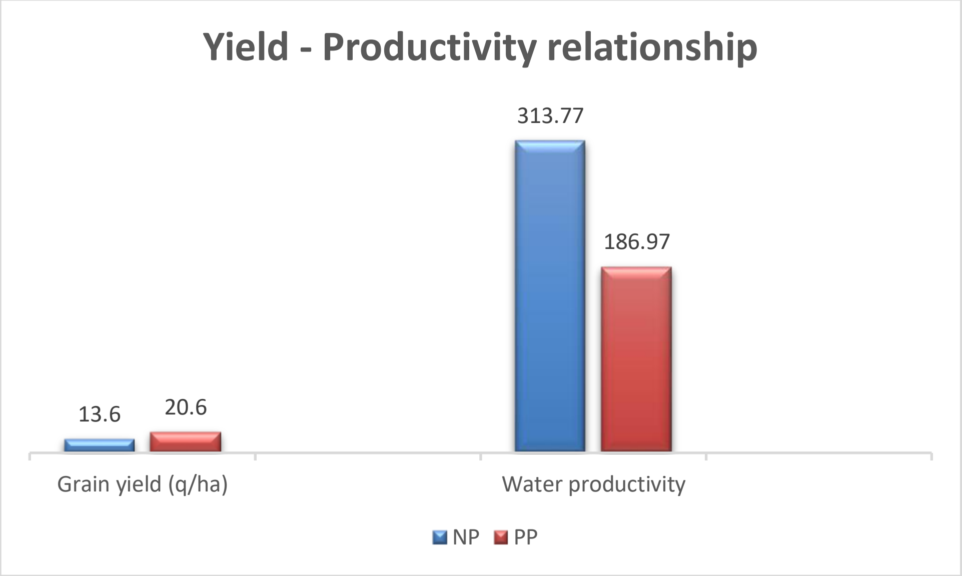


Figure 36 : Grain yield – Productivity relationshipaccording to treatments

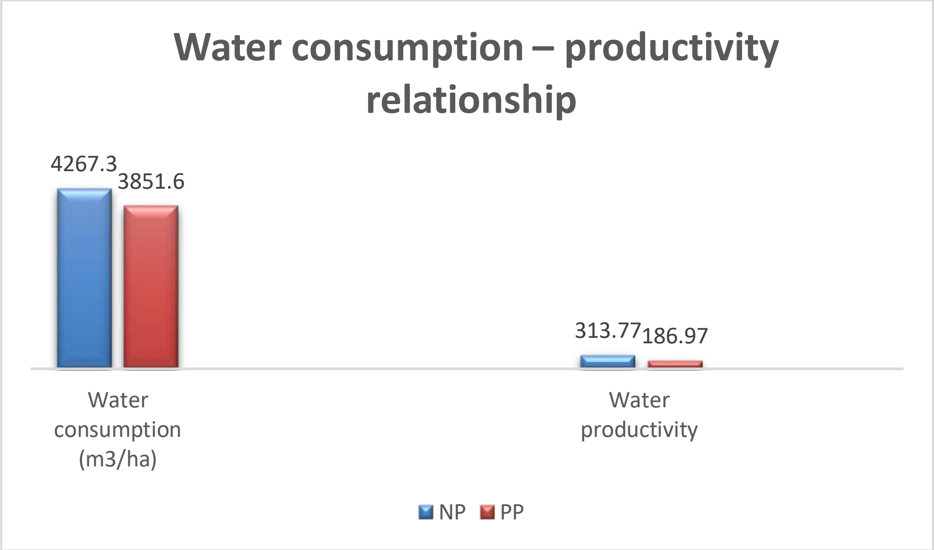


Figure 37: Relationship between water consumption and water productivity according to treatments

IV.5. Parametric correlations

IV.5.1. Correlations between the different variables marking the effect of irrigation management on the physical and chemical characteristics of the soil

The results of analyses of soil chemical characteristics were expressed in interrelated ways. Their manifestation has been marked by correlations determining the composition and mobility of fertilizing elements in the soil.

Statistically, **the Pearson test** indicated that there is a correlation **(R2)** between the different variables studied. The results show that there are two types of correlation :

- **Strong positive correlation** : which determines the close link between the variables and their interactions together (common action).

- CE Six leaves and PH Flowering **(R2 = 0.922)** and Humidity before Sowing **(R2 = 0.533)**
- EC Flowering and Humidity Six Leaves **(R2 = 0.878)**
- PH Six leaves and PH Before sowing **(R2 = 0.523)**
- PH before sowing and humidity before sowing**(R2 = 0.845)**

- **Strong negative correlation** : which determines the close connection between variables and their inverse interactions (reverse action).

- EC Flowering and EC Six Leaves **(R2 = -0.942)** and PH Flowering **(R2 =-0.880)**
- EC Six leaves and Humidity six leaves **(R2 = -0.830)**
- EC before sowing and before sowing **(R2 = - 0.821)** and PH before sowing **(R2 = - 0.703)**
- PH Flowering and Humidity Six Leaves **(R2 = -0.794)**
- PH Six leaves and humidity : six leaves **(R2 = -0.669)**

IV.5.2. Correlationsbetween the different variables marking the effect of irrigation management on the yield components

The performance components were expressed in interrelated ways. Their manifestation has been marked by correlations determining yields (straw and grain).

Statistically, **the Pearson test** ; indicated that there is a correlation (R2) between the different variables studied. The results show that thereis a strong positive correlation and interdependence between all performance components.

IV.6. PROXIMITY MATRIX

(Pearson correlation coefficient)

Correlations between the different variables marking the effect of irrigation management on the physical and chemical characteristics of the soil

	HUMIDITY BEFORESOWING	HUMIDITY SIX LEAVES	HUMIDITY FLOWERING	pH BEFORESOWING	PH SIX LEAVES	pH FLOWERING	SALINITY BEFORESOWING	SALINITY SIX LEAVES	SALINITY FLOWERING
HUMIDITY BEFORE SOWING	1	-0.226	-0.188	0.845	0.294	0.481	-0.821	0.533	-0.335
HUMIDITY SIX LEAVES	-0.226	1	0.304	-0.079	-0.669	-0.794	-0.291	-0.830	0.878
HUMIDITY FLORAISON	-0.188	0.304	1	0.124	-0.138	-0.224	0.194	-0.389	0.143
pH BEFORE SOWING	0.845	-0.079	0.124	1	0.523	0.109	-0.703	0.189	-0.097
pH SIX LEAVES	0.294	-0.669	-0.138	0.523	1	0.217	0.053	0.335	-0.384
PH FLOWERING	0.481	-0.794	-0.224	0.109	0.217	1	-0.052	0.922	-0.880
SALINITY BEFORE SOWING	-0.821	-0.291	0.194	-0.703	0.053	-0.052	1	-0.039	-0.232
SALINITY SIX LEAVES	0.533	-0.830	-0.389	0.189	0.335	0.922	-0.039	1	-0.942
SALINITY FLOWERING	-0.335	0.878	0.143	-0.097	-0.384	-0.880	-0.232	-0.942	1

IV.7. PROXIMITY MATRIX

(Pearson correlation coefficient)

Correlations between the different variables marking the effect of irrigation management on yield components

	HEIGHT SIX LEAVES	BRANCH HEIGHT	FLOWERING HEIGHT	BRANCH LENGTH	FLOWERING LENGTH	NUMBER OF BRANCHES	PMG (g)	RDT GRAIN (q/ha)	BIOMASS(g/m2)
HEIGHT SIX LEAVES	1	0.605	0.639	0.721	0.625	0.452	0.493	0.582	0.589
BRANCH HEIGHT	0.605	1	0.942	0.860	0.924	0.848	0.877	0.899	0.974
FLOWERING HEIGHT	0.639	0.942	1	0.953	0.983	0.929	0.950	0.947	0.975
BRANCH LENGTH	0.721	0.860	0.953	1	0.910	0.839	0.950	0.971	0.936
FLOWERING LENGTH	0.625	0.924	0.983	0.910	1	0.883	0.923	0.888	0.937
NOMBRE RAMIFICATION	0.452	0.848	0.929	0.839	0.883	1	0.856	0.866	0.898
PMG(G)	0.493	0.877	0.950	0.950	0.923	0.856	1	0.975	0.954
RDT GRAIN Q/HA	0.582	0.899	0.947	0.971	0.888	0.866	0.975	1	0.972
BIOMASS G/M2	0.589	0.974	0.975	0.936	0.937	0.898	0.954	0.972	1

Conclusion

Conclusion

The present work was carried out to study the influence of the application of irrigation scheduling methods on the development of *Quinoa* cultivation (Giza1 variety) in saline and arid conditions. Effective management of water resources, saving the quantity of water and improving the physical properties of soils with a view to boosting their fertility are necessary to maintain or even optimize crop yields. The general objective of this studyis to contribute to the rationalization of irrigation water and, more specifically to assessits impact on the physicochemical characteristics of the soil, but also to evaluate its productivity on water use in irrigation following the growth and production of the crop.

The study revealed variations in soil properties as well as the growth and development of the *quinoa* crop and its yield components.

1- Effect of irrigation management on the physical and chemical properties of the soil

Effect on average soil moiture : the scheduling plot (PP) had a better significant average humidity level compared to the non-scheduling one (NP); **22.8%** against **22.5%**.(an increase in soil reserve of **0.3%)**

The effect on avergae pH value : soil analyses showed statistically significant differences. The scheduling plot (PP) expressed a relatively decreasing Ph compared to the non-scheduling plot (NP) which went from **7.49 to 6.75**.

Effect on avrage salinity (EC) : The results obtained during the experiment ; revealed a progressive decrease in soil salinity (EC) for the two treatments from the pre-sowing stage until flowering and stabilized at around **2.5 - 2.7 ds/m** respectively, for (PP) and (NP).

2- Effect of irrigation management on the morphological parameters of the plant and yield

The expression of the results relating to the vegetative parameters made it possible to evaluate the growth and development of the plant according to the treatments. The SNK test revealed a significant difference between the scheduling plot (PP) and the non-scheduling plot (NP).

Effect on precocity : The analytical study showed that the application of irrigation control had an effect on the appearance of the growth stages of the plant. The plot (PP) showed a fairly short development cycle ; of **120 days**, an **earliness** of **22 days** compared to the non-scheduling plot (NP) of **142 days**.

The overall water consumption during the growing cycle for the scheduling plot is **3851.6 m3/ha** compared to **4267.3 m3/ha** for the non-scheduling plot; a gain of approximately **09% in irrigation water**.

Effect on plant height and root length : Biometric analyses revealed that the application of rational irrigation ; had a **positive** influence on the aspects of plant height and root length. The maximum height and length are observed in the plants in the scheduling plot.

Effect on the number of branches : The best count is observed in the scheduling plot with a difference of **6 branches** per plant and a **precocity of 7 days** for a difference in water consumption of **527.6 m3/ha**.

Effect on grain yield : The application of irrigation control had a significant effect on grain yield (including PMG). The maximum grain yiel disnoted in the scheduling plot with **22.2 q/ha** and the minimum in the non-scheduling plot with **12.2 q/ha**. That is an average difference of **10 q/ha**.

Effect on water productivity : The results of the experiment showed that the scheduling plot gave an average grain yield of **20.6 q/ha** for a water consumption of **3851.6 m3/ha**, or **186.97 m3** to produce (01) quintal of quinoa, and the non-scheduling plot gave an average grain yield of **13.6 q/ha** for a water consumption of **4267.3 m3/ha**, or **313.77 m3** to produce **one (01) quintal of *quinoa***

Climate change, marked by an increase in temperatures, evapotranspiration and dryness of the soil and a modification of the spatial and temporal distribution of rainfall in arid regions, leads to a more systematic use of irrigation for agricultural systems. However, faced with this growing imbalance between resources and uses, the agricultural world is seeing its availability of water decrease. There is an increasing need to save money.

Better water management, as close as possible to the needs of plants, has therefore become essential to combine the preservation of water resources and the maintenance of agricultural production.

Taking into account the results obtained in this study, it appears that the contribution of management scheduling irrigation by the program of Acsad Itads to improving yield is indisputable.

With a potential water savings of 09% for the *Quinoa* crop; irrigation management is one of the important levers to respond to this challenge and thus strengthen the resilience of agricultural systems with regard to the fragility of water resources. This “good practice” is certainly known and proven, but it is not yet generalized. There is still plenty of room to maneuver.

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Annexes

Annex 01 : irrigation schedule

Month	Day	D/ha (m^3)	Irrigation time plot (S)	
11	29	61.7	80.69	Sowing – Lifting 297.1 m^3/ha
11	30	24.8	32.47	
12	1	25.6	33.49	
12	2	24.9	32.57	
12	3	24.2	31.65	
12	4	23.5	30.74	
12	5	22.8	29.84	
12	6	0.0	0.00	
12	7	44.2	57.83	
12	8	22.6	29.50	
12	9	22.8	29.79	
12	10	23.0	30.07	Lifting – Two leaves 187.8 m^3/ha
12	11	23.2	30.36	
12	12	23.3	30.51	
12	13	23.5	30.67	
12	14	23.6	30.83	
12	15	23.7	30.98	
12	16	23.8	31.14	
12	17	23.7	30.97	
12	18	23.6	30.80	Two leaves–Four leaves 332.7 m^3/ha
12	19	23.4	30.63	
12	20	23.3	30.47	
12	21	23.2	30.31	
12	22	23.0	30.06	
12	23	22.8	29.81	
12	24	22.6	29.57	
12	25	0.0	0.00	
12	26	44.4	58.09	
12	27	22.7	29.62	
12	28	23.1	30.16	
12	29	0.0	0.00	
12	30	0.0	0.00	
12	31	0.0	0.00	
1	1	80.6	105.33	
1	2	0.0	0.00	
1	3	0.0	0.00	Four leaves – six leaves 282.2 m^3/ha
1	4	0.0	0.00	
1	5	89.5	117.04	
1	6	0.0	0.00	
1	7	0.0	0.00	
1	8	0.0	0.00	
1	9	94.8	123.95	
1	10	0.0	0.00	
1	11	0.0	0.00	
1	12	0.0	0.00	
1	13	97.9	127.96	
1	14	0.0	0.00	
1	15	0.0	0.00	Six leavrs - Branching 100.1 m^3/ha
1	16	0.0	0.00	
1	17	100.1	130.82	
1	18	0.0	0.00	Branching – Panicle 951.1 m^3/ha
1	19	0.0	0.00	
1	20	0.0	0.00	
1	21	101.9	133.18	
1	22	0.0	0.00	
1	23	0.0	0.00	
1	24	0.0	0.00	
1	25	106.5	139.17	
1	26	0.0	0.00	
1	27	0.0	0.00	
1	28	0.0	0.00	
1	29	112.5	147.12	
1	30	0.0	0.00	
1	31	0.0	0.00	
2	1	0.0	0.00	

2	**2**	**122.1**	**159.58**	
2	**3**	**0.0**	**0.00**	
2	**4**	**0.0**	**0.00**	
2	**5**	**0.0**	**0.00**	
2	**6**	**129.6**	**169.39**	
2	**7**	**0.0**	**0.00**	
2	**8**	**0.0**	**0.00**	
2	**9**	**0.0**	**0.00**	
2	**10**	**125.9**	**164.58**	
2	**11**	**0.0**	**0.00**	
2	**12**	**0.0**	**0.00**	
2	**13**	**0.0**	**0.00**	
2	**14**	**0.0**	**0.00**	
2	**15**	**152.5**	**199.37**	
2	**16**	**0.0**	**0.00**	**Panicle–Flowering 414.8m^3/ha**
2	**17**	**0.0**	**0.00**	
2	**18**	**0.0**	**0.00**	
2	**19**	**132.2**	**172.78**	
2	**20**	**0.0**	**0.00**	
2	**21**	**0.0**	**0.00**	
2	**22**	**0.0**	**0.00**	
2	**23**	**139.3**	**182.04**	
2	**24**	**0.0**	**0.00**	
2	**25**	**0.0**	**0.00**	
2	**26**	**0.0**	**0.00**	
2	**27**	**143.3**	**187.34**	
2	**28**	**0.0**	**0.00**	
3	**1**	**0.0**	**0.00**	**Flowering – Maturity 1385.8 m^3/ha**
3	**2**	**0.0**	**0.00**	
3	**3**	**165.6**	**216.42**	
3	**4**	**0.0**	**0.00**	
3	**5**	**0.0**	**0.00**	
3	**6**	**132.1**	**172.67**	
3	**7**	**0.0**	**0.00**	
3	**8**	**0.0**	**0.00**	
3	**9**	**142.5**	**186.28**	
3	**10**	**0.0**	**0.00**	
3	**11**	**0.0**	**0.00**	
3	**12**	**155.3**	**203.07**	
3	**13**	**0.0**	**0.00**	
3	**14**	**0.0**	**0.00**	
3	**15**	**154.6**	**202.11**	
3	**16**	**0.0**	**0.00**	
3	**17**	**0.0**	**0.00**	
3	**18**	**154.4**	**201.82**	
3	**19**	**0.0**	**0.00**	
3	**20**	**0.0**	**0.00**	
3	**21**	**157.8**	**206.23**	
3	**22**	**0.0**	**0.00**	
3	**23**	**0.0**	**0.00**	
3	**24**	**161.0**	**210.52**	
3	**25**	**0.0**	**0.00**	
3	**26**	**0.0**	**0.00**	
3	**27**	**162.5**	**212.40**	

Annex 02 : Phenological stages and quantity of irrigation water (m3/ha)

	Stadiums Varieties	Lifting stage	Two leaves	Four leaves	Six leaves	Branching stage	Panicle stage	Flowering stage	Maturity stage	Total
PP	Stadium date	**09/12/2023**	**17/12/2023**	**02/01/2024**	**14/01/2024**	**18/01/2024**	**15/02/2024**	**28/02/2024**	**27/03/2024**	**-**
	Quantity of water (m3/ha)	**297.1**	**187.8**	**332.7**	**282.2**	**100.1**	**851.1**	**414.8**	**1385.8**	**3851.6**
	Nbr days	**11**	**08**	**16**	**12**	**04**	**29**	**13**	**27**	**120**
	Total day	**11**	**19**	**35**	**47**	**51**	**80**	**93**	**120**	
NP	Stadium stage	**09/12/2023**	**17/12/2023**	**03/01/2024**	**19/01/2024**	**25/01/2024**	**26/02/2024**	**06/03/2024**	**14/04/2024**	
	Quantity of water (m3/ha)	**297.1**	**384.9**	**664.5**	**633.1**	**628.7**	**936.4**	**302.5**	**440.1**	**4267.3**
	Nbrdays	**11**	**08**	**17**	**16**	**06**	**26**	**19**	**39**	**142**
	Total day	**11**	**19**	**36**	**52**	**58**	**84**	**103**	**142**	

Annex 03 : Plant height(cm)

		Lifting	Two leaves	Four leaves	Six leaves	Branching stage	Panicle stage	Flowering stage	Maturity stage
PP	**R**	**09/12/2023**	**17/12/2023**	**02/01/2024**	**14/01/2024**	**18/01/2024**	**15/02/2024**	**28/02/2024**	**27/03/2024**
	R1	**3.1**	**10.8**	**19.2**	**27.1**	**44.7**	**70.4**	**82.1**	**101.2**
	R2	**3.4**	**12.1**	**18.5**	**25.7**	**44.9**	**66.6**	**80.4**	**99.8**
	R3	**3.1**	**11.6**	**14.2**	**26.4**	**50.2**	**60.4**	**84.3**	**105.2**
	A	**3.2**	**11.5**	**17.3**	**26.4**	**46.6**	**65.8**	**82.2**	
NP	**R**	**09/12/2022**	**17/12/2022**	**03/01/2024**	**19/01/2024**	**25/01/2024**	**26/02/2024**	**06/03/2024**	
	R1	**3.1**	**9.4**	**14.7**	**24.7**	**33.4**	**59.5**	**64.2**	**68.2**
	R2	**3.4**	**10.3**	**15.2**	**24.5**	**38.2**	**61.4**	**63.3**	**64.7**
	R3	**3.1**	**10.9**	**15.7**	**17.1**	**35.5**	**64.3**	**64.1**	**66.9**
	A	**3.2**	**10.2**	**15.2**	**22.1**	**35.7**	**61.7**	**63.8**	

Plant height(cm)

Treatment	Repetition	Stadium Sixl eaves	Stadium Branching	Stadium Flowering
PP	**R1**	**27.1**	**44.7**	**82.1**
	R2	**25.7**	**44.9**	**80.4**
	R3	**26.4**	**50.2**	**84.3**
	Average	26.4	46.6	82.2
NP	**R1**	**24.7**	**33.4**	**64.2**
	R2	**24.5**	**38.2**	**63.3**
	R3	**17.1**	**35.5**	**64.1**
	Average	22.1	35.7	44.6

Annex 04 : Root length(cm)

Treatment	Repetition	Stadium branching	Stadium flowering
PP	**R1**	**24.1**	**31.2**
	R2	**22.8**	**33.0**
	R3	**22.5**	**33.7**
	Average	23.1	32.6
NP	**R1**	**33.4**	24.8
	R2	**38.2**	23.5
	R3	**35.5**	24.1
	Average	18.8	24.1

Annex 05 : Morphological characteristics

Treatment	Repetition	Branching Number	Panicle length (cm)	Panicle diameter (cm)	Rdt grain q/ha	Biomass g/m2
PP	**R1**	**18**	**44**	**12**	**22.2**	**685**
	R2	**15**	**45**	**14**	**19.6**	**648**
	R3	**19**	**53**	**13**	**20.1**	**710**
	Average	**17.3**	**47.3**	**13**	**20.6**	**681**
NP	**R1**	**12**	**39**	**08**	**12.2**	**435**
	R2	**10**	**41**	**10**	**14.5**	**502**
	R3	**13**	**36**	**09**	**14.2**	**488**
	Average	**11.6**	**38.6**	**9**	**13.6**	**475**

Annex 06 : Weight of Mille Grain (PMG) in g

Repetition	Weight of Mille Grain g			
Plot	R1	R2	R3	Average
Scheduling plot	3.86	3.79	3.62	3.75
Non-scheduling plot	2.48	2.67	2.88	2.67

Annex 07 : water and soil analyses

BEFORE SOWING 22/10/2023

NON-SCHEDULING PLOT

SAMPLE	DEPTH	EC (ds/m)		pH		RALATIVE HUMIDITY (%)	
NP	0-30	3.51	3.24	7.25	7.57	21.56	22.37
		3.12		7.62		22.63	
		3.09		7.84		22.92	

SCHEDULING PLOT

SAMPLE	DEPTH	EC (ds/m)		pH		RELATIVE HUMIDITY (%)	
PP	0-30	3.16	3.20	7.33	7.49	22.01	21.97
		3.22		7.51		21.89	
		3.24		7.65		22.02	

SIX LEAVES 14/01/2024

NON-SCHEDULING PLOT

SAMPLE	DEPTH	EC (ds/m)		pH		RELATIVE HUMIDITY (%)	
NP	0-30	3.17	3.21	7.22	7.25	21.45	21.53
		3.24		7.28		21.54	
		3.22		7.25		21.62	

SCHEDULING PLOT

SAMPLE	DEPTH	EC (ds/m)		pH		RELATIVE HUMIDITY (%)	
PP	0-30	2.97	2.90	6.99	7.15	22.22	22.08
		2.87		7.25		21.89	
		2.88		7.22		22.13	

PANICLE 21/02/2024

NON-SCHEDULING PLOT

SAMPLE	DEPTH	EC (ds/m)		PH		RELATIVE HUMIDITY (%)	
NP	0-30	2.47	2.50	7.48	7.56	22.7	22.5
		2.54		7.46		21.8	
		2.49		7.74		23.0	

SCHEDULING PLOT

SAMPLE	DEPTH	EC (ds/m)		PH		RELATIVE HUMIDITY (%)	
PP	0-30	2.70	2.73	7.02	6.75	22.6	22.8
		2.74		6.84		22.7	
		2.71		6.39		22.9	

Annex 08 : PHYSICO-CHEMICAL CHARACTERISTICS OF THE SOIL

	RELATIVE HUMIDITY (%)			pH			SALINITY (ds/m)		
	HUMIDITY BEFORE SOWING	HUMIDITY SIX LEAVES	HUMIDITY FLOWERING	pH BEFORE SOWING	pH SIX LEAVES	pH FLOWERING	SALINITY BEFORE SOWING	SALINITY SIX LEAVES	SALINITY FLOWERING
PP	22.01	22.22	22.6	7.33	6.99	7.02	3.16	2.97	2.70
PP	21.89	21.89	22.7	7.51	7.25	6.84	3.22	2.87	2.74
PP	22.02	22.13	22.9	7.65	7.22	6.39	3.24	2.88	2.71
NP	21.56	21.45	22.7	7.25	7.22	7.48	3.51	3.17	2.47
NP	22.63	21.54	21.8	7.62	7.28	7.46	3.12	3.24	2.54
NP	22.92	21.62	23.0	7.84	7.25	7.74	3.09	3.22	2.49

Annex 09 : Physico-chemical analysis of the Soil **(October 22, 2023)**

Sample	**Deep**	**EC (ds/m)**		**Ph**		**Humidity relative %**	
Ground	**0-30**	3.51	**03.24**	7.25	**07.57**	21.56	**22.37**
		3.12		7.62		22.63	
		3.09		7.84		22.92	
	30-60	3.22	**03.36**	7.44	**07.53**	23.01	**22.74**
		3.43		7.65		22.11	
		3.43		7.50		23.10	

Annex 10: Soil grain size

Sample	**Coarse sand (%)**	**Fine sand (%)**	**Silt + Clay (%)**	**Texture of the ground**
01	**59.96**	**36.73**	03.31	**Sandy soil**
02	**81.14**	**08.89**	09.97	
03	**89.64**	**05.85**	04.51	
Average	**76.91**	**17.15**	05.94	**Sandy soil**

Annex 11 : Plant characteristics

	PLANT HEIGHT			**ROOT LENGTH**		**Branching**	**PMG**	**Yield**	**BIOMASS**
	HEIGHT SIX LEAVES	**BRANCH HEIGHT**	**HEIGHT Flowering**	**BRANCH LENGTH**	**FLOWERING LENGTH**	**Branching number**	**Poids Mille Grains (G)**	**RDT GRAIN Q/HA**	**BIOMASS G/M2**
PP	**27.1**	**44.7**	**82.1**	**24.1**	**31.2**	**18**	**3.86**	**22.2**	**685**
PP	**25.7**	**44.9**	**80.4**	**22.8**	**33.0**	**15**	**3.79**	**19.6**	**648**
PP	**26.4**	**50.2**	**84.3**	**22.5**	**33.7**	**19**	**3.62**	**20.1**	**710**
NP	**24.7**	**33.4**	**64.2**	**18.9**	**24.8**	**12**	**2.48**	**12.2**	**435**
NP	**24.5**	**38.2**	**63.3**	**19.2**	**23.5**	**10**	**2.67**	**14.5**	**502**
NP	**17.1**	**35.5**	**64.1**	**18.4**	**24.1**	**13**	**2.88**	**14.2**	**488**

Annex12 : The cultural coefficient of quinoa cultivation

Stade de croissance	**Kc initial**	**végétatif**	**Mi- saison**	**Fin de saison**
Kc	0,52	Dynamique	1.00	0.70

الملخص

صنف) على نمو وإنتاج وإنتاجية مياه الري لزراعة الكينوا Acsad ITDA تهدف دراستنا إلى رؤية تطبيق أسلوب الإدارة من قبل برنامج
في الظروف المالحة في منطقة عين بناوي بسكرة. في قطعتين إحداهما مزروعة بالبرنامج والأخرى مروية بدون تجريب (Giza1

أظهرت نتائج هذه الدراسة وجود فرق معنوي في النمو الخضري: ارتفاع أطوال جذور النباتات وكذلك عدد الأفرع في قطعة الأرض
12.2 غرام PMG 3.86 المسيطرة مقارنة باسم قطعة الأرض المسيطر عليها بالإضافة إلى تحسين إنتاجية الحبوب المعنوية 22.2 ق/هك، و
ف/هك و وزن 1000 حبة

2.48 غرام على التوالي في قطعة الأرض الخاضعة للرقابة وغير المدارة بمتوسط فرق قدره 10 ق/هك، و 1.38. وبلغت كمية المياه المقدمة
م3 /هك في القطعة التي يديرها البرنامج: 3851.6 م3/هك مقابل 4267.3 م3/هك في القطعة غير المرشدة، بفارق 415.7

وستوفر النتائج التي تم الحصول عليها معلومات قيمة للمزارعين ومديري المياه لتحسين إدارة ري الكينوا، وبالتالي المساهمة في زراعة أكثر استدامة وكفاءة.

الكلمات المفتاحية: *الكينوا*، الجرعة، الإدارة، المحصول، بسكرة

.Résumé

Notre étude vise à voir l'application d'u méthode de pilotage par un programme Acsad ITDA sur la croissance, la production ainsi la productivité de l'eau d'irrigation pour une culture du *quinoa* (variété Giza1) en conditions salines dans la région d'AIN BENAOUI Biskra. Dans deux parcelles une piloté par le programme et l'autre irrigué sans pilotage. Les résultats de cette étude a montrée une différence significative sur la croissance végétative : hauteur des plants longueurs de racines aussi le nombre de ramifications dans la parcelle piloté comparativement a la parcelle nom piloté ainsi un meilleures rendements de grain significatif : 22,2 q/ha et 12,2 q/ha, et PMG 3, 86gr et 2.48 g Respectivement sur la parcelle piloté et non piloté avec un écart moyen de 10 q/ha, et 1,38 . La quantités de l'eau donné dans la parcelle piloté par le programme est de : 3851,6 m3/ha contre 4267,3 m3/ha la parcelle non piloté, avec un écart de 415,7 m3/ha.

Les résultats obtenus fourniront des informations précieuses aux agriculteurs et aux gestionnaires de l'eau pour une meilleure gestion de l'irrigation du quinoa, contribuant ainsi à une agriculture plus durable et plus efficace.

Mot clés : *Quinoa*, dose, Pilotage, Rendement, salinité, Biskra

Abstract

_Our study aims to see the application of a scheduling method by an Acsad ITDA program on the growth, production and productivity of irrigation water for growing *quinoa* (Giza1 variety) in saline conditions in the region. of AIN BENAOUI Biskra. In two plots, one planted by the program and the other irrigated without scheduling. The results of this study showed a significant difference in vegetative growth: height of plant root lengths as well as the number of branches in the scheduling plot compared to the plot non-scheduling, as well as better yields of significant grain: 22.2 q/ha and 12.2 q/ha, and PMG 3.86gr and 2.48 g Respectively on the scheduling and non-scheduling plot with an average difference of 10 q/ha, and 1.38. The quantity of water given in the scheduling plot by the program is : 3851.6 m3/ha compared to 4267.3 m3/ha in the non-scheduling plot, with a difference of 415.7 m3/ha.

The results obtained will provide valuable information to farmers and water managers for better irrigation management of quinoa, thus contributing to more sustainable and efficient agriculture.

Key words: *Quinoa*, amount, Scheduling, Yield, salinity, Biskra