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BY: BEN MATOUG SOULAF / BARKAT IMANE

Title

Agronomic evaluation of five quinoa varieties (*Chenopodium quinoa* Willd.) in the Bordj Bou Arreridj region .

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الاهداء:

من قال انا لها "نالها"
وان ابت رغما عنها اتيت بيها ,نلتها و عانقت اليوم مجدا عظيما
فعلتها بعد انا كانت مستحيلة. كانت دروبا قاسية وطرقا خسرت بها
الكثير ولكني "وصلت".
الحمدالله حبا وشكرا وامتنانا. ماكنت لافعل هذا لولا فضل الله
فالحمدلله على البدء وعلى الختام.
....

(وٌآخِر دِعٌوٌآهّمً آنِ آلَحًمًدِلَلَهّ ربً آلَعٌآلَمًيَنِ)

اهدي ثمرة جهدي ودراستي الى فرحتي الدائمة الى مصدر قوتي فخري لطالما عاهدتها بهذا النجاح وها انا اتممت وعدي واهدتيها اليك (ماما الغالية **زعبار حبيبة**) لكِ كل الفخر والعرفان، فهذا الإنجاز ثمرة تعبكِ وصبركِ معي. أدعو الله أن يرزقكِ السعادة والفخر الدائم بي كما أسعدتني طوال عمري.

الى العزيز الذي حملت اسمه فخرا, وبكل اعتزاز انا لهذا الرجل ابنة الى من كلله الله بالهيبة و الوقار (بابا الغالي بركات يوسف).

والى ملهمي نجاحي صناع قوتي صفوة ايامي سلوة اوقاتي الى الشموع التي تنير لي الطريق دوما إخوتي (**سليمان، عبدرزاق، ياسين، صابر، سماح، فاطمة**) .

والى من مدت يديها في اوقات الضعف وراهنت على نجاحي وتذكرني بمدى قوتي واستطاعتي اختي التي لم تلدها امي ورفيقتي (**بن معتوق سولاف).**

أهدي هذا النجاح والإنجاز إلى نفسي، على كل لحظة صبر واجتهاد وقوة، لكل تحدٍ تخطّيته، ولكل حلم حلمته واستطعت الوصول إليه. إلى نفسي التي لم تستسلم رغم الصعاب، وعلى ما بذلته من جهد وعطاء.

بركات
ايمان

2025

الاهداء

(وَآخِرُ دَعْوَاهُمْ أَنِ الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ)
حمدلله الذي ماتمّ جُهد ولا ختم سعي إلا بفضله تعالى .

اهدي تخرجي

الى أعظم رجل، إلى من زين اسمي بأجمل الألقاب من دعمني بلا حدود اعطاني بلا مقابل من علمني ان الدنيا كفاح و سلاحها العلم و المعرفة إلى فخري واعتزازي أبي العزيز (بن معتوق موسى) أسأل الله أن يحفظك لي دائمًا، وأن يجعلني مصدر فخر لك كما كنت دائمًا مصدر فخر لي.

الى من جعل الجنة تحت اقدامها، إلى أعظم قلب، وأحنّ روح، إلى السند الدائم، والنور الذي أضاء دربي و الصوت الذي شجعني في لحظات الضعف، والحضن الذي احتواني في لحظات التعب امي الحبيبة (حماش م) ، وأرجو أن أكون دائمًا مصدر فخر لك.

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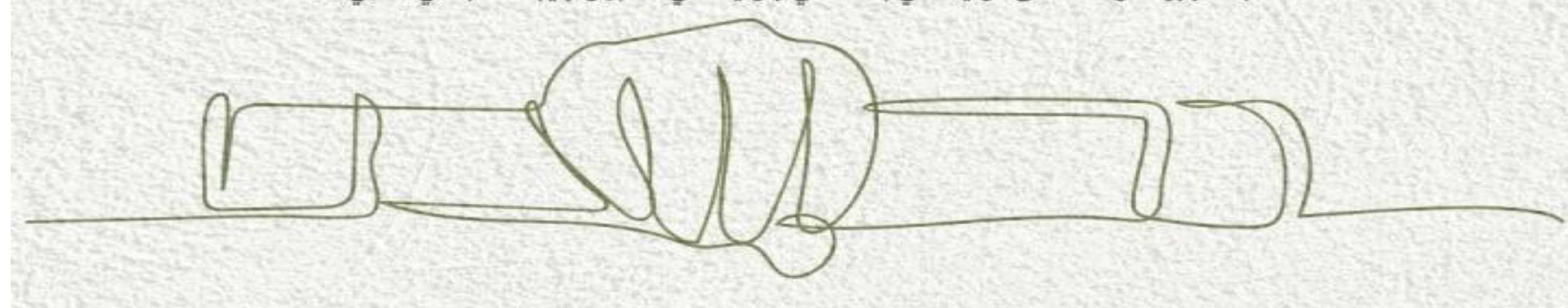

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Thanks to all of you, we have learned that generosity and guidance are the keys to excellence, and we hold you in the highest esteem and appreciation.

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List of abbreviations

%: Percent

m^2: Square meter

°C: Degrees Celsius

ANOVA: Analysis of variance

Avg: Average

B: Block

Cm: Centimeter

D: Day

FAO: Food and Agriculture Organization

G: Gram

ha: Hectare

ITDAS: Technical Institue for the Development of Saharan Agronomy

WHO: World Health Organization

Kg: Kilogram

L: Litre

m: Meter

mm: Millimeter

PMG: Weight a thousand grains

Q1: Amarilla Sacaca

Q2: CQ57

Q3: REGALONA

Q4: UDEL ll

Q5: TITICACA

q: Quintaux

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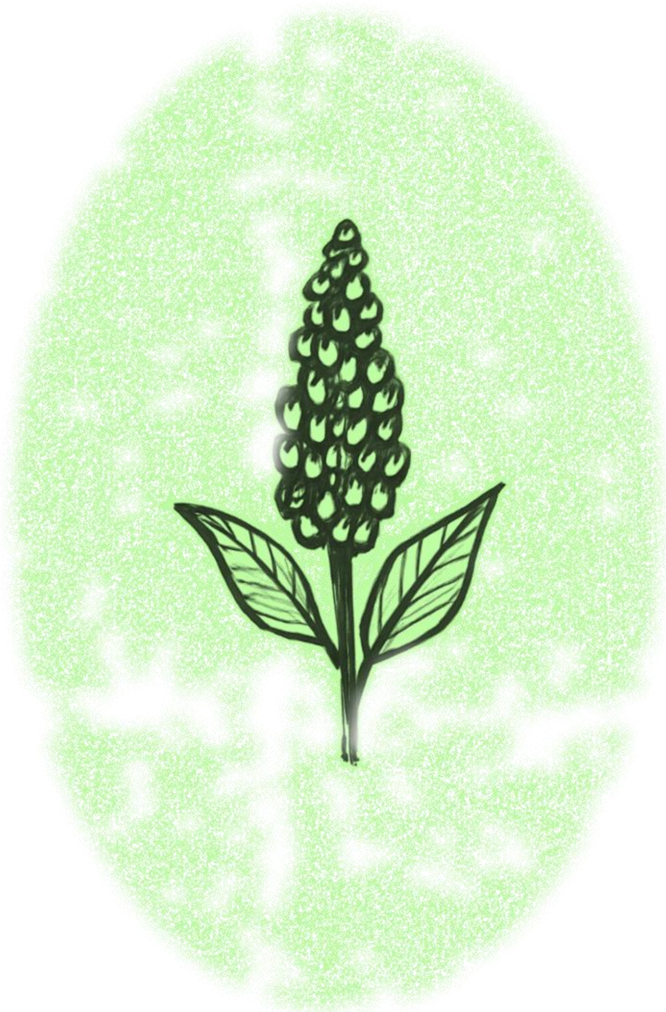


General introdcution

General Introduction

Quinoa (*Chenopodium quinoa* Willd.) belongs to the Amaranthaceae family and grows as an annual herbaceous plant. It originated in the Andes of South America and was domesticated by Aboriginal peoples over thousands of years **(LEDRA Ahmed Dia, 2020)**.Its morphology, color, and behavior vary depending on the agro-ecological zone where it is grown. It has been used as a food since time immemorial, with domestication estimated to occur around 7,000 BC. It is highly adaptable to various environmental conditions. It is grown from sea level to 4,000 m high altitude, from desert to humid and tropical places, from cold temperate to warm; particularly tolerant of adverse abiotic variables such as drought, frost, soil salinity, and others that affect crops **(Adjal Izdihar, 2020)**.

It's a pseudo cereal with an excellent combination of carbohydrates, fat, and protein. Several investigations on inheritance, molecular cytology, DNA markers, and single locus variability have indicated that it is an allotetraploid ($2n = 4x = 36$). It has been farmed for five millennia in the Andes, where it most likely evolved from wild and weedy species. The domestication process resulted in the elimination of numerous characteristics that were detrimental to farmers, resulting in a narrower genetic base. However, there is still significant variability in terms of plant color, seed color, branching and panicle kinds, productivity, abiotic stress tolerance, and disease resistance. This variety is also mirrored at the molecular level, and plant breeders around the world use it to generate improved plant types in terms of uniformity, early maturity, seed yield, protein content, and reduced saponin content in see**(Bhargava & Ohri, 2016)**

Where quinoa's genetic progenitors originated in North America, but quinoa production and the culture that evolved alongside its cultivation and use are known to have been shared by ancient South American peoples **(Martínez, Fuentes et *al.*, 2015)** .

Worldwide Quinoa covers an area of around 99,313 acres, and production in 2010 was 78,025 tons **(LATRECHE, 2020);** Bolivia, Peru, Ecuador, and the United States are the world's top quinoa producers. In 2013, quinoa agriculture covered over 75,000 hectares in Bolivia and more than 45,000 hectares in Peru. These two countries remain the top producers in the Andes and worldwide. Quinoa cultivation has spread to other nations, including Tibet, Morocco, France, India, China, the United Kingdom, Sweden, Denmark, the Netherlands, and Italy **(Bazile, Biaggi, & Jara, 2022).**

In Africa, incorporating quinoa into the diet has the potential to improve food and nutritional security. Because of its remarkable nutritional characteristics and adaptability, the FAO chose quinoa as one of many promising crops with the potential to guarantee food security in the next century. Quinoa was introduced to Africa in the late 1990s in Kenya, and more recently in Malawi in 2012. The original breeding experiments sought to identify quinoa cultivars and types capable of growing well and yielding grain for African communities to produce and consume **(Maliro & Guwela, 2015)** .

In 2009 , were planted 83 thousand hectares of quinoa, yielding 69 000 tons of grain with an average yield of 0.8 tons per hectare**(Anonyme, 2012).**

According to (Khaled Halima, 2020) quinoa arrived in Algeria at the end of 2013 and beginning of 2014 **(BELLOUATI et *al*., 2024)**.

It is grown experimentally to investigate its behavior and production potential in eight sites across four universities with varying agro-ecological parameters. Recognized in Algeria and neighboring nations where repeated droughts, pests, and crop diseases have devastated the economy, particularly the agricultural sector , and it is growing in Algeria has the potential to provide significant growth opportunities. Indeed, the attraction of this plant stems from its ability to survive extreme climatic circumstances (drought, soil poverty, salt), making it highly efficient in combatting desertification while producing acceptable returns **(LEDRA Ahmed Dia, 2020)**.

Quinoa is a dicotyledonous angiosperm plant from the Chenopodiaceae family. Since 2009, quinoa has been classified into the Amaranthaceae family using a new phylogenetic (APG III) system **(Adjal Izdihar, 2020)**.

Early quinoa classifications considered the color of the plant and fruit, as well as the form and flavor of the grains. One of the initial classifications described four quinoa species: Chenopodium album has soft grains. Chenopodium pallidus has bitter grains. Chenopodium ruber has scarlet grains. Chenopodium niger has black grains**(TEBRI, 2020).**

The high genetic diversity of quinoa ecotypes made it possible to yield quality grains at soil pH levels of 4.5-9.5>, different annual rainfall 200-2000 mm, and very low temperatures during blooming and grain-filling times, with illnesses, insect epidemics, and other negative management methods. The discovery of quinoa's usefulness since the 1980s has substantially raised demand and interest from other countries in growing this plant on marginal soils **(Gomez-Pando et *al.*, 2019).**

Its morphology is distinguished by various different characteristics, quinoa has a pivotal root system that is vigorous, deep, well-branched and fibrous, which may provide drought resistance and plant stability. During germination, the first thing that begins to grow is the radicle. She grows and leads to the root, reaching a depth of 1.80 cm in dry conditions. According to **(LEDRA Ahmed Dia, 2020)**, the depth of roots is closely related to the height of the plant.

Its stem is cylindrical, except for branches where it is angular due to the alternation of the leaves, resulting in an unusual arrangement. The thickness of the stem is also varies, with the base being than the top. This is mainly determined by genotype, plant density and nutrient availability. The color of the stem varies from green to red. Stem diameter varies by genotype, planting distance, fertilization and growing conditions, ranging from 1 to 8 cm **(Berdji & Bouaka, 2023)**.

Where branches grow from the base of each on the stem. Their length varies depending on the variety and environmental conditions, ranging from a few centimeters to the length of the main stem **(Jacobsen & Stølen, 1993)**. Some quinoa genotypes are highly ramified (e.g, quinoa from valleys), whereas others have distinct characteristics (e.g., quinoa from high plains). There are also intermediate genotypes**(Mujica & Jacobsen, 2006)**.

That plant's leaves are very polymorphic, with large basal leaves that might be rhomboidal or triangular. According to Del Castillo et al. (2008), the alternate leaves have lance-shaped, triangle-shaped, flat, or oval, charnu, and tender limbs. The leaves have serratedt on the edges. The color of leaves can range from green to red, yellow, and violet, depending on the nature and importance of pigments**(LEDRA Ahmed Dia, 2020).**

Also the inflorescence is a typical panicle, meaning it is made up of a primary axis from which secondary and tertiary axes emerge. Two forms of inflorescences have been described in quinoa: glomerular and amaranth form.

All members of the chenopodiaceous family, including the genus chenopodium, have incomplete, sessle, and petal-deprived flowers. One significant feature of quinoa is the presence of hermaphrodit flowers located at the proximal extremity and unisexuated female flowers located at the distant extremity of a group.

The fruits of quinoa is derived from a dorso-ventral symmetry and a supero-ocular ovary. Cylindric-lenticular, slightly angled toward the center, in the ventral region of the akene, observe a scar that is the fruit's inserton into the flower container, it is made up of perigonium that completely envelops the grain and contains a single grain, varying in color, with a diameter of 1.5 to 4 mm, which separates readily as it maturity and in some cases can remain attached to the grain even after threshing, making it difficult to select, the moisture content of the fruit at harvest is 14.5%.

The graines of the plant's edible parts can be in three shapes: conical, cylindrical, or ellipsoidal. Saponin residues (an anti-nutritional compound) that are bitter and naturallu repel birds are eliminated by washing , there are three clearly defined parts: episperm, embryo, and perisperm . the periphytic embryo surrounds the core perisperm (reservoir tissue) and is covered by the pericarp and two tegumentary layers. The grains are smooth or have a smooth leather finish, with colors ranging from white, yellow, red, violet, and maroon to black , quinoa's pericarp contains saponins, which contribute to its savory flavor. The primary tissue the grain storage organ is the perisperm**(LEDRA Ahmed Dia, 2020)** .

Plants and animals have particular requirements that determine their geographical spread.

According to Kabalan and Beridi (2016), the best temperature for quinoa development is between +4°C and 35°C. The plant becomes sensitive to low temperatures (less than 0°C) at stages 2 and 6 leaves, and high temperatures (+35°C) at flowering stage **(TEBRI, 2020)** .

According to Zaki (2015), quinoa requires one-third the amount of water that wheat does. Quinoa is a drought-tolerant plant, thus it does not require a lot of water **(ITDAS, 2017).**

the quinoa plant possesses a physiological mechanism to tolerate and withstand drought **(HADJ HAMMOU, 2019)**.

Quinoa is a plant that can grow in a variety of conditions, including desert, hot and dry, cold and dry, temperate to high humidity; there are variants that adapt to each temperature, and its favors well-drained, light soils rich in organic matter, although it can also thrive in poor and saline soils with a pH ranging from 4.8 to 8.5 **(HADJ HAMMOU, 2019)**.

For the nutrients are added as follows: Nitrogen 10kg per 500m2 or 02 q/ha divided into three inputs; At the stage two true leaves ;At the branching stage ; At the stage milky grain ; Phosphorus (TSP) 10 kg per 500 m^2 or 02 q/ha ; Potassium (potassium sulphate) 05 kg per 500 m^2 or 01 q/ha **(HADJ HAMMOU, 2019)**.

It is harvested manually or mechanically using a wheat harvester with a few changes. By ploughing or cutting according to soil conditions, the pre-drying harvest allows up to 12% moisture to dry**(HADJ HAMMOU, 2019)**.

Quinoa has multiple applications, including food, feed, medicine, and industry. Quinoa seeds can be eaten as rice or ground into flour to make bread. They were prepared and put to soups by the Andeans, where they were cooked like cereal in the form of pates . They may be fermented into beer . The leaves are eaten as cooked or salad spinach . Quinoa is now available in stores in various form such as juice, soup, bread, cereals, pasta, biscuits, and baby formulae. In 2015, Burkina Faso's institute for Applied Sciences and Technologies (IRSAT) turned quinoa seeds into native dishes such as gnongon, dégué, biscuits, pancakes, and couscous, also the plant can be utilized as green fodder for animals, and the harvest residues are highly nutritious for cattle, sheep, and poultry **(RIDA & MERIOUMA, 2023)**.

Andeans have historically employed quinoa leaves, stems, and grains for therapeutic uses, such as wound healing , edema reduction, toothache relief, and urinary canal disinfection. The plant can be utilized as an antibiotic or to make cancer vaccines.

Quinoa has enemies (animal, plant, or virus) that may feed on crops, either directly or indirectly . Mildew, produced by Peronospora farinose, is a major fungal disease that affects quinoa. Excess moisture stimulates its growth . Use of Bouille bordelaise is a form of struggle**(HADJ HAMMOU, 2019)**.

Quinoa pests, including woodlice, aphids, and sparrows, can cause significant damage, particularly at late sowing . The larval stage of the *Eurysacca melanocampta* to the FAO (2011), the employment of bio-pesticides and natural methods is considered the control average**(HADJ HAMMOU, 2019)**.

Quinoa has numerous water stress resistance mechanisms, drought is a major limiting factor for grain yiled, despite the fact that moderate early-cycle droughts can have a positive hardening effect on plants . Drought resistance encompasses many morphological, anatomical, phenological, and biochemical systems. The salar region of southem Altiplano, Bolivia, is the world's greatest quinoa production area, with soils heavy in salts, particularly sodium chloride **(Del Castillo et *al.*, 2008).**

Quinoa can handle salt in the soil. Seeds of salt-tolerant genotypes germnat at more than 75% six to seven days after seeding at saline concentrations of 0.6 M Nacl (57mS. Cm-1), indicating that the salt does not kill the embryo but rather delays there are significant physiological variances in salt tolerance amongst cultivars. The majority of them produce more under moderately saline than non-saline circumstances, making quinoa an optional halophyte . Resistance against illnesses, parasites, and pests the high saponin content of the seed in most kinds of quinoa makes it less susceptible to bird or pest attacks because of its bitter taste and toxicity to tiny animals **(Del Castillo et *al.*, 2008)** .

With Altiplanic quinoas, I was able to differentiate ten obviously distinguishable morpho-anatomical stages, which are as follows: Emergence defined as the appearance of a little seedling on the soil surface, extending its two cotyledonary leaves, which varies depending on the seed's storage time and variety; hence, the time required after germination till the emergence of the cotyledons ranges between 5 and 8 days, then two true leaves is the stage after emergence when, addition to the cotyldonary leaves, two true leaves appear stretched in a rhomboidal shape, with the next pair of leaves in bud form; this occurs 10 to 15 days afters sowing ,then comes a stage of Four leaves, 18 to 25 days after sowing. The previously visible prophylls will become the appendages, or future shoots that begin to differentiate. This stage concludes with the complete growth of the leaves and the formation of sixth pair of alternate leaves , followed by a six-leaf stage (panicle differentiation); during this stage, the apical meristematic tissue transitions from the vegetative to the reproductive stage, that is, from the process of forming only leaf primordial (growth) to the process of forming both leaf and reproductive primordia (growth and developement). This period lasts between 22 and 30 days.

Branching from the eighth leaf stage (25-39 days after the semis), varieties with axillary bourgeons can be identified until the third knot. The jaunty cotyledonary leaves fall and leave a scar on the stem. The inflorescence is not yet visible as it is covered by leaves **(ATIA, 2020)** .

Start of panicle formation at the end of 46-50 days, the inflorescence appears at the plant's apex, surrounded by a cluster of little leaves that partially cover it. Similarly, the first pair of true leaves is no longer photosynthetically active. The stem grows in length and diameter . Then, Panicle emergence stage, characterized by floret budding up to pre-flowering, during this stage, which lasts between 50 and 59 days, no flowers open. The budding of the floret (inflorescence), which consists of a large number of panicles, resembles an acorn with the cusp pointing upward. After that flowering begins when the apical hermaphrodite flower opens, revealing the divided stamens, this usually happens between 59 and 68 days. This phase is extremely vulnerable to a lack of water and frost. The beginning of blooming and flowering are critical and high-risk events in grain production.

Moreover ,flowering is the stage of highest longitudinal growth; the flowering stage is defined as 50% of the flowers in the primary panicle population being in bloom. The duration varies depending on environmental conditions, although it typically ranges between 78 and 80 days from the first to the last flower in the panicle.

Subsequently , Milky grain is the stage that occurs after fertilization; in the flower's ovule, a receptacle develops from which a milky liquid can be extracted with light pressure off the fingers. At this point, longitudinal growth is predominantly driven by upper-third elongation. This happens between 83 and 106 day .Next , pasty grain refers to the stage between 91 and 127 days when the perispermic tissue transitions from a milky to a semi-solid pasty form. It is a change that occurs when the starch content increases and the water content decreases.

Finlly, Physiological maturity occurs when the fruit resists penetration when pressed with the fingernails, indicating that thee starchy components of the perisperm have consolidated, reducing the water content to 15-20%.

Similarly, the plants exhibit yellowing leaves and slow defoliation, which happens between 116 and 182 days **(Derradji, 2020)**.

Our work objective mainly consists of observing the behavior of five genotypes and measuring their growth and production under the agroecological conditions of the Bordj Bou Arreridj region.

That is why we formulated these questions:

- ✓ What is the optimal genotype concerning morphological traits?
- ✓ What is the most productive genotype in terms of yield?
- ✓ Which genotypes are best suited to environmental conditions?

We hypothesize that long-cycle varieties will have better yields, but that short-cycle varieties will be more resilient to end-of-cycle water stress.

To tackle this topic in the Bordj Bou Arreridj province, our work is arranged into the following chapters:

Introduction.

Chapter 1: Presentation of the Study Region.

Chapter 2: Materials and Methods.

Chapter 3: Results and Discussion.

Conclusion.

Chapter I:

Presentation of Study Region

CHAPTER I: Presentation of the study region

I.1 Presentation of the province

I.1.1 Geographical location:

The province of Bordj Bou Arreridj covers an area of 3,920.42 Km^2.

Geographically, it is located between the latitude of 36°4°60° to the north and 4°45°0° to the east(**Saad et *al.*,2025**).

Located on the highest plateaus in the east of the country, it is limited and extend along the

Alger-Constantine axis and is bordered by the following province:

- To the north, the province of Bejaia.
- To the east, the province of Setif.
- To the west, the province of Bouira.
- To the south, the province of M'sila.

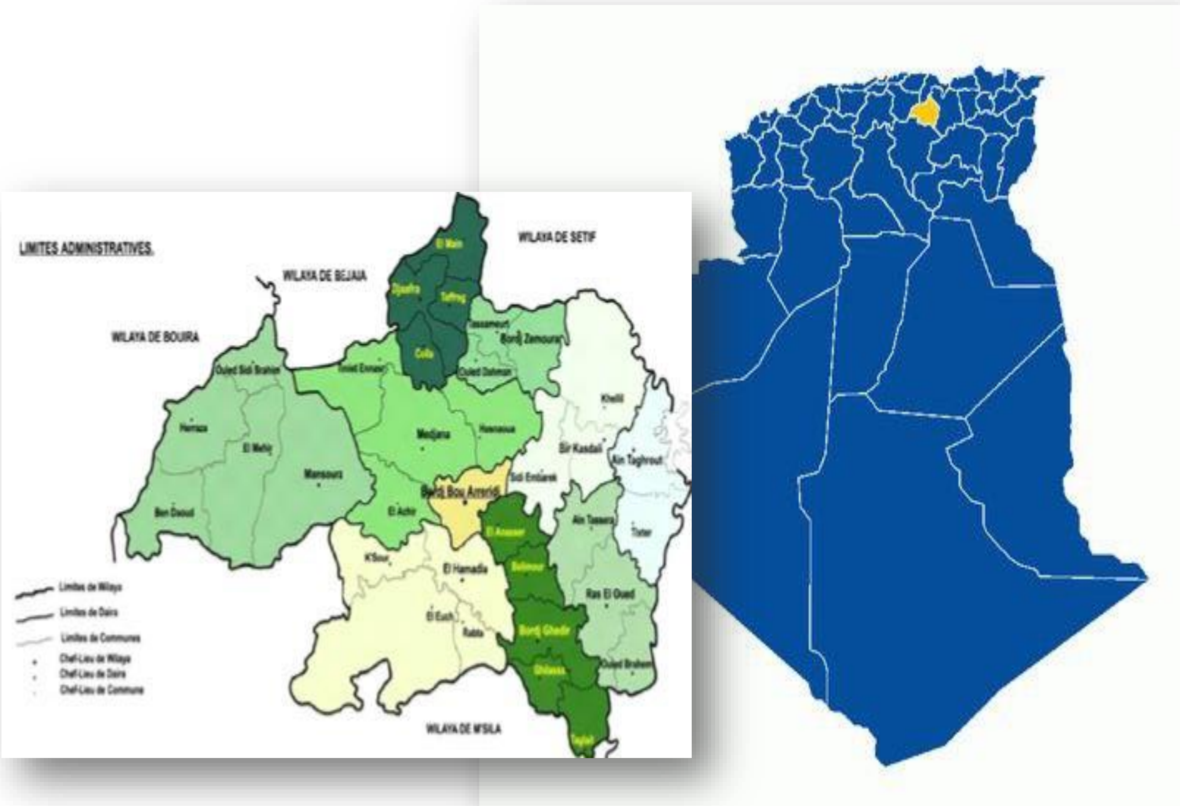


Figure 1:Geographical location of Bordj Bou Arreridj province(author's own adaptation).

Therefore, the province of Bordj Bou Arreridj stands out for its importance, being located northeast of Algiers at 243 km, west of Setif at 67 km and north of M'sila at 58 km. In addition, this locality is located 175 km from Bejaia and 100 km from Bouira to the east **(PDAU, 2021).**

According to Tennah and Saidat (2019), the wilaya is divided into three successive geographical zones:

- A mountainous region in the north (the Bibans mountain range).
- An area of high plateaus, which represents the majour part of province.
- A steppe zone located in the southwest, with an agropastoral vocation.

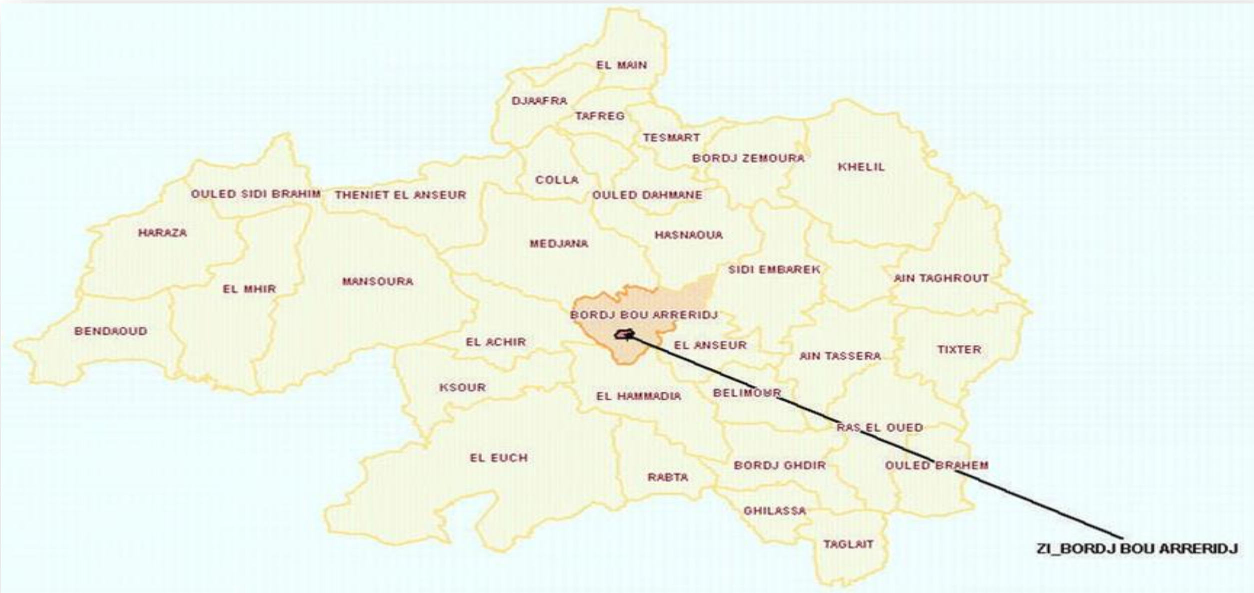


Figure 2: Administrative boundaries of the Bordj Bou Arreridj province.

Geographical delineation for each region:

- **Mountainous Zone:** the mountainous area in the northwest, which is an extension of the medjana mountains in the form of hills and mounds, At 1499 m, Djbel Morissane is the highest point. It is a homogeneous mountain range that overlooks the high plains with moderate and valleys surrounding it with steep slopes. Its topography is asymmetrical.

- **High Plains Zone:** It extends form the Ain Zada Dam in the east to the Bibans mountain range in the west. To the north, it is bordered by the heights of Teniet Ennasr and Bordj Zemoura, and to the south, by the Maadid mountains. The southerm part is relatively flat with a slight slope, forming a semi-enclosed basin with an average altitude ranging from 800 m to 900 m.

- **Steppe Zone:** The northeastm part of the province is characterrized by a range of hills named Draà, with altitudes ranging from 800 m to 1100 m. This range is intersected by many dry riverbeds and ravines, reflcting the ruggred nature of the terrain.

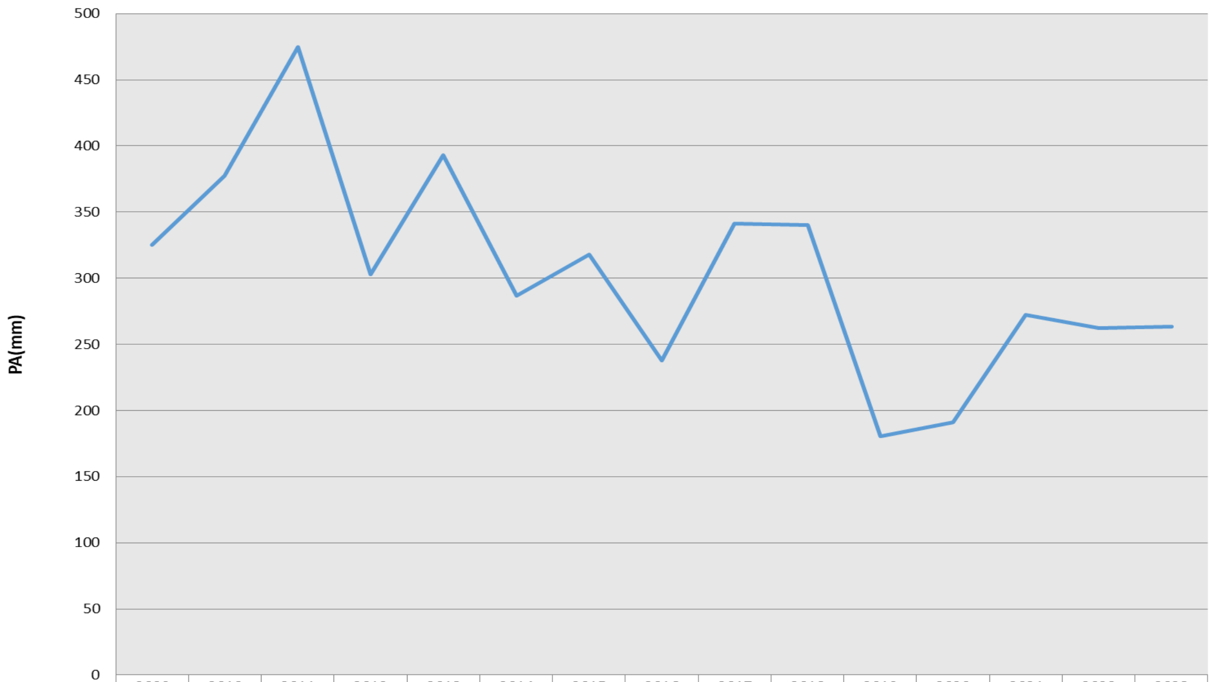
I.1.2 Climatology:

Climate is characterized by the interaction of several factors, including temperature, precipitation, humidity, winds and frost. In the Mediterranean region, climate is critical factor due to its institution, organizations and its importance in maintaining ecosystems. Its plays a vital role in the distribution and life of living beings .

Climate depends on many factors such as temperature, precipitation, humidity and wind. Temperature and precipitation are the most important factors of climate**(Saad et *al.*, 2025)**.

I.1.2.1 Rainfall:

Pluviometry is total amount of water measured by a rain gauge or a pluviograph. In includes all forms of meteorological water, such as rain, hail, etc..



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
PA (mm)	324.88	377.45	474.98	302.77	392.93	286.51	318.05	237.74	341.35	340.3	180.51	190.8	272	262.2	263.59

Figure 3: Evolution of precipitation during the period 2009-2023(**source: Tutiempo, 2024**).

The line graph illustrates a dataset from 2009 to 2023, illustrating the fluctuations in the values of PA (mm) over this period. The greatest recorded measurement is 474.98 (mm) in 2011, while the lowest value is close to 190 (mm) in 2020. Notably, there is a substantial decline following 2017, followed by a slight increase after 2020.

I.1.2.2 Temperature:

Temperature is the most significant factor in climate since it influences all metabolic processes (Dajoz, 2006). It like air humidity, characterized the soil and biotope microclimates **(Saad et *al.*, 2025)**.

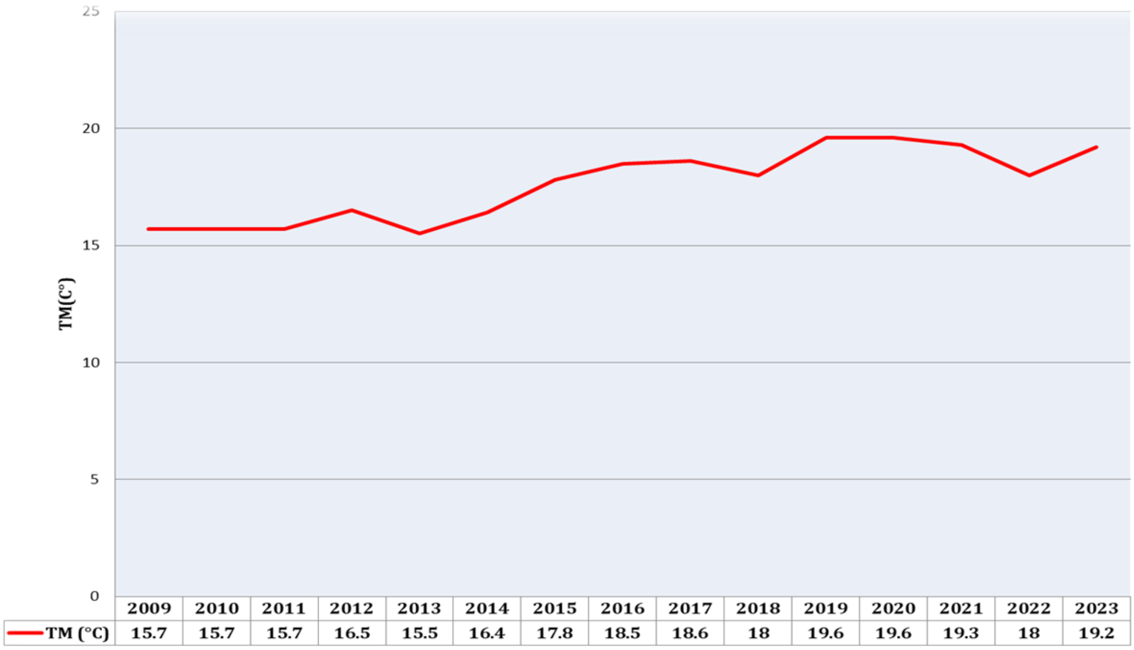


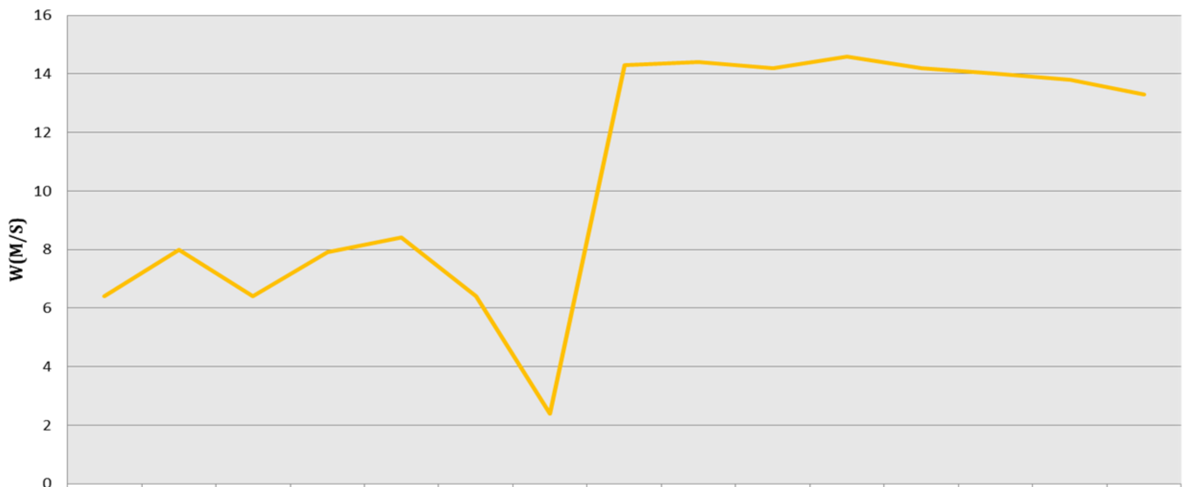
Figure 4: Evolution of the annual Mean temperature 2013-2023**(source: Tutiempo, 2024).**

The line graph of figure 4 illustrates the trend of temperature over several years from 2009 to 2023. Notably, There are slight fluctuations in temperature during this period. It began at 15.7 C° in 2009, reached its peak at 19.6 C° in 2020, and then slightly decreased to 19.2 C° in 2023.

I.1.2.3 Wind:

Wind is the movement of air in the atmosphere. It arises because of variations pressure and temperature. Air flows from the region of higher pressure, where it is colder, to the region of lower pressure differential between two places.

Air flows from high pressure to low pressure, to put it another way, The sun is the main cause of this phenomenon**(Saad et *al.*, 2025).**



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
W(M/S)	6.4	8	6.4	7.9	8.4	6.4	2.4	14.3	14.4	14.2	14.6	14.2	14	13.8	13.3

Figure 5: Evolution of winds during the period 2009-2023**(source: Tutiempo, 2024).**

The line graph of figure 5 displays the variability in values from 2009 to 2023. In 2009, the value was 6.4 (m/s), But decreased significantly to 2.4 (m/s) in 2015. However, there was a gradual uptick from 2015 to 2017, reaching roughly 14 (m/s). This increase suggests a stable trend since that year.

I.1.2.4 Humidity:

The amount of water vapor in the air (from water surfaces and living organism's transpiration) can vary greatly, it cannot exceed a certain maximum.

This maximum depends on the temperature. Most often, there is less water vapor in the air than these maximum quantities. The ratio between the amount of water vapor present in the air and the maximum amount it can hold at a given temperature is called relative humidity, expressed in %. Absolute humidity is also distinguished, measured in g/ m^3.

Table 1: The monthly and annual average humidity percentages (%)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
H (%)	76,79	70,9	64,54	60,06	54,42	45,01	38,47	42,9	56,28	61,93	71,77	76,6	59,81

Source: (ONM, 2023).

According to the table 1 , we can observe that the month of january has the highest humidity at 76.79%, While the lowest average monthly humidity is recorded during july with 38.47%. The annual average humidity in the study area is 59.81%.

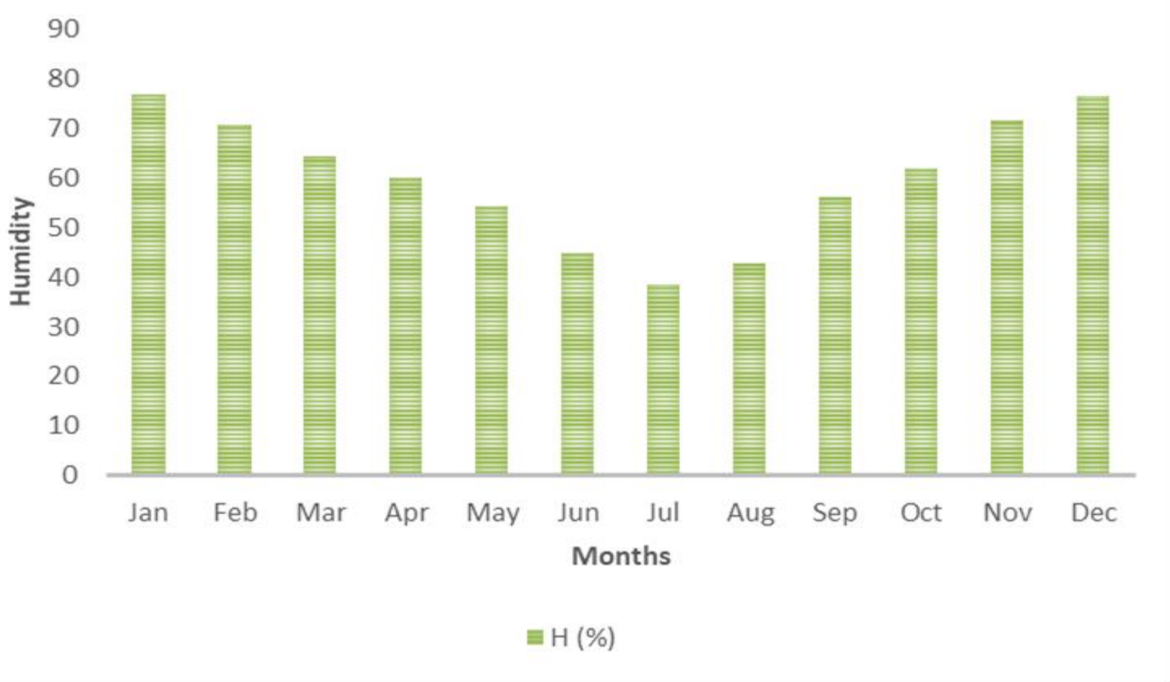


Figure 6: Variation in average monthly humidity at the Boumerdes station.

I.1.3 Ombrothermic diagram:

The compete thermal graph allows Bognouls and Gaussen (1954) to compute the duration of the dry season, which is highly influenced by vegetation and land use occupation. It takes into accounte the average monthly temperature plotted on axes with precipitation scaled twice as high as temperature (P = 2T), and intersection of these two curves indicates the drying period of the station .

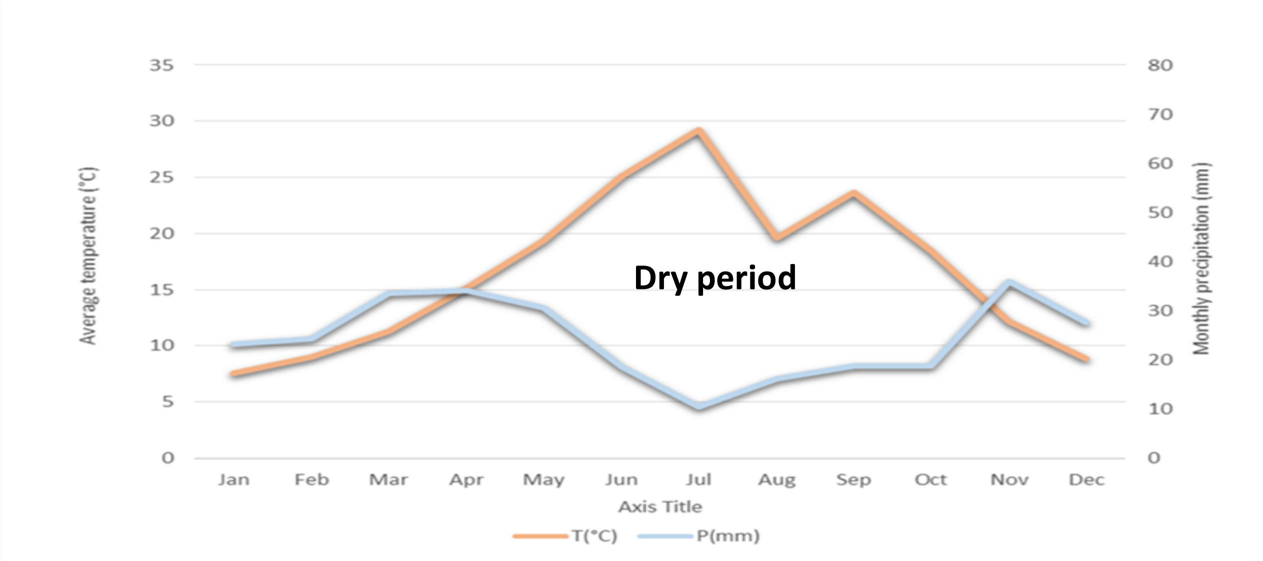


Figure 7: Ombrothermic diagram of the Bordj Bou Arreridj province (2014-2024).

According to the Ombrothermic diagram presented in Figure 07, the region of Bordj Bou Arreridj experiences a dry period, characterized by low precipitation and high temperatures, which extends from April to November, Therefore, irrigation is necessary, depending on the capabilities and objective of quinoa growers.

I.1.4 Pluviometric Quotient and climagram:

The climagram of EMBERGER allows for the determination of the bioclimatic level of a given station.

It is determined from the formula:

$$Q2 = \frac{2000\,P}{M^2 - m^2}$$

Of which:

Q2: The pluviometric quotient of EMBERGER

P: Annual precipitation (mm).

M: The maximum temperature of the hottest month in (C°).

m: The minimum temperature of the coldest month in (C°).

By applying the following formula developed by STEWART for Algeria and Morocco, namrly:

Q2= 3.34 (P/M-m) (Stewart, 1968).

Q2: The pluviometric quotient of EMBERGER.

P: Average annual rainfall in mm.

M: Average maximum temperature of the hottest month in (K= C° + 273.15).

m: Average minimum temperature of the coldest month in (K= C° + 273.15).

To determine the bioclimatic stage of our study area, we utillized sauvage's (1963) pluviometric and thermal Climagram,which combines two climatic indices.

The values of the quotient (Q2) are represented on the ordinate axis, while the values of minimum temperature (m) for the coldest month. This climagram includes five bioclimatic stages: **Saharan**,**Semi-aride**, **sub-humid**, and **humid**. The Bioclimatic Lithotope is determined using the Emberger Diagram.which divides it into lower, middle and higher substage and thermal variants based on (m).

The available data are:

T max (C°) = 29.27

T min (C°) = 9

P mean (mm) = 292.37

Calculation according to the Emberger diagram :

1. Calculation of the annual average temperature (T):

T = (T max + T min) / 2

T = (29.27 + 9) / 2

T = 19.14

2. Calculation of the Emberger dryness index (P/T):

P/T = 292.37 / 19.14

P/T = 15.28

3. Using the Emberger diagram, based on the P/T value of 15.28.

Therefore, according to the Embereger diagram, The Bioclimatic zone of this region is

Semi-arid.

Table 2: Value of the pluviometric quotient Q2

Region	P (mm)	M (K)	m (K)	Q2	The Bioclimatic zone
Bordj Bou Arreridj	292.37	302.42	282.15	49.34	Semi-arid

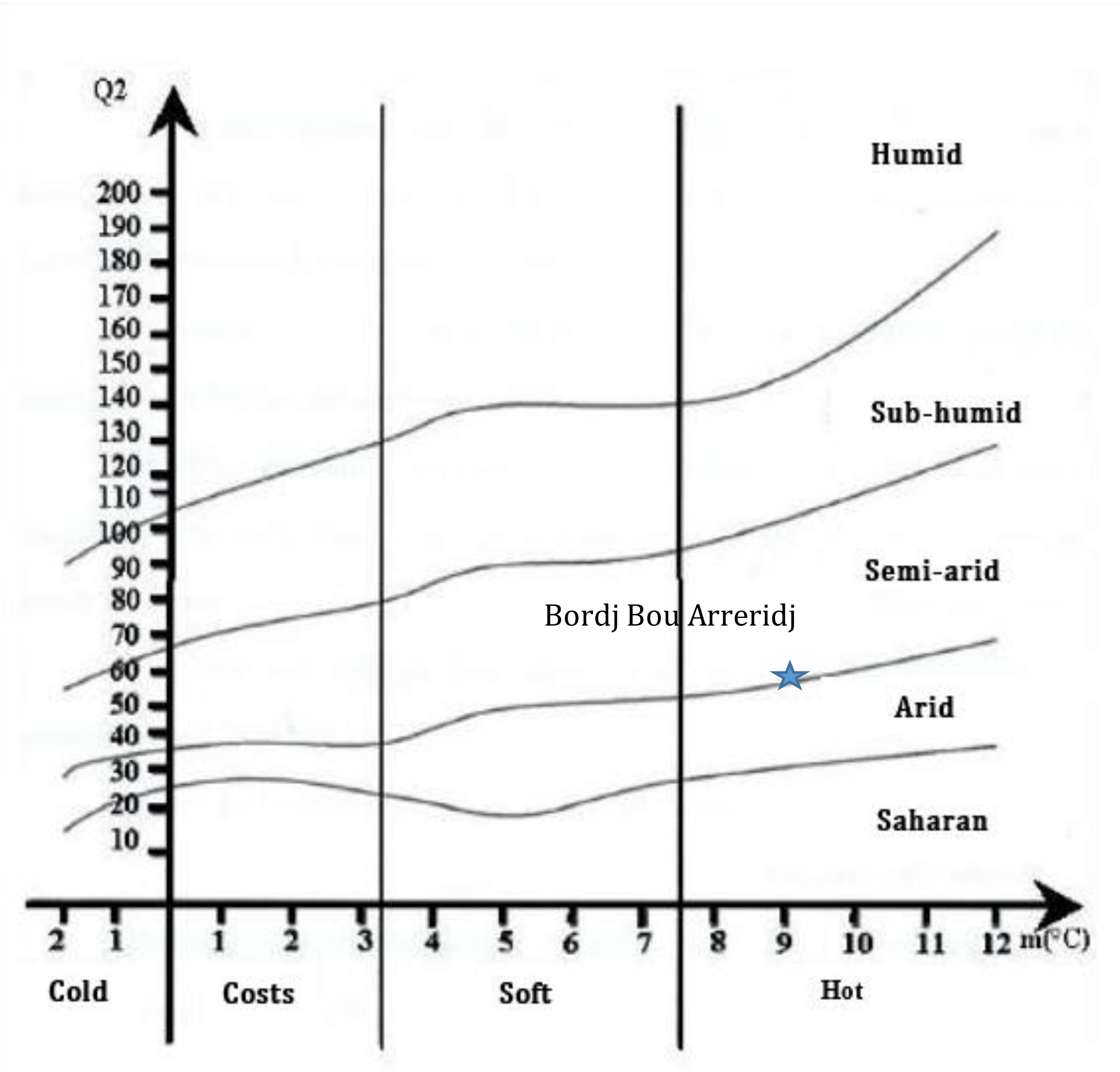


Figure 8 : Climagram of Bordj Bou Arreridj .

I.1.5 Climate synthesis:

During the agricultural campaign 2014/2024, shows that Bordj Bou Arreridj region has a Mediterranean climate, with hot and dry summers and cool and humid winters. The average maximum temperatures in summer (july) are around 29.27 C°. The average minimum temperatures in winter (January) are around 7.6 C°. Thus, precipitation is mainly concentrated in autumn and winter, the rainiest months are November (36.05mm), while the driest months are july and august. Due to its geographical location, the Bordj Bou Arreridj region is subject to strong winds, especially during the winter months. The winds generally blow from the northwest, but can also come from the southeast in summer.

Climate change has direct impacts on agricultural production, crop quality, and the health of plants and animals. Thus, variations in precipitation patterns affect water sources for irrigation and hydroelectric production, while extreme weather events such as floods, storms, and drougths generate deluges and devastating effects on local infrastructure and livelihoods.

I.1.6 Agricultural production systems:

The Wilaya of Bordj Bou Arreridj is agricultural or dominating the cereal-livestock system, which includes arboriculture and fodder. For animal production, other than sheep, cattle, goats, horse breeding, poultry farming, and beekeeping on mountains **(Chenouf Rihab, 2023)** .

I.1.7 Land distribution:

The total agricultural area of the wilaya of Bordj Bou Arreridj covers 245.120 hectares (62.50%), with 75.86% of the usable agricultural area (UAA).

Table 3: Distribution of agricultural lands in the wilaya of Bordj Bou Arreridj

Land distribution		Surface in Ha	
Total area of the wilaya		392252	
Total agricultural area		245120	62.50%
Useful agricultural area		185966	75.86%
Foresty	Wood, forest, scrub	97184	
	Alfa	10000	
Rangeland and unproductive land	Rangeland	48598	
	Unproductive land	10556	
Land not allocated agriculture	Public domain	9532	
	Miscellaneous urban	30416	

Source : Author's estimates based on DSA, 2023.

I.1.8 Plant Production:

The plant species cultivated in Bordj Bou Arreridj are diverse and important, including cereals, fodder, market gardening, pulses, viticulture, the seeds, and olive production **(Chenouf Rihab, 2023).**

Table 4 : The plant production of the wilaya of Bordj Bou Arreridj

Category	The set goals (e)	Production forecast (s)	Cultivated area (h)	Harvested area (h)	The resulting Output(Q)
Green fodder by type					
Barley	432	3343.5	491.5	466.5	15266
Fodder oats	79	450	16	16	360
Fodder corn (mais)	112	13440	34.5	34.5	3450
White corn (sorgho)	48	1021.5	9.5	9.5	1130
alfalfa	9	36.5	9	9	944
Peas oats	6	12.5	0	0	0
Total green fodder	686	18304	560.5	535.5	21150
Dry feed by type					
Vetch oats	54	929.5	25	25	1375
Fodder oats	483	5153.5	485	474	9877
Barley oats	473	10138	399	399	10854
Fodder pea	30	252.5	5	5	25
Peas oats	34	422.5	20	20	310
Total dry feed	1074	16896	934	923	22441
Cultivated fodder group	1760	35200	1494.5	1458.5	43591
Natural feed group	28015	489692	/	22925.5	134006

At present, quinoa is not produced in the province of Bordj Bou Arreridj. However, with the growing interest in healthy and sustainable products, agricultural initiatives in the region, we have begun experimenting quinoa cultivation. This marks the first attempt to introduce quinoa cultivation in Bordj Bou Arreridj.

I.1.9 Agronomic synthesis:

Agronomic synthesis of forage crops in BBA and perspectives for the introduction of new species an analysis of the 2024 date on forage crop production in the Bordj Bou Arreridj (BBA) region highlights a farming system largely based on two major forage groups: **green forage** (535.5 ha harvested for 21.150 quintals) and **dry forage** (923 ha for 22.441 quintals). The main cultivated species include barley, forage oats, and maize, both in monoculture and in association. Mixed cropping systems such as vetch-oat and barely-oat stand out for their agronomic and nutritional advantages, particularly through their contribution to soil fertility and forage protein content.

Despite this diversity, the overall productivity remains heterogeneous and relatively limited. Climatic constraints, suboptimal agronomic practices, and reliance on traditional species with low resilience to abiotic stress (e.g, drought, salinity, nutrient-poor soils) restrict the efficiency of the local forage production systems. Some species, such as lucerne or pea-oat mixtures, are cultivated on marginal surfaces with limited yields, indicating underutilized potential or unsuitability to local conditions.

In light of these challenges and the increasing demand for resilient and high-quality forage resources, the introduction of new, climat-resilient crops such as quinoa appears highly promising. Quinoa, a pseudo-cereal native to the Andes, is renowned for its exceptional tolerance to drought, salinity, and poor soils, as well as for its hight protein content and balanced amino acide profile. As a potential forage crop, quinoa offers strong potential to diversify cropping systems, improve farm resilience, and strengthen the feed autonomy of livestock systems, particularly in semi-arid regions.

This synthesis underscores the urgent need to broaden the forage crop base in BBA and suggests, as a research perspective, the experimental introduction of quinoa as an innovative forage species. Such an approach could contribute to the development of more sustainable and adaptive agricultural systems in the face of ongoing climatic and nutritional challenges.

I.1.10 Animal resources:

Sheep farming is the most common, with 264.868 head, followed by cattle farming, which has an estimated 21.783 heads, including 10.128 dairy cows. And goat cultivation, with 59.448 animals **(Chenouf Rihab, 2023)**.

Table 5: Animal resources

1/ Livestock numbers heads	All
Cattle	21783
Including cows	10128
Sheep	264868
Including ewes	143383
Goats	59448
Including goats	33049
Equines	2009
HORSES	1339
Total	536007

Chapter II :

MaterialS

and

Methods