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The influence of biochar amendment to sandy  
soils on the plant development

Submitted by

GHEDIERI Mohammed

BEDRA Asma

FEZZAI Safa

MEHDA Yahia

Board of examiners

Name and surname

Establishment

Chairmen: ALALI Ahmed (MCA)

University of El-Oued

Supervisor: BABAOUSMAIL Mahfoud (MCB)

University of El-Oued

Examiner: NILI Mohammed seghir (MCA)

University of El-Oued

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## Dedication

*Thanks and praise to Allah Almighty first for  
the grace of patience and the ability to accomplish the work.  
I thank those who raised me, taught me and delighted for me.*

*\*\*\* My beloved mother \*\*\**

*And whoever tried to see me at the top*

*\*\*\* daddy \*\*\**

*To my siblings, dear and strong, to my loved ones  
and friends and to all who supported me even by word.*

*Mohammed, Asma, Safa and Yahia*

### Abstract:

Sandy soil is very poor soil of plant nutrients as well as microorganisms that contribute to plant growth such as bacteria. So, our research aims to assess the effect of biochar on potato plant and sandy soil in the Oued Souf region. The experiment was carried out on a private farm at Guemar city from February to May 2022 under green house. A biochar was made from palm date residues using barrel technique and then manually grinded. The biochar then mixed with poultry manure at different proportions 10,20,30 and 40 %. The mixtures were applied into the soil according to the design of the experience .We planted potato tubers at rate 6 for each treatment. We have noted a positive impact of biochar on the physical, chemicals and biological soil characteristics. The percentage of moisture level in each treatment has a percentage of biochar was increased by biochar treatment especially in T4 where the humidity was 90%. It modified pH of soil, so biochar reduced the pH value in the soil to 7 in T4. As it reduced the salinity level in all treatment with biochar T4, T2 and T1 except T3. Biochar has also increased the biological activity of bacteria and fungi in correlation with the biochar rate applied. A significant positive effect on the arial part of the plant was observed in plants treated with biochar. However, for the underground parts, the effect of biochar was not significant.

**Keyword:** Bio-char, Sandy soil properties, Potato farming, Oued souf

### المخلص :

التربة الرملية هي تربة فقيرة للغاية من العناصر المغذية للنبات وكذلك الكائنات الحية الدقيقة التي تساهم في نمو النبات مثل البكتيريا. لذلك، يهدف بحثنا إلى تقييم تأثير الفحم الحيوي على نبات البطاطس والتربة الرملية في منطقة واد سوف. أجريت التجربة في مزرعة خاصة في مدينة قمار من فبراير إلى مايو 2022 تحت البيت البلاستيكي. صنع الفحم الحيوي من بقايا النخيل باستخدام تقنيات البرميل ثم تم طحنه يدويًا. بعدها تم خلط الفحم الحيوي مع روث الدواجن بنسب مختلفة 10.20.30 و 40%. تم وضع الخليط في التربة وفقًا لتصميم التجربة. زرنا درنات البطاطس بمعدل 6 لكل تكرار. لقد لاحظنا تأثيرًا إيجابيًا للفحم الحيوي على الخصائص الفيزيائية و الكيميائية و البيولوجية للتربة. حيث ازدادت نسبة الرطوبة في كل معالجة لديها نسبة مئوية من الفحم الحيوي وخاصة T4 حيث بلغ معدل الرطوبة 90%. كما قام الفحم الحيوي بتعديل درجة الحموضة في التربة، حيث خفض الفحم الحيوي قيمة الحموضة إلى 7 في T4. قلل الفحم الحيوي من مستوى الملوحة في جميع المعالجة التي بها الفحم الحيوي T2 و T4 و T1 باستثناء T3، كما زاد النشاط البيولوجي للبكتيريا والفطريات. لذلك يزداد نشاط البكتيريا والفطريات مع زيادة نسبة الفحم الحيوي. الفحم الحيوي له تأثير إيجابي على الجزء الهوائي من النبات (أوراق، الساق....) من ناحية طول الساق ومساحة الاوراق والنبات، أما بالنسبة للجزء الأرضي، فإن تأثير الفحم غير ملحوظ.

**الكلمات المفتاحية :** الفحم الحيوي، التربة الرملية، زراعة البطاطا، وادي سوف.

## Abstract

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### Résumé :

Le sol sableux est un sol très pauvre en éléments nutritifs végétaux ainsi qu'en microorganismes qui contribuent à la croissance des plantes, comme les bactéries. Notre recherche vise donc à évaluer l'effet du biochar sur les plants de pommes de terre et les sols sableux de la région de l'Oued Souf. L'expérience a été réalisée sur une ferme privée de la ville de Guemar de février à mai 2022 sous serre. Le biochar a été fabriqué à partir de résidus du palmiers dattiers en utilisant des techniques de baril, puis broyé manuellement. Le biochar a ensuite été mélangé avec du fumier de volaille à différentes proportions 10,20,30 et 40 %. Les mélanges ont été appliqués dans le sol selon le dispositif expérimental. Nous avons planté des tubercules de pommes de terre à l'ordre de 6 pour chaque traitement. Nous avons noté un impact positif du biochar sur les caractéristiques physiques, chimiques et biologiques du sol, dans le niveau d'humidité dans chaque traitement a un pourcentage de biochar en particulier T4 90%, il a modifié le pH du sol, donc le biochar a réduit la valeur du pH dans le sol à 7 en T4, réduire le niveau de salinité dans tous les traitements avec le biochar T4, T2 et T1, sauf T3, et aussi augmenter l'activité biologique des bactéries et des champignons. Ainsi, l'activité des bactéries et des champignons augmente à mesure que le pourcentage de biochar augmente. Le biochar a un effet positif sur la partie aérobie de la plante (feuilles, tige.....) longueur des tiges superficie des feuilles et des plantes, car pour la partie du sol, l'effet du charbon n'est pas perceptible.

**Mots-clés :** Biochar, Sol sableux, Culture de la pomme de terre, Oued souf.

## List of abbreviations

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### list of abbreviations

**Ha:** Hectar.

**Qx:** Quintal.

**PNDA:** Plan national de development agricole.

**FNRDA:** Fonds national de regulation et de development agricole.

**INRA:** L'institut national de la recherché agronomies.

**ITDAS:** L'institut technique de development agriculture saharienne.

**ITCMI:** Institute of techniques of market gardening and industrial.

**DSA:** La direction des services Agricola.

**FDPS:** Ferme de demonstration et de production de semences.

**S.O.C:** Soil organic carbon.

**CEC:** Cation exchange capacity.

**BD:** Bulk density.

**BET:** Brunauer's theory, Emmet and Teller.

**USDA:** United ,states department of agriculture.

**NRCS:** Natural resources conservation service.

**BC :**Bio charbon .

**PDA :** Potato dextrose agar.

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# Introduction

### Introduction

Sandy soils cover approximately 900 million HA worldwide particularly in arid and semi-arid regions, there are extensive areas of sandy soils under cultivation, but the soil fertility is often low and dependent on the levels of soil organic carbon (SOC), (Huang et al., 2016). They are being increasingly used for food production.

The percentage of organic matter in sand formations ranges from 15 % to 35% which is considered less than that of clay soil, and it is characterized by having a coarse texture. It is important to note the proportion of organic matter that is present in the soil because it controls many things related to how that soil is used (Buol et al., 1973).

Organic amendments break down very quickly in the soil and therefore leave few humic substances in the soil. Moreover, this technique is sometimes limited by the availability of plant species and the difficulty of controlling the decomposition dynamics of amendments (Kumar et al., 2015). Sandy soils are characterized by a deficit organic balance, and aggravated on the other hand by the dominance of sand. In fact, sand causes physical cover organic matter, which promotes its strong oxidation and increases its accessibility to physical agents of degradation to the damage of biological agents (Badiane et al., 2001). For agriculture in the Saharan environment to become a system of sustainable production.

Biochar is a sustainable option to provide long-lasting improvements in soil fertility (Lehmann et al., 2003; Novak et al., 2009), especially in sandy soils where sustainable agriculture faces large constraints due to low water holding capacity, and high leaching of soil nutrients (Uzoma et al., 2011). Because of its ability to retain nutrients and to improve soil water holding capacity.

Biochar soil application can be used to overcome some of the limitations faced when land farming sandy soils (i.e. additional requirements for artificial fertilizers and intensive irrigation) providing a promising soil management option for these conditions. Positive effects of biochar on soil properties and plant growth in sandy soil are well documented (Uzoma et al., 2011). Recent studies have shown that biochar soil additions increase pH of acidic, enhance cation exchange capacity (CEC), increase soil water-holding capacity, modify soil bulk density, and increase exchangeable basic cations soils (Novak et al., 2009; Sika, 2012).

## **Introduction**

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### **Problematic:**

The problem addressed by our research work is: what is the effect of biochar on the characteristics of the sandy soils in the region of Souf? and how it affects the potato plants?.

### **Hypothesis:**

Biochar application to the sandy soil will positively influence seedling agronomic response of potato plants, resulting in better yield under field conditions.

Biochar added to sandy soil under arid conditions will improve soil nutritional traits, by either introducing nutrients to the soil (release from biochar surfaces) or modifying soil mechanisms to increase nutrient transformation to plant-available forms.

### **The objective of study:**

The main objective of the current research is to investigate the effect of Biochar on plant growth and proprieties of a sandy soil under field conditions through:

- ✓ Contribute in sustainability of Saharan agro-systems by the valorization of date palm residues in Biochar production and its incorporation in soil.
- ✓ Testing different concentrations of Biochar mixed with manure on the physical and the microbiological proprieties of soil.
- ✓ Measure the influence of Biochar on potato plants (appearance, yield.... ).

# **Literature review**

## 1.Sandy soils

### 1.1. Sandy soil properties:

Soil characterized by a physical and chemical structure, the biological activity of the soil are fundamental elements to ensure the sustainability of agricultural productivity and determine, in their complexity, the fertility of the soil (**Sliman et al., 2019**).

#### 1.1.1. Physical properties:

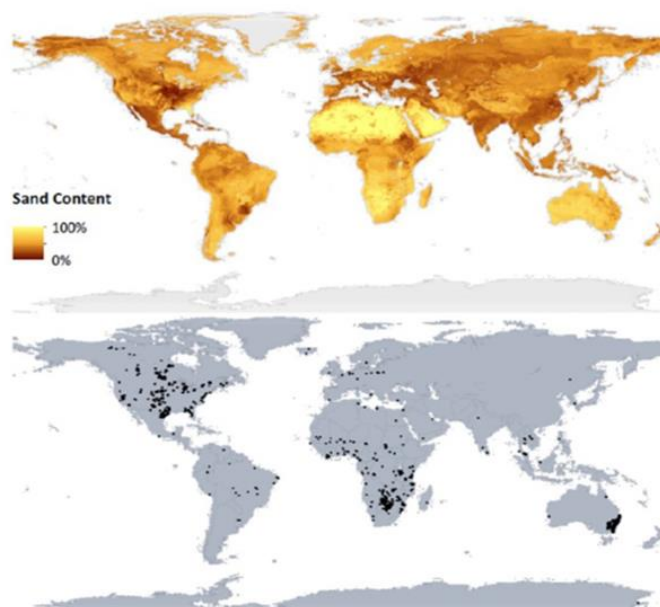
Sandy soil is soil that is often considered soil with physical properties that can be easily identified regardless of its complexity. One of its most important characteristics is the size distribution of sand grains, which in turn allows for increased porosity (**Bruand et al., 2006**).

The dominant factor of soil formation is the wind (but can be considered as negligible as the author says, the temperature and the drought which allow the action of the wind and whose own action provides the movable material (**Aranyos et al., 2016**).

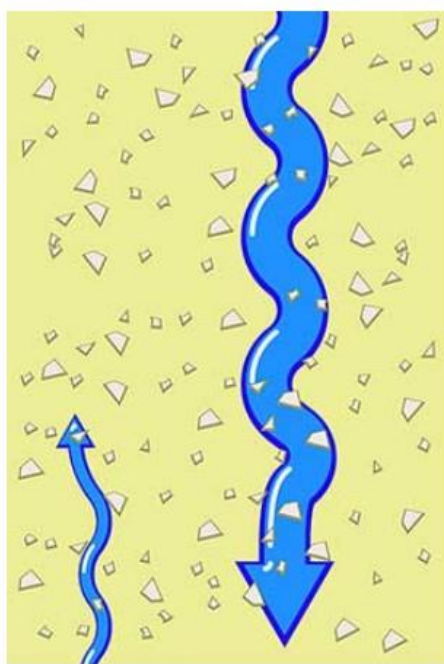
#### a) Structure:

Degraded structure: reduction of permeability and aeration.

- poor structural stability
- low availability of water to the plant. (**Mennasser et al.,2009**).
- they usually have a single grained structure and poor physical properties which result in a low water holding capacity. (**Andry et al., 2009**).



**Figure 1** : Global map of sand content in the top 30 cm, and location of pedons (n= 1317) from the five databases . the sand content map was derived from soilgrids.org.



**Figure 2** : Sandy soil characteristics.

**b) Texture:**

size >0.05mm

filtering: it allows water to pass through and only retains a few elements that are easy to work with, lack of cohesion.

### 1.1.2. Advantages:

- The roots develop easily.
- A quick return to the plot after the rain.
- Plots heat up very quickly in spring (Jozsef,2016).

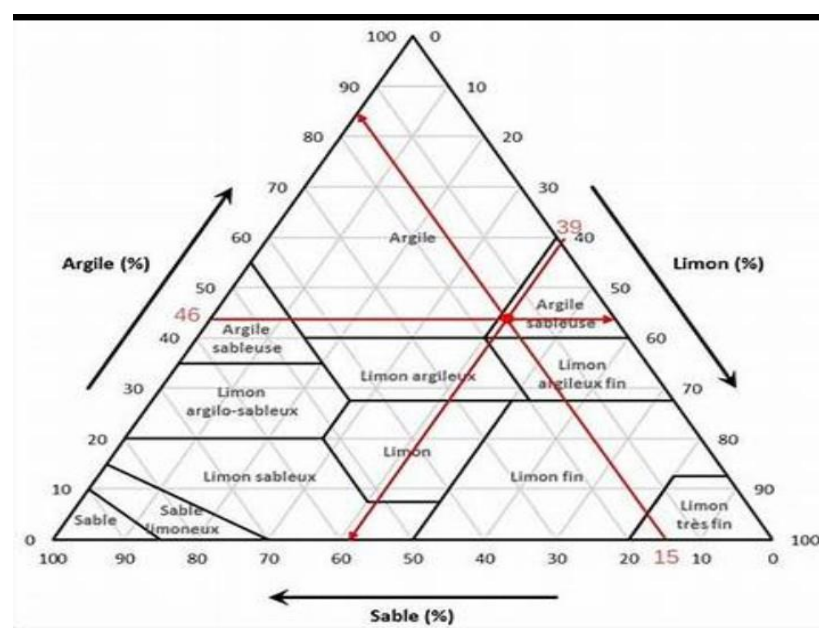
### 1.1.3. Disadvantages:

Sand is the largest of the mineral particles, sand particle create large pore spaces quickly, soils with a high percentage of sand are generally well drained.Sandy soils lack the ability to hold nutrients and are not fertile , sandy soils also feel gritty to the touch .

- Usually, they are dry soils.
- They do not retain water and nutrients. (Jozsef,2016).

Where a study of sand texture classification showed the following:

- dry loose and single grained: feels gritty
- moist-will form very easily crumbled ball
- sand :85 - 100 % , silt: 0 – 10 % , clay: 0 – 10 %.



**Figure 3:** Sandy soil texture.

#### 1.1.4. Large range of porosity:

Sandy soils in the tropics show a large range of porosities and consequently bulk density ( $D_b$ ) porosity ranges from 33% ( $D_b = 1,78 \text{ g cm}^{-3}$ ) to 47% ( $D_b = 1,40 \text{ g cm}^{-3}$ ) are commonly recorded the porosity in sandy soils is usually smaller than in clayey and silty soils (**Bruand et al., 2006**).

#### 1.1.5. Ventilation:

These lands are well ventilated due to the high percentage of large pores macropores in it, which makes it quick to exchange, because these Pores are specialized in the movement of air, and this is at the expense of their content of air Moisture that moves into the capillary micropores which is from Its effect is the lack of water retention. Aeration decreases with decreasing particle size Or by increasing the bulk density of the Earth, which reflects the effect of thin layers The granules should reduce ventilation in some sectors (**Robert., 2012**).

#### 1.2. Chemical property:

Sandy soils, characterized by a low binding capacity for chemical elements, which makes them particularly sensitive to acidification, on the other hand, properties rapid infiltration which makes them unsuitable to play the role of buffer, with inconsequence of the risks of pollution of deep-water tables (**Stengel et al., 1998**).

##### 1.2.1. Soil moisture:

Dry soils show no microbial activity, but when moisture increases the activity of microorganism gradually increases to a maximum then decreases (**Morel.,1989**).

Since sandy soil types quickly drain excesses moisture, you may need to water them more frequently. providing mulch on the surface will also help reduce water loss through evaporation.

##### 1.2.2. The cation exchange capacity (C.E.C):

The cation exchange capacity expresses the ability of a material to retain cations in exchangeable form. It is a property of soils that is both useful and interesting (**Calvet., 2003**).

According to (**Bockman et al., 1990**), certain soils (particularly light sandy soils) have a low cation exchange capacity. The application of organic matter to this type of soil therefore contributes to the increase in the cation exchange capacity of these soils (**Charreau., 1975**).

When the soil is completely dry, moisten it briefly, then wait a minutes to allow the water to penetrate through the sand particles. Then do a slow, deep watering with a soaker hose or other drip irrigation method to make sure the liquid can spread through the soil (**Sparks.,1981**).

### 1.2.3. pH soil reaction:

The soil reaction (PH) is influenced by the nature of the soil. Which some salts are acidifying ( Ca SO<sub>4</sub> , kcl , Mg SO<sub>4</sub>) Others are alkalizing (Na H CO<sub>3</sub> , Ca CO<sub>3</sub> Na<sub>2</sub> CO<sub>3</sub> ESP(exchangeable sodium rate ))(**Rutkowska et al., 2009**).

The PH level of sandy soil can easily change the PH level of soil like clay.

The PH level of sandy soil is between 7,00 and 8,00.

### 1.2.4. Salinity of sandy soil:

So sandy lands can be divided from salinity to:

(a) Non-saline lands (total salinity does not exceed 0.2%).

(B) Saline lands (total salinity does not exceed 0.5% ).

(C) highly saline lands (the salinity in it is higher than %) (**Robert., 2012**).

## 1.3. Biological properties:

Sandy soil is characterized by low microbial activity, as the living organisms in it have a special ability to adapt to difficult climatic conditions (**Hampton et al, 2011**).

### 1.3.1. Soil microorganisms:

The organisms living in the soil are bacteria, hongii, algos, the lathy underground part of the plant as well as very varied animals . all participants in one way or another in training and soil evolution. (**Agnieszka, 2015**).

### 1.3.2. Bacteria:

Bacteria help maintain natural cycles such as: carbon cycles, nitrogen cycles, and sulfur cycles, which keep sandy soils fertile and aerated.Genus: Nocardiosis, Actinomadura, Microtetraspora, Saccharothrix,Streptosporangium, Spirillospora and especially; Planomnospora (worldwide rare), arepresent in significant quantities in sandy soils (**Jan., 1990**).

### 1.3.3. Fungi:

Fungi are living organisms that are resistant to dry climatic conditions. Fungi are found in all ecosystems of deserts dry up to the oceans, the numbers of fungi species have reached Knowledge in the world is over 1.5 million (**Hawksworth., 1991**).

Where it was studied for dry areas in sandy soils and found the distribution of four genera of fungi, in order according to their spread, the first genus *Aspergillus*, the second genus is *Blastomyces*, then nectarial, and finally *Fusarium* (Fatma.,2003).

#### **1.3.4. Algae:**

The presence of algae is characteristic of the weak pedological evolution of the environments colonized. They thus constitute the initial stage of the vegetation of rocks and mineral soils. they also produce the oxygen necessary for the metabolism of the consumer organisms (Lee.,1989). That algae are important components of arid and semi-arid ecosystems. Furthermore, their distribution and condition may indicate the health of the environment. Additionally, the presence of algae leads to reduced erosion by regulating the water flow into soils. Similarly, they play a role in soil fertility, soil reclamation, bio-controlling of agricultural pests, formation of microbiological (Ibraheem., 2007).

#### **1.3.5. Infertility:**

Salty land, deserts, degraded soils. Their abundance has been demonstrated, even during summer drought and in samples taken between 10- and 15-centimeters depth (Chlorophyceae predominate due to their ability to produce spores) (Ruiz-García et al, 2005).

#### **1.3.6. Sandy soils and organic matter:**

Do not present an intimate link between the organic matter and mineral particles: there is simply juxtaposition between them, without strong cohesion. The subjects organic, unprotected, are therefore more easily degraded than in other types of soil: we say that sandy soils “burn” organic matter. These are well aerated soils, but they do not retain water and are sensitive to erosion risk (Monnier.,1965) .

#### **1.4. Sandy soil problems:**

Since sandy soils contain more than 85% of sand grains singular, therefore: It is poor in its content of fine granules, and therefore it is without construction. Quick permeability. Organic matter decreases rapidly due to drought and high temperature conditions so that its percentage does not exceed 0.2% Deficiency of colloids such as clay granules, iron and aluminum oxides, as well as Organic Colloids Very low exchange capacity, which results in a clear decrease in the fertility of these species of lands. Very little vital activity due to lack of moisture and nutrients. Heterogeneity in the distribution of water after irrigation, so we find that the areas close to the drain the watershed receives a large share of the water, while the end of the field may be denied access water to it.

These lands are subject to erosion by water and wind and are subject to precipitation. The sand on its surfaces and the transfer of sand dunes is a clear phenomenon in the area Desert. **(Bortoluzzi,2003).**

## 2. Potato production in the El-Oued region:

What characteristics made the Oued souf region an important national pole in potato production?

### 2.1. Potato history in the El-Oued region

It should be remembered that the first trials of potato cultivation were from 1995 in the Souf area, by the technical assistance of the agricultural services (**DSA**) of the wilaya of El Oued in close collaboration with the institute of techniques of market gardening and industrial (**ITCMI**), the technical institute of development of Saharan agriculture (**ITDAS**) and the National Research Institute agronomic (**INRA**), and with the help of state subsidies through irrigation equipment by sprinkling to encourage Sufi farmers (**DSA, 2018**).

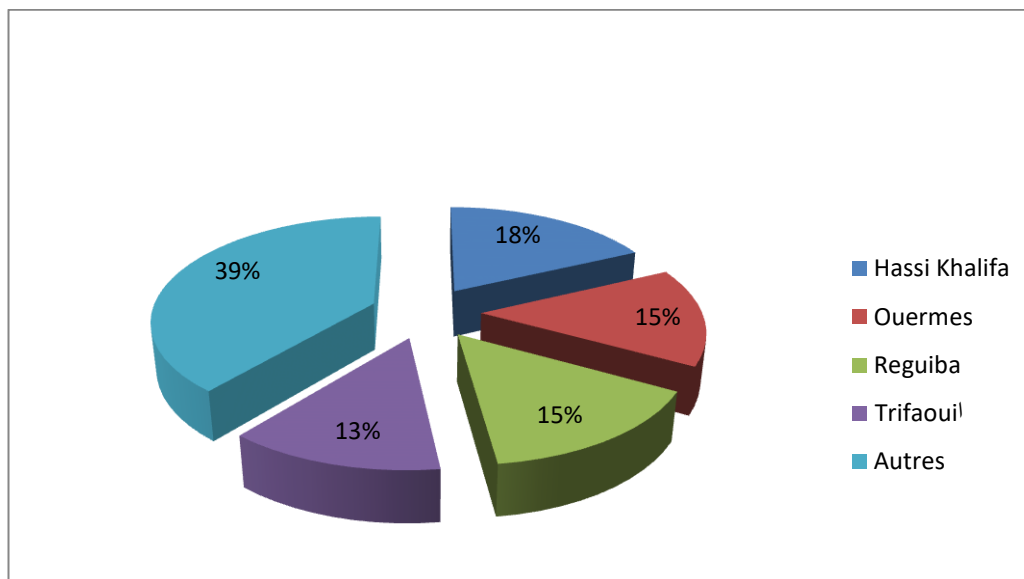
The real development of potato cultivation began during the 1997 -1998 on an area of 640 ha, and since then potato cultivation has multiplied quickly throughout the Souf area, including the municipality of Taghzout, and has rapid expansion in recent years from which the results obtained were encouraging quantitatively (550 Qx/ha) and qualitatively (**DSA, 2018**). In general, the potato is a profitable production for the areas from the south, which could in future produce seeds for the northern regions (**ITDAS, 2011**). During the period 1995-2018 are as follows (**Benlamoudi, 2009**, **DSA, 2018**).

### 2.2. The main potato production areas in the region El-Oued:

**Table 1:** Shows the distribution of cultivated areas and production by apple the region of the souf during the campaign (2017/2018) (**DSA, 2019**).

<b>Common</b>	<b>Total area (ha)</b>	<b>Total production (qx)</b>	<b>Late Season production (qx)</b>
<b>Hassi Khelifa</b>	6530	2039000	147900
<b>Ouermes</b>	5529	1733700	1208700
<b>Reguiba</b>	5500	1739450	1113300
<b>Trifaoui</b>	4578	1428400	1043400
<b>Autres</b>	14072	5804550	4346700
<b>Total wilaya</b>	36200	11360000	7860000

According to Table 01 two-thirds of potato production in El Oued is a late-season potato. On a total area of 36200 ha in 2018 and a production of approximately 11.6 million tonnes, the municipality of Hassi Khelifa ranked in first position with an area of 18% of the total area of the wilaya followed by the municipalities Ouermes, Reguiba, Trifaoui and other regions, which occupy respectively 15%, 15%, 13% and 39% of the total area.



**Figure04** : Distribution of the area of the main potato production areas.

### 2.3. Main varieties grown in the region

In Algeria the varieties listed in the catalogue are of the order of 120 varieties. According to data acquired from the Wilaya of El-Oued Chamber of Agriculture and Agricultural Services Directorate of the El-Oued Wilaya, about sixteen varieties of potatoes are grown in the Souf region: Spunta, Desirée, Kondor, Diamant, Bartina, Atlas, Cornado, Exort, Maradona, Bolla, Tomate, Marosa and Lisita, but the most cultivated are Spunta, Desirée, Kondor and Bartina, where the area planted in white-skinned varieties represents about 60% of the total area planted (CAW, 2018).

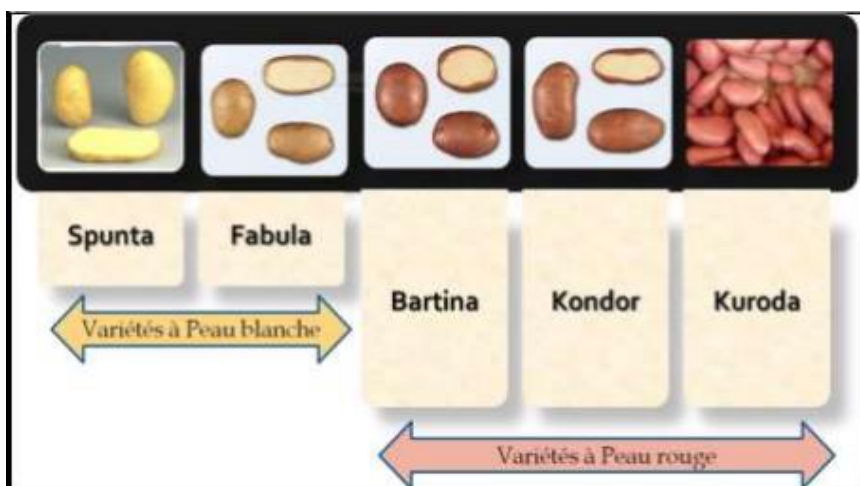


Figure 05: Main varieties grown in the Souf region (CAW ,2018).

**2.4. Evolution of cultivated area**

During the period 1995-2006, the productive areas of the potato showed a gradual and remarkable increase and especially during the period 2001-2006 which represents the most significant period of change (DSA, 2018).

Since 2012, the spread of potato cultivation has experienced a strong and regular speed and continuity within the growing systems in the Souf region. The productive area is increasing and is around 36200 ha for the year 2018.

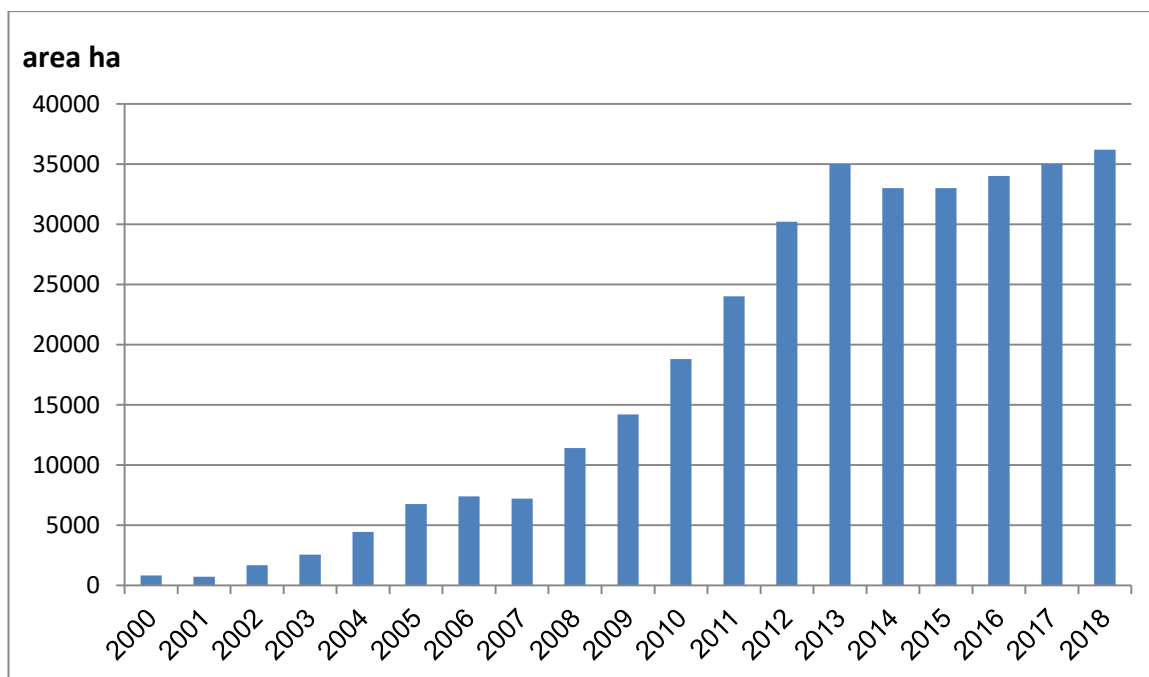


Figure 06: Evolution of the potato area in the El Oued region (DSA.2000-2018).

## 2.5. Evolution of potato production (season and late-season):

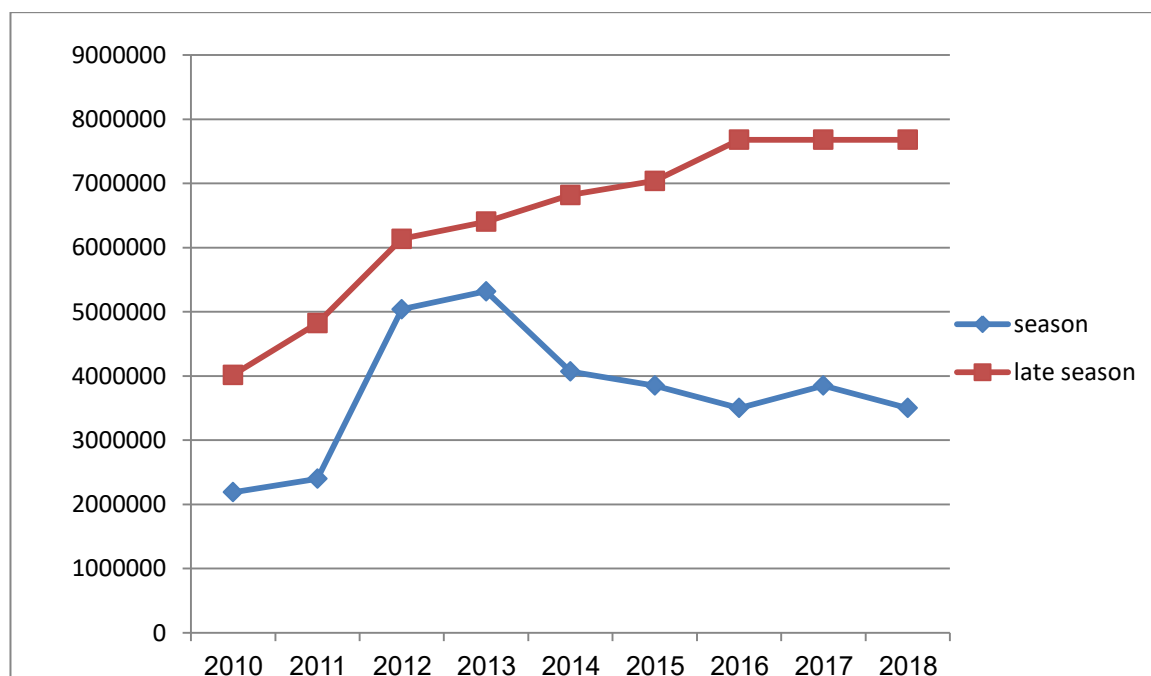
The genetic plasticity of the species allows it to adapt to the diversity of Algerian agro-ecosystems and the short period of growth and development of the plant allows the realization of three campaigns and three harvests per year.

A distinction is therefore made between:

Seasonal crops (planting January - March) dominant both in terms of area occupied (70,000 ha on average over the last five years, or 51% of areas) and in terms of their participation in total production.

Those in the latter season (planting in July - August) which occupies the second place with 47,500 ha or 45% of the area. The main driver of the strong growth in planted areas over the past decade has been the generally better economic profitability of the back-season potato.

Early crops (planting October-November). They occupy only a minor place (less than 5000 hectares) in all areas and production. Implementation difficulties and higher risks for growers explain the decline in early potato acreage In the El Oued region, potatoes are grown twice a year: seasonal potatoes (planted between August and September) and late-season potatoes (planted between January and March) (DSA, 2017).



**Figure 07:** Evolution of potato production (Qx) (2010-2018).

## **2.6. Success factors and promoted the development of potato cultivation in the region of El Oued**

### **a) Nature of the soil**

The light sandy soil promotes the good development of the plant and the leaching of salts, the rapid development of roots and tubers and the ease of soil work (DSA ,2018).

### **b) Water Reserves**

The water reserves of the water table are sufficient ranging from 10000 to 60000 m<sup>3</sup> throughout the region of Souf easily exploitable and within the reach of farmers. This water medium salt (03 to 5 g/l) does not limit performance (DSA, 2018).

### **c) Climate**

The souf climate is of the Saharan type favorable to the development of potato cultivation.

### **d) Support Program**

Within the framework of the support program on the FRNDA and FNDIA the supported actions concerning the cultivation of consumer potatoes with regard to the irrigation sector such as the irrigation network (drip) (DSA ,2018).

### **e) Electrification**

The extension of the agricultural and rural electrification network has contributed to the development of potato cultivation through the extension of areas, since 2000 more than 300 km have were carried out (various state program) (DSA, 2018).

### **f) Agricultural Trails**

The launch of various opening-up program has led to the creation of agricultural trails, which are the driving forces behind the expansion of areas and the creation of new production areas (500 km have been realized since 2000) (DSA ,2018).

### **g) Cultural cycle**

The potato is characterized by a short crop cycle of about a hundred days on average that has allowed to have two productions per year.

### **h) Performance**

The current average potato crop yield at the farm level is 350 Qx/ha while the average experimental yields have reached levels of 550 to 770 Qx/ha (**DSA ,2018**).

**i) Commercial fluidity**

The marketing of production has not yet experienced problems in terms of sales, since the favorable harvest period is more than conducive to its fluidity (early and good quality) (**DSA, 2018**).

**j) Popularization**

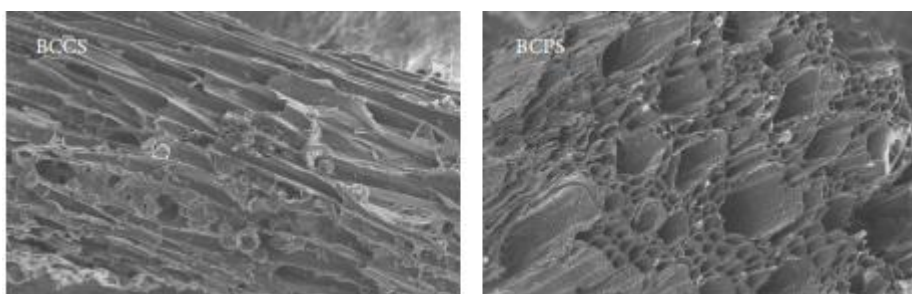
The agricultural extension policy established by the **M.A.D.R** translates into valuable information on culture and this by grouping together the spots of the programs, radio and technical days (seminars, workshops, etc.) (**DSA, 2018**).

### 3. Biochar:

#### 3.1. Definition:

Known as black carbon, it is a solid product resulting from heating biomass at high temperatures between 300 and 700 degrees Celsius and in conditions without oxygen, which is the process of pyrolysis and is mixed in the soil as an additive to increase its ability to retain nutrients, improve its productivity and mitigate the effects of climate change (**Lehmann et al., 2007**).

Biochar is a by-product of a cellulosic matter thermal treatment under an/low-oxygenic regime (Pyrolysis, Gasification or Hydrothermal Carbonization). The combustion process releases gas or oil that can be used for energy or heat supply, leaving about 25 percent of the carbon content under a non-bio-degradable structure, the Biochar. Incorporated into the soil, it can remain under this stable form for hundreds to thousands of years. The feedstock should be from biomass waste material such as field residues and processing residues (nut shells, fruit pits, bagasse, etc), as well as yard, food, human and forestry wastes, and animal manures. The properties of the Biochar produced depend on the feedstock nature (N/C content) and the baking conditions. Production units vary in technologies, size, cost and mobility, which allow a wide scope of implementation. It can be produced directly from modified energy efficient stoves that provide heating and cooking supply at the same time that they reduce health problems and slow down deforestation(**Lehmann.,2007**).



**Figure08 :** Biochar Photomicrograph from SEM

#### 3.2. History:

The origin of charcoal is 80000 years age when the amazon was black and darker than the peripheral soil betty muggers (**Sohi., 2012**).

The name of guidance of the sol Terre Preta, which came from the practices and activities of routine village such as pits, waste disposal and burning fields before agriculture and carbon proportion may reach 9% of the peripheral soil (**Mustin., 2013**).

Plaggen were created in the middle ages in northern Europe by speeding cattle bedding made from peat, along with manure to agricultural soils over time, plaggen soils have accumulated to over 1 meter in depth (Glaser et al.,2002).

And in the grass plains of Romania, Russia, Germany and the mead of north America, and in Spain, the burning of pasturs contributed to the high carbon content in the soil (Lehmann et al, 2009).

There are even older descriptions of charcoal use in non-tropical agriculture. In 1697, Yasusada Miyazaki of Japan called charcoal "fire manure"; he described roasting organic wastes and mixing them with nutrient-rich manures (Taylor., 1945).

Thmoughout Asia rice husk biochar has been mixed with nutrient-rich martials to enhance fertilization Crops were also fertilized with a mixture of human waste and charcoal powder called 'haigoe' (Ogawa et al , 2010) .

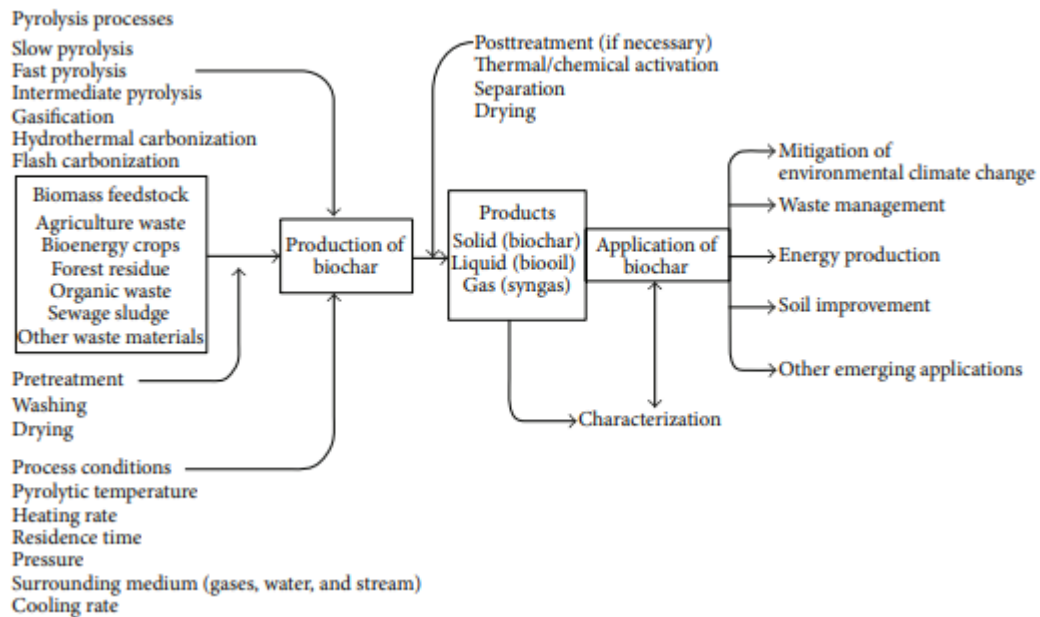


**Figure09:** The soil Terre Preta.

### 3.3. Biochar formation processes:

Biochar is the by-product of artisanal or industrial biomass pyrolysis green coal. Pyrolysis is slow charring. in an environment with little or no oxygen. In the industrial process, CO<sub>2</sub> synthesized during production is recycled in the system as energy which allows to limit or even eliminate CO<sub>2</sub> emissions to the atmosphere. This is a advantage over CO<sub>2</sub>-emitting artisanal processes. Biochar production generates the synthesis of other liquid (bio-oil) or gaseous (syngas) products that will be used as energy or fuel. The composition of the biochar varies according to the pyrolysis and the raw material used. Biochar is produced from a wide range of raw materials such as wood chips, crop residues, organic waste or municipal (Day et al., 2005; Das et al., 2008;Gaunt., 2008). 9 Raw materials with high lignin content have the greatest

biochar yield when pyrolysis occurs at a moderate temperature (about 500°C) (Fushimi et al, 2003; Demirbas, 2006).



**Figure10:** Schematic process diagram for the factors affecting BC production and application (Obemah et al.,2014).

### 3.4. The physicochemical properties of biochar:

The raw material the temperature, the rise speed, the heating and particle size can affect physicochemical properties and the quality of a biochar (Lehmann et al.,2009; Pituello et al.,2015).

#### 3.4.1. Physical properties:

##### a) Porosity:

During biochar formation, the pyrolysis temperature selected affects the porosity **Dutta et al (2012)** noted that biochar produced between 350 °C and 400 °C had the total porosity is higher than that produced at 300°C.

Also, biomass residence time in Pyrolysis can have an effect on the porosity of biochar (**Novak et al, 2009**).

##### b) Specific surface:

The specific surface of an adsorbent is by definition a surface per unit mass ( $\text{m}^2 \text{g}^{-1}$ ). This surface is created essentially by micro- and mesopores. More the surface specific, the greater the contact surface and the greater the quantity of materials adsorbed is important. This parameter is

obtained by applying Brunauer's theory, Emmet and Teller, hence the name BET surface (**Schimmelpfennig and Glaser, 2012**).

**c) Water retention capacity:**

The O:C ratio of a biochar would be a potential indicator to determine its character hydrophilic and its polarity. Normally, when the temperature of pyrolysis increases, biochar has a low oxygen content and therefore a very low O:C ratio. According to one study by **Wang et al., (2013)** increasing the temperature of pyrolysis can decrease the polarity on the surface of the biochar resulting in a decrease in its retention capacity in water. (**Kinney et al., 2012**) observed low hydrophobicity of three different pyrolyzed biochar between 400°C to 600°C.

**3.4.2 Chemical properties:**

**a) Mineral composition:**

The composition and availability of the mineral elements of the biochar vary a lot. The raw material and the conditions of the pyrolysis would be the source of this variation (**Ding et al., 2016**). **Chan et al (2009)** observed a large variation phosphorus content depending on the biomass and the pyrolysis conditions used.

For As for the nitrogen content, this tends to be lower in the biochar when the pyrolysis temperature increases. Moreover, it has been reported that when the temperature pyrolysis reaches 500°C, more than half of the nitrogen and sulfur content of the biomass can be lost (**Bagreev et al., 2001; Chan et al., 2009; Lang et al., 2005**). The Nitrogen reduction could be caused by a loss of volatile organic compounds during pyrolysis. Increasing the pyrolysis temperature can promote the greater release of volatile matter trapped in the biochar (**Bagreev et al., 2001; Dutta et al., 2012**).

**b) Production of toxic compounds:**

The type of biomass and the pyrolysis temperature have an influence on the concentration of polycyclic aromatic hydrocarbons (PAHs) and dioxins in biochar (**Schimmelpfennig and Glaser, 2012**). In addition, the pyrolysis conditions can also influence the concentration of PAHs (**Brown et al., 2006**). During pyrolysis, the organic compounds contained in the biomass are partially fragmented into smaller unstable compounds. These fragments are composed of highly reactive free radicals that combine to form a new compound more stable through recombination reactions and form PAHs (**Hale et al., 2012**).

**c) Cation exchange capacity:**

It has been established that the lower the pyrolysis temperature, the lower the CEC and vice versa (Lehmann, 2007). In addition, the amendment with a biochar possessing a high specific surface area may further promote CEC of soils (Liang et al., 2006). The CEC of biochar is attributed in part to increased oxygenation of the functional groups found on the surface of the biochar (Cheng et al., 2006). Those different functional groups that interact with the medium are the groups pyrans, phenolics, carboxylic, lactones and amines (Brennan et al., 2001). Those groups can act on the aggregation of soil particles, on organic matter dissolved and on the transport of gases and water (Joseph et al., 2009). According to some researchers, the oxidation of the surface of the biochar would lead to a greater CEC by unit of soil carbon (Liang et al., 2006; Mao et al., 2012).

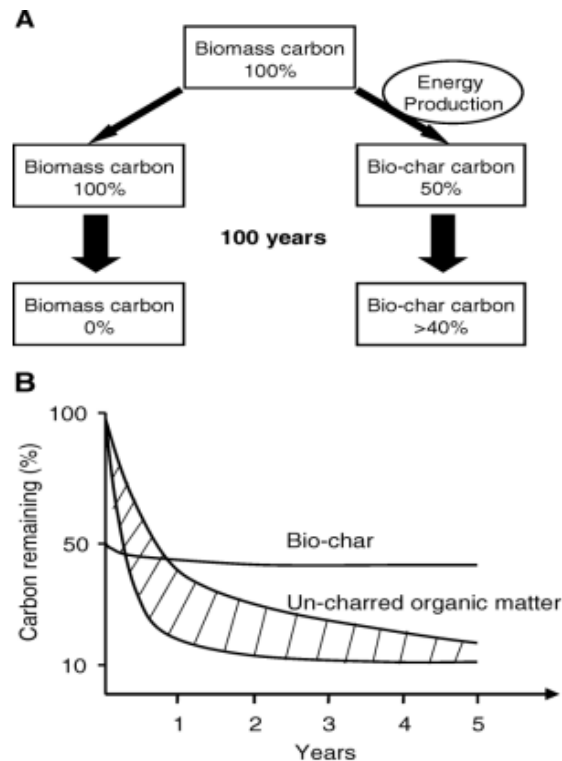
#### **d) Carbon mineralization and sequestration:**

At high temperatures during pyrolysis, aliphatic carbon converts to aromatic carbon. For example, when the pyrolysis temperature increases by 150°C to 550°C, the OH and CH<sub>3</sub> groups of organic matter decrease and the C=C double bonds increase. In addition, the H:C and O:C ratios of the biochar decrease when the pyrolysis temperature increases. In general, biochar produced at high temperatures, between 500°C to 700°C, are well charred and stable. This biochar has a low H:C ratio (< 0.1) and a large specific surface. Conversely, biochar produced at low temperatures (300°C and 400°C) are partially charred and less stable. In this case, the H:C ratio and the oxygen concentration are high and biochar has a low specific surface area. The presence of groups aromatics causes a reduction in the rate of carbon mineralization and consequently a reduction in the availability of nutrients such as nitrogen, phosphorus and sulfur (Ameloot et al., 2013; Chan et al., 2009; Xiao and Yang, 2011).

#### **E) PH and electrical conductivity:**

The temperature of the pyrolysis can influence the pH of the biochar. For example, (Novak et al., 2009) observed that a biochar produced at a high temperature (700°C) had a pH higher compared to a biochar produced at low temperature (250°C). Another one study reports an increase of 2 pH units between biochar produced at a temperature of 300°C and 600°C. The increase in pyrolysis temperature can promote ash production and an increase in base cation content (Na<sup>+</sup>, K<sup>+</sup>, Mg<sup>2+</sup> and Ca<sup>2+</sup>) which are directly correlated with the biochar pH (Singh et al., 2015). The chosen raw material can also vary the pH of biochar, ranging from pH=4 to pH=12 (Cheng et al., 2006; Lehmann, 2007; Rogovska et al., 2012). A biochar produced from

wood, a very ligneous material, generally has a higher pH than a biochar produced from crop residues because its Ca<sup>2+</sup> content is higher (Singh et al., 2015).

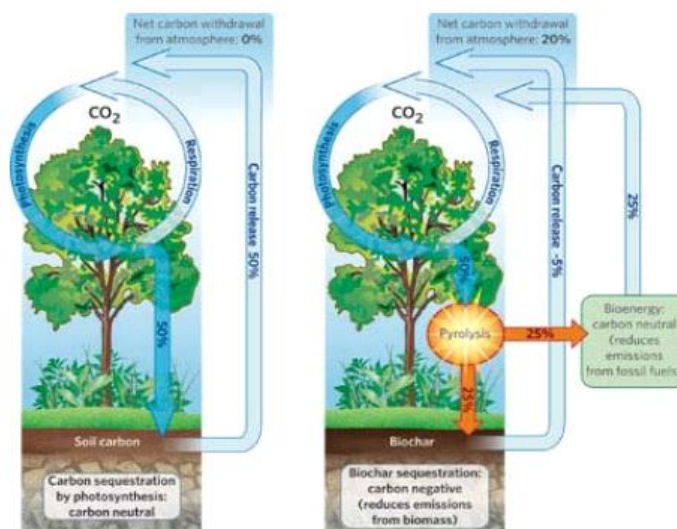


**Figure 11:** Evolution of the mineralization of biochar and non-carbonized biomass in the soil over time according to (Lehmann et al 2006)

### 3.5. Uses and impact of biochar:

#### 3.5.2. Effect of biochar on greenhouse gas emissions:

Carbon sequestration absorption and reduction of dioxide (CO<sub>2</sub>) emitted into atmosphere. Reducing the emission of nitrous oxide N<sub>2</sub>O and methane CH<sub>4</sub> from the soil and other environmental pollutants such as heavy metals and pesticides (Yao., 2011) charcoal reduces production N<sub>2</sub>O by inhibiting the nitrous oxide process (Van et al.,2009). Improving the state of nitrogen in the soil if the percentage is higher low (Deluca.,2006) stripping the biological formula in the presence of biochar stimulates the microorganisms responsible for reducing (N<sub>2</sub>, N<sub>2</sub>O) and increasing the pH (Yanai .,2007) it is a good strategy to reduce its greenhouse gas emission , sequester carbon reduce its amount in the atmosphere and lock it in the form of organic matter in the soil .( Zheng ., 2010 ).



**Figure 12:** Carbon sequestration in a system without (left) and with (right) production and incorporation of biochar in the soil (Lehmann et al 2006).

### 3.5.3. Effect of biochar on plant growth:

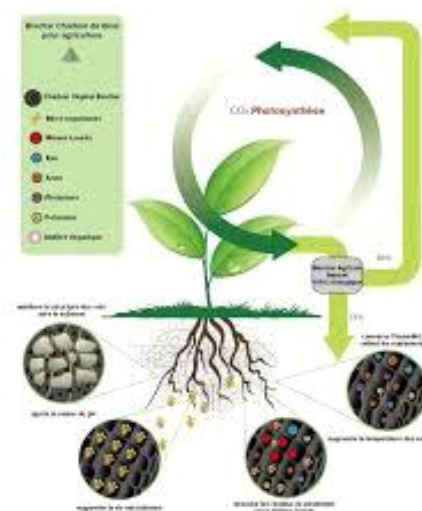
There are many researchers who have confirmed that charcoal has a beneficial effect on plant growth (Biederman et al., 2013).

For example, Graber (2010) in his experiment on the growth of tomatoes and peppers in consent fiber, the growth of this planet was significant higher in the substrates modifieds with biochar. Another study showed effect of charcoal on the growth of tomatoes and peppers in sandy soil benefice (Harel et al., 2012).

An amendment on bio-effect can be a useful impact on the growth of plants conclude that in average biomass stimulates the productivity of biomass over the surface of the earth and agricultural crops (Harpole et al., 2013) .

Also charcoal modification can have a neutral or even detrimental effect on plant growth, and this depends on the physical and chemical properties of charcoal. Biochar made from poultry droppings has a high sodium concentration and this is according to a study of Revel and it contains a high percentage of soluble salt (1- 1.2 dSm) (Rajkovich et al., 2012).

High concentration explains the decrease in maize growth in the study (Rajkovich et al., 2012). and that the application of greater than 2% (mm) (26 ha -1) of charcoal did not improve maize growth there for, the effect of charcoal varies greatly withe the type of soil the type of crop, the interaction between the plant, the soil and the type of charcoal (Rajkovich et al., 2012).



**Figure 13:** Effect of biochar on the soil mineral component(Lehmann et al 2006).

### 3.5.4. Effect of biochar on soil biology:

Most of the studies prove that microbial biomass increases after adding biochar to the soil (Gul et al., 2015). and that adding charcoal effects the growth of a group of microorganisms involved in the nitrogen, carbon and phosphorous cycle in the soil (Xu et al., 2014; Harter et al., 2014) but so far, they are few studies on the relationships between charcoal and the diversity of microbial communities in the soil (Ding et al., 2016; Gul et al., 2015; Harter 2016).

Studies indicate that charcoal promotes the growth of certain groups of organisms (Graber et al., 2010) an increase in Pseudonoros Spp Bacillus Spp , Trichodermr Spp was observed in the atmospheric roots of the biochar modified pepper crop compared a control.

As for the study he conducted Kolton.,(2011) where different effect were observed on bacterial communities an increase of 12-30% percentage in bacterial diseases and decrease of 71-47% in proteobacterial after modification with charcoal (Harel et al., 2012). It was also moted that an increase in the total number of bacteria Bacillus Spp from 1 to 3(m/m) from biochar and it appears that charcoal has an important role in drainage a systemic respond in plants against pathogenic microorganisms (Elad et al., 2010) and there were no clear negative effects on plants in their study.

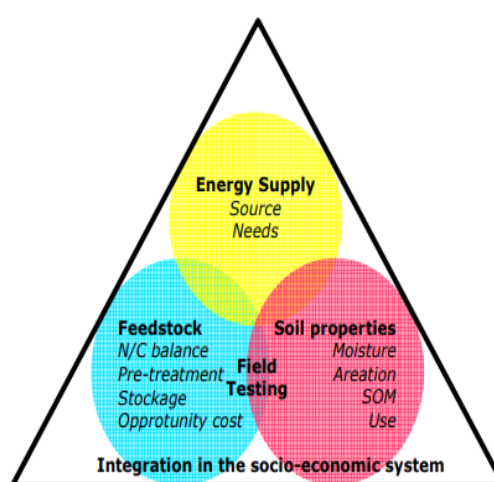
And Matsubara (2002) agreed that charcoal can increase the effectiveness of rhizomes which are tree fungi, to protect the roots of their host plant from infection and the pores of charcoal can be a refuge for bacteria and fungi and protect them from minute arthropods and soil predators (Warnock et al, 2007; Gul et al, 2015). On the microbial groups of coal and release toxic products present in the coal that inhibit the growth of microorganisms in the soil (Warnock et al.,2007; Ding et al.,2016).

### 3.6. Impacts on the physical and chemical properties of the soil:

Biochar has a porous structure which gives it absorption and water retention (**Brodowski et al., 2006; Liang et al., 2006**). Biochar increases porosity of the soil, allowing the supply of oxygen to the soil under a wide range of water conditions and reduces anaerobic microsites favorable to denitrification (**Yanai et al., 2007**). Since the pore volume of the soil is filled with either air or water, its increase can therefore lead to an increase in the water retention capacity of soils.

However, the magnitude of the changes will depend on the porosity characteristics of each type of biochar and application rates. The pore size distribution of the biochar depends on the anatomical structure of the raw material and the conditions of pyrolysis including carbonization temperature. Furthermore, the interaction between the biochar, clay and soil organic matter can lead to the formation of micro aggregates over time (**Brodowski et al., 2006; Cheng et al., 2006; Liang et al., 2006**), which will also contribute to a change in porosity.

Like the residues of burnt plants, biochar can contain concentrations variety of alkaline ash which could be easily released and leached into the ground and reduce its acidity (**Raison, 1979; Brennan et al., 2004**). However, the oxidation of biochar can lower soil pH near biochar particles (**Cheng et al., 2006**). The effect of biochar on the pH of the soil is conditioned by the content and the nature of the ashes, in relation directly with the raw material and the production process used. Biochar can enrich the soil with nutrients. It also allows a better retention of nutrients by the soil and can also be used to improve the quality of its physical and biological properties.



**Figure14:** Fields to take into consideration in a biochar project.

# **Materials and methods**

## 4. Materials and methods:

### 4.1. Geographic location:

The Souf is a berber river name, synonymous with El -Oued. Originally, the inhabitants of El-Oued living from agriculture, from the land everyone had his palm grove and his vegetable garden the outcome of a considerable amount of effort. The form of agriculture (Ghouth system ( was to dig bowls to plant near the water (aquifer), this the situation caused the agglomeration to be implanted through funnels or crater making any planning of the difficult terrain, and more expensive development (O.N.R.G.M, 1999). The wilaya is located in the southern part of the country.

This region is at an average altitude of 80 m, showing a noticeable decrease from south to north to be 25 m below sea level in the Melghir chott which occupies the bottom of the immense basin of the lower Sahara (Nadjah, 1971).

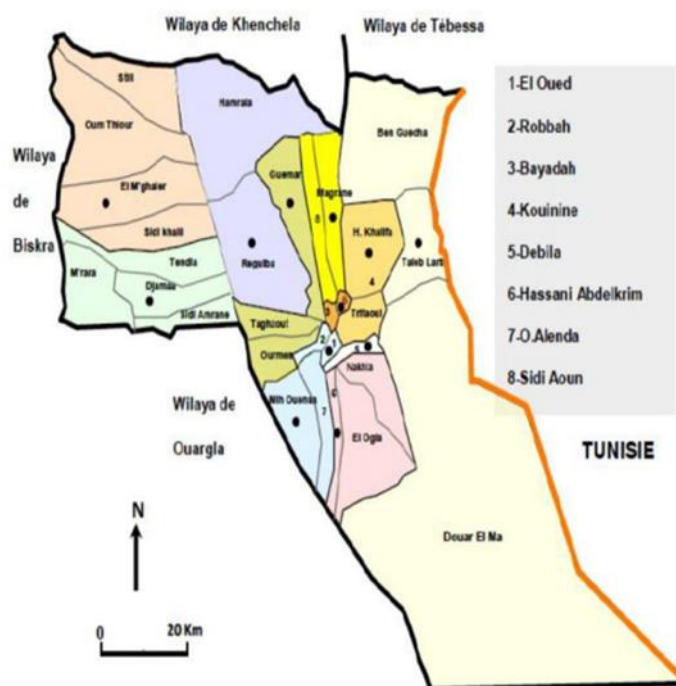


Figure15: Geographical situation of the wilaya of El Oued (Mehda, 2014).

### 4.2. Ecological factors of the Souf region:

#### 4.2.1. Abiotic factors:

##### 4.2.1.1. Relief:

The soil of the Souf takes two aspects. The most dominant is the dune complex. These are large sandy accumulations. The other aspect is locally called “Shounes” (several sahanes), were

## Materials and methods

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the surface of the soil is sometimes stony with gypsy crusts surrounded by high dunes (Ghroud) which give them the shape of craters (ONRGM, 1999).

### 4.2.1.2. Soil:

The soils of the region are diversified and distributed according to (Halitim,2011), in 8 soil classes, differ mainly in their texture, morphology and in the level and mode of salinization. They are characterized by the presence of a water table close to the surface and are also subjected to a very important salinization which jeopardizes their valorization by irrigation.

The soil of the Souf takes two aspects. The most dominant is the whole dune. These are large accumulations Sandy. The region of Oued Souf is characterized by light soils, predominantly sandy, with special structure. These soils are known by low levels of organic matter, high salinity, alkaline pH and good aeration (DSA, 2018).

### 4.2.2. Hydrogeological factors:

From a hydrogeological point of view, the Souf region is represented by two acquired systems, namely the Terminal Complex and the Intercalary Continental. These two systems are surmounted by a free water table called a water table (Voisin, 2004)

#### a) Water table:

The water is everywhere in the Souf. It rests on the clay-gypsum floor of the upper Pontian. The aeration zone that separates the surface of this water from the soil surface never exceeds an average vertical distance of more than 20 m of non-aqueous sand (Voisin, 2004).

#### b) Terminal Complex Tablecloth:

The Terminal Complex's aquifer is the most exploited in the region, the flow The production area, which is captured from a depth of 250 to 400 m, experiences a significant drawdown of more than 20 m/s over 10 years. The relatively high salinity of the groundwater can reach 6 g/l in some areas, which has accentuated the phenomenon of soil salinization. (ANRH, 2005).

#### c) Intercalary Continental Tablecloth:

The waters of the Intercalary Continental (Albien) of this region are springing, they are captured at a depth of 1800 to 2100 m, the average flows at the head The chemical quality is generally acceptable with a dry residue of 1.8 to 2 g/l (ANRH, 2005).

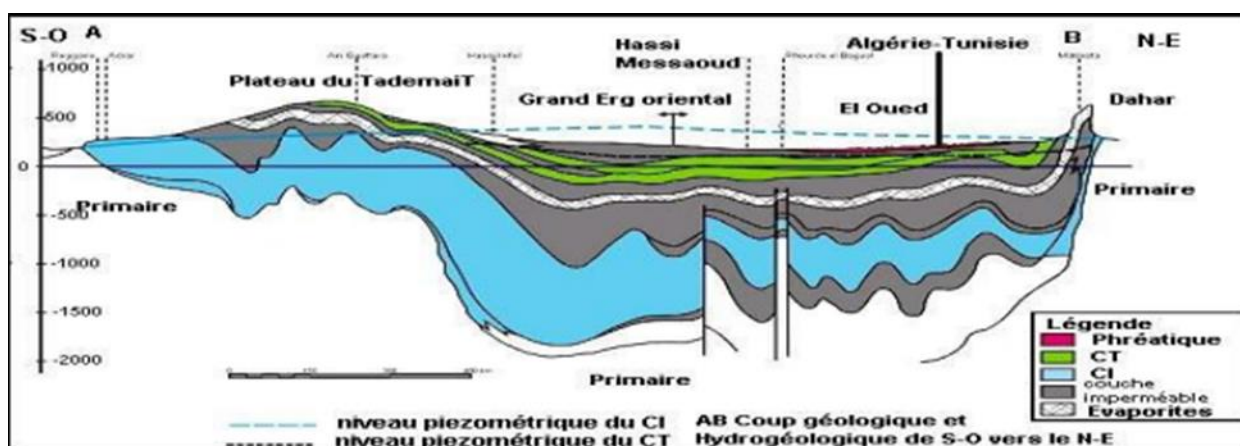


Figure16: Hydrogeological section of the Northern Sahara aquifers .

### 4.2.3. Climate Factors:

#### 4.2.3.1. Climate:

The region of El Oued is characterized by an arid climate of desert Saharan type, in winter the temperature drops below 0°C when in summer it reaches 50°C; rainfall average varies between 80 and 100 mm/year (October to February period) (DPAT, 2000).

#### 4.2.3.2. Climate data of the region:

The climate of the region of Souf is of Saharan type, desert characterized by a warm summer period, and a mild winter. The main climatic constraints are: the frequency of high winds such as sirocco and sand winds (DPAT, 2000).

Table 02: Climate data for the Souf region (2019-2020). (Source: DSA, 2019).

Climatic parameters Months	Temperature (C°)	Precipitation (Mm)	Moisture Relative (%)	Speed of Wind (m/s)
January	10.14	0	55.4	11.2
February	12.5	0	44.5	11.9
March	16.9	11.7	47	11.5
April	21.6	31.23	43.5	14.8
May	24.9	9.66	37.8	12.9
June	34.2	0	25.1	13.6
July	35.7	0	25.7	12.9
August	35.1	0	30.7	12.9
September	30.8	10.93	42.4	12
October	24	3.05	48.2	9.5
November	15.7	8.33	53.7	12.2
December	13.9	1.02	56.3	10.9
average annual	23	6.3	42.5	12.2

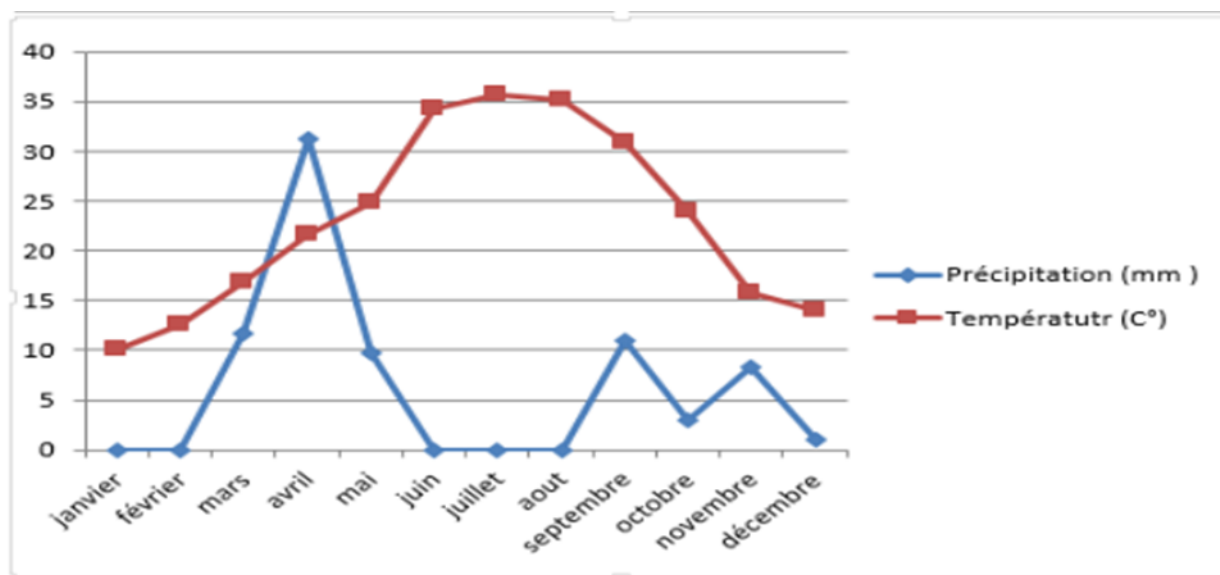


Figure17 : Diagramme ombrothermique de "Gaussen" de la région du Souf (2019-2020).

#### 4.2.3.3. Temperature:

Temperature is an important parameter for characterization Our study area (Tables 01) is characterized by the warmest month is July with 35.7C.° The coldest month is January with 10.4C. A cold period spanning from November and April with an average of 15.12C .°A warm period from May to October.

They are irregular between seasons and years. Indeed, the average precipitation is 6.3 mm/year (DSA, 2019).

From the graph of the evolution of precipitation during the year 2019 we noticed that there are months when there is no precipitation completely (January-February) and (June – July – August)

We have seen some precipitation over the months (March – May) and (September– November) In April we recorded the highest precipitation value 31.23 mm.

#### 4.2.3.4. Precipitation:

The precipitation of the Souf region is seasonal extremely variable, reach their maximum in autumn, as other winter rainy period (Voisin, 2004). The monthly precipitation values of the Souf during the year 2008 to 2018.

#### 4.2.3.5. Wind:

Wind is one of the most characteristic elements of climate (Seltzer., 1946). According to Dajoz (1996), it has an indirect effect in changing temperature and humidity. It increases plant perspiration (Elhai., 1968). The strongest winds, are those of the East blow mainly during the

## Materials and methods

period from February to August. These high sand-laden winds can have detrimental effects on crops in the region, and generate intense wind erosion dynamics (DSA., 2019).

### 5. Location of the experiment:

The experiment took place on a farm on the outskirts of Guemar city, El-Oued State and the coordinates of the geographic area as follow: 33°51'89.47" N 6°78'90.70" E.



**Photo01:** Location of the experiment (google earth 2022).

### 5.2. material:

#### 5.1. Biochar:

Biochar (BC) is the carbon-rich product obtained when obtained Biomass, such as wood, manure or leaves, is heated in a closed place. A container with little or no air available. In more technology Terms, BC is produced by what's called pyrolysis. Organic matter under limited oxygen supply (O<sub>2</sub>- and at a relatively low temperature (< 700 °C) (Lehman.,2009).

It is used to improve the physical, chemical and biological soil characteristics of sandy soils.in our experiment we produced the equivalent of 15 kilograms of biochar from palm residues according to the following process.

#### 5.1.1. Biochar preparation stages:

##### 5.1.2. Stove preparation:

We bring two barrels the first 80-litre and the second 200-litre and then we make 5 holes at the bottom of the smaller one (photo), and then we make holes along the big barrel, which allows oxygen to enter to ensure good combustion and good biochar quality.

## Materials and methods

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We weld a pipe in the big barrel hood to make it easier for smoke and carbon to come out (photo03)



**Photo02:** Drums hole to enter the air.



**Photo03:** Welding the tube in the lid to simulate the chimney.

### 5.2. Biochar preparation stages:

We chop the palm residue into small pieces to get it full-blown, and then we fill the small barrel with it, and we close it tight.

## Materials and methods

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**Photo 04:** Cut the waste and put it inside the barrel.

We put the small barrel inside the larger barrel and fill the vacuum between them with wooden pieces or palm residue itself to be burned like it is shown in photo, and then we close the large barrel tightly and blaze the wooden pieces that are in between the barrels.



**Photo05:** The beginning of the combustion process.

After about 5 hours, the process is over, and the waste is burnt. Through the experiment we found that every 14 kilograms of palm residue after the charred process gives about 4.5 kilograms of biochar (photo) which is approximately 30 fresh biomasses



**Photo06:** Final product.

### **5.3. Preparing biochar for use in the experiment:**

Biochar grinding requires several hours and we need a bucket and wooden stick, we hand grinded the biochar well by wooden stick to turn it into powder. It is important process for batter heterogeneity later with manure.



**Photo07:** Biochar powder.

### **The manure:**

We used the chicken residue fertilizer that we brought from one of the farms in the area that was going to use for Planting potatoes.

## Materials and methods

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### 5.4. Plant material:

#### 5.4.1 Potatoes seed cultivar (Bartina):

##### 5.4.1.1. Taxonomic position:

(USDA (United States Department of Agriculture), NRCS (Natural Resources Conservation Service):

**Kingdom:** Plantae (plants)

**Subkingdom:** Tracheobionta (vascular plants)

**Superdivision:** Spermatophyta (seed plants)

**Division:** Magnoliophyta (flowering plants)

**Class:** Magnoliopsida (dicotyledons)

**Subclass:** Asteridae

**Order:** Solanales

**Family:** Solanaceae

**Subfamily:** Solanoideae

**Genus:** Solanum L. (Linnaeus)

**Section:** Petota

**Subsection:** Potatoe

**Series:** Tuberosa

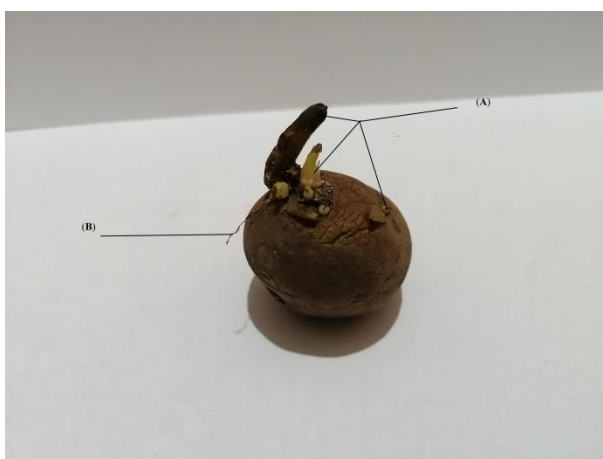
**Species:** Solanum tuberosum L. (Linnaeus)

#### 5.4.2. Information of the used potatoes seeds:

In our experiment, we used potato seeds imported from the Netherlands diversity Bartina, which have many characteristics, including salinity, poor ground nutrients and good market demand. From the information sign we read that the Bartina seed imported from the Netherlands was harvested on 15/11/2021.

## Materials and methods

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**Photo08:** Potatoes seed (A): potatoes shoots (B): root.

### 5.4.2.1. Properties of potatoes Bartina variety:

**Name:** BARTINA

**Parentage:** SATURNA X ZPC 62-75

**Maturity:** MEDIUM

**Table03:** Properties of potatoes diversity bartina.

<b>Development</b>	<b>shape</b>	<b>Resistance</b>
<b>Leaf development good</b>	<b>Tuber's shape short oval</b>	<b>virus Y: medium</b>
<b>Eye depth shallow</b>	<b>Skin colour red</b>	<b>Virus X: medium</b>
<b>Size of tubers large</b>	<b>Flesh colour yellow</b>	<b>Wart disease:</b>
<b>Yield high</b>	<b>Dry matter content medium</b>	<b>PLRV: slightly susceptible</b>

### 5.4.3. Preparation of potatoes for planting:

We brought 7 kilograms of potato seeds we picked Bartina-imported potatoes ,and we split them into pieces so that each part has eyes to grow in the future.We got 180 parts, so every square has 6 parts .

## Materials and methods

### 5.5. Methods:

#### 5.5.1. Calculation:

We used 1.44 kilograms per 0.36 m<sup>2</sup> of poultry excrement, and that's what farmers currently use, so that for every hectare 40 tons of poultry excrement is used. We divide 40 tons over 1 hectare.

How we calculate:

$$40 \text{ tons} = 40000\text{kg} \quad 1\text{hectare} = 10000\text{m}^2$$

$$\frac{40000\text{kg}}{10000\text{m}^2} = 4\text{kg}/\text{m}^2$$

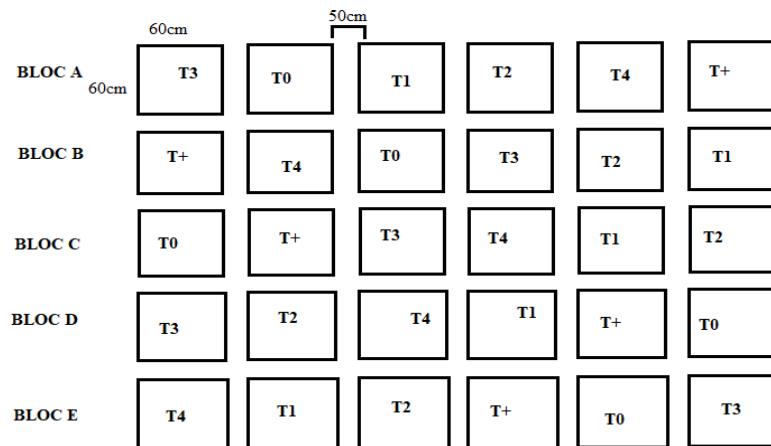
For every square meter, it means 4 kilograms of manure. So, we have 0.36 m<sup>2</sup>

$$4\text{kg} \rightarrow 1\text{m}^2$$

$$? \rightarrow 0.36\text{m}^2$$

$$\frac{4 \times 0.36}{1} = 1.44\text{kg}$$

#### 5.5.2. Experimental design:



**Figure18:** An outline explaining our experimental design. T+ sand, T0 Poultry manure, T1, T2, T3, T4 Poultry manure+ biochar.

#### 5.5.3. Treatments:

The treatments were as follow:

## Materials and methods

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**T +:** 0 %Poultry manure, 0% bio char

**T0:** 100 % Poultry manure (1.44kg)

**T1:** 90 % Poultry manure (1.3kg) +10% biochar (0.14kg)

**T2:** 80 % Poultry manure (1.15kg) + 20% biochar (0.29kg)

**T3:** 70% Poultry manure (1kg) + 30% biochar (0.44kg)

**T4:** 60% Poultry manure (0.86kg) + 40% biochar (0.58kg)

### 5.5.4. Field experiment:

We started our experiment on 06/12/2021, we prepared the necessary amount of biochar, then on 08/01/2022 we installed the greenhouse with an estimated area of 64 square meters.



**Photo09:** The greenhouse preparation

On 02/02/2022 we prepared the soil, started deep tillage of the soil, then settled the soil, and then we divided it into squares according to the work plan and appropriate to the study.

## Materials and methods

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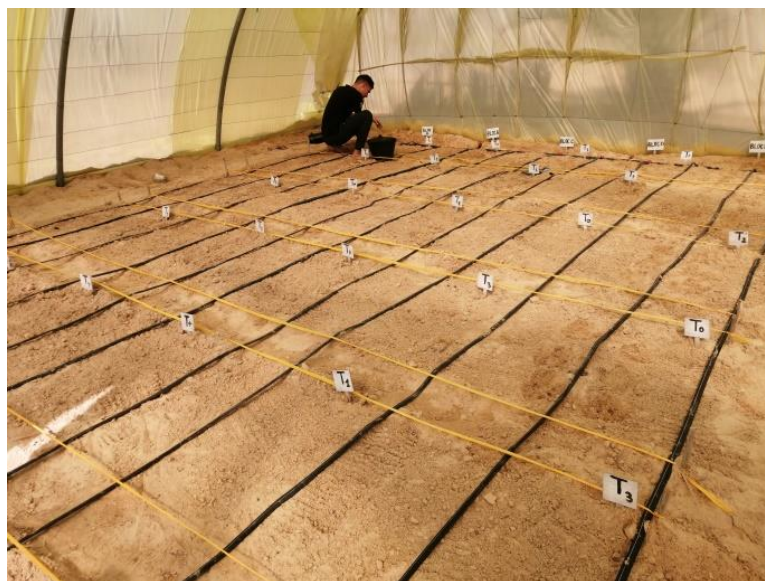
**Photo10:** Deep tillage of the soil and dividing it into squares.

We added the right mixture to each square, distributed randomly, and each square held a label, and then we mixed the soil well for each square.



**Photo11:** Distribution of the mixture to each square.

We grew potatoes on 12/02/2022 at an estimated depth of 7 to 10 centimeters and an estimated distance of 25 to 30 centimeters watered by the drip system.



**Photo12** : Planting potato seeds.

### **5.6. The parameters studied:**

#### **5.6.1. Parameters analysis:**

##### **5.6.1.1. Measures soil moisture:**

To measure soil moisture, we use a device that measures moisture and gives us value (annexes), and that's to study the impact of biochar on soil in each different treatment we've done.

##### **5.6.1.2. Measure soil pH:**

pH reflects the degree of acidity or alkalinity (basicity) of the water in contact with the soil water pH. Through its interactions with many chemical and biological processes, the pH conditions and reflects the availability of elements in the soil.

We add 20 grams of soil in becher, and then we add 50ml of distilled water to it, and then we mix the solution well, and we filter it with filter paper, and we take the slug, and we put in the poles of the meter to measure the acidity.

##### **5.6.1.3. soil salinity:**

###### **5.6.1.3.1. Effects of salinity on plants and soil:**

The accumulation of salts in soils is a serious environmental problem threatening the plant physiological processes and soil fertility. (**Halitim., 2011**).

## Materials and methods

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In saline soils, the excessive presence of neutral soluble salts flocculates the fraction clay, but keeps them stable, while in alkaline soils an excess of sodium Exchangeable promotes the dispersion of clay and makes the soil structure unstable.

add 20 grams of soil in Becher, and then we add 50ml of distilled water to it, and then we mix the solution well, and we filter it, and we take the solution we filtered, and we put in the poles of the meter to measure the salinity.



**Photo13:** Measurement of soil pH and salinity (Original 2022).

### 5.6.2. Biological analysis:

#### 5.6.2.1. Microbiological Analysis:

##### I)Method of Numeration of Microflora:

For bacteria count there are two types of techniques. The first method consists of indirect counting on solid culture media. The second method consists of direct counting by microscopic observation. In our study, we adopted the first method.

The technique used for the enumeration of telluric germs includes several steps from the preparation of the suspension dilutions to the interpretation of the results .

## Materials and methods

The measurement of microbial densities by the technique of soil suspensions and dilutions is a good general indicator. This measure is easy to implement, economical, and reliable and reproducible results.

### II)Preparation of Decimal Dilutions of Soil Solution:

The cascade dilution consists of passing the (basic) solution (SM)to a much lower dilution, which can be 4-5 depending on the need .In general, a cascade dilution in microbiology is intended to count the bacteria present in a given sample, as the number of bacteria in a pure sample is too large to be counted, so it is appropriate to dilute the samples.

First, the soil is suspended as homogeneously as possible (1 g of soil and 9 ml of physiological water), from this (SM) with a concentration of  $10^{-1}$ , a series of dilutions are prepared (of  $10^{-1}$ until dilution  $10^{-5}$ ). The dilutions thus prepared must be used immediately for the different seedings. Three replicates have been carried out for each dilution in solid medium and the values expressed are the average of the three replicates.



**Photo14:** Decimal Dilutions of Soil Solution (Original., 2022).

#### a) The Bacteria :

To get bacteria from the soil, just put a few grams of soil suspended in water.

After stirring and settling, we calibrate two (02) drops of the supernatant on the surface of a suitable agar culture medium.

## Materials and methods

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The quantity of bacteria being considerable, it is always dilutions of the initial suspension that are put in culture.

Colonies are then obtained that are separated from each other, each of which in principle comes from a single bacterium.

For counting soil bacteria, we use the nutrient agar culture medium. Reading the results by counting the colonies. After placing them in the oven for 4 days at 30 °C.

### **b) The fungal activity :**

For the enumeration of soil fungi, we use the **PDA** culture medium: potato extract medium, dextrose medium and agar medium. Reading the results by counting the colonies. After placing them in the oven for 4 days at 28°C.

## **5.6.3. The development and production parameters of potatoes:**

### **5.6.3.1. Biometric parameters:**

It's important to collect data on plant growth at different stages of evolution, so that these data help a lot and are very important in interpreting the overall plant later.

The potato development cycle is annual and includes: planting, development, flower formation, blossoming, fruiting, drying and tuber maturation.

### **a) Percentage appearance of plants :**

We calculate the proportion of plants that have appeared above the soil surface.

Percentage of plant appearance = total number of plants shown / total number of darts planted after 50 days.

### **b) The leaves:**

Monitor and follow up on develops paper in size, and paper area, giving general plant status indicators, which we use to explain several phenomena, so we make measurements at the age of 50-75-90 days of potato to make sure that there's any change in any of the test squares and compare it with other processors.



**Photo 15: Leaf measurements.**

**b.1.) Leaf area index (LAI):**

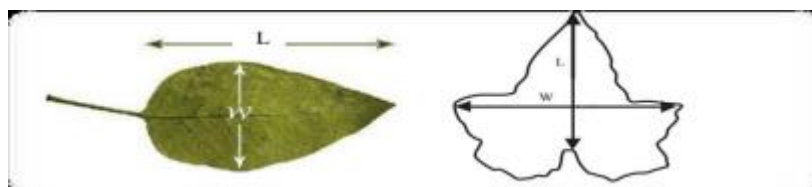
The paper area and area of the paper surface were determined by the method of measuring the height and width of the foliage of the plant leaves, which was maintained in the plant.

The measurements of the leaves were 3.4.5, at Three different stages of plant life in days 50, 75, 100 per five plants per transaction, and measuring the length and width of three leaves per compound sheet, and taking the average to determine the area of the leaf and the paper surface .

**b.2.) Leaf and plants surface CM<sup>2</sup>:**

$$\text{leaf area(cm}^2\text{)} = \text{leaf length} \times \text{leaf width} \times \text{Potato leaf form factor (674.0)}$$

**plants surface cm<sup>2</sup>/plant** = The surface of the leaves x the number of leaves x the number of papers



**Figure 19: Method of measuring paper area.**

**C) Average stem length (plant height):**

We measured stem length by ruler from the soil surface to the top leg end of the plant at three stages of plant life in days 50-78-90 days.



**Photo 16:** Stem measurements.

### **d) Tubers:**

Tubers is the part responsible for storing nutrients needed by both plant and human, so our goal is to get tubers of excellent quality, so our art monitors the state of the plant in each square of the experiment and compares it with other squares to explain the results later.



**Photo 17:** Tuber measurements.

### **e) Characteristics of productions:**

**Average number of tubers in the plant:** weigh the number of tubers per treatment and divide them by the number of plants

## Materials and methods

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**Average tubers weight (g):** We divide the total weight of tubers by the number of tubers per treatment

**Average tubers production:** Average plant crop (tubers/treatment) = total number of tubers of experimental treatment / total number of the same experimental treatment

**Percentage of marketing tubers:** determined by average marketable production only, as expressed by Zamotaeva (1997) in standard tubes weighing at least 40 g

**Average production per area (tons/hectare):**

The production in each pilot unit was calculated based on the area under cultivation in hectares, and then calculated the average duplicate trial units for each transaction according to

the following formula: Average production (Tons/Hectare) = Average Production of Experimental Modules (Ton)x10000m<sup>2</sup>/ Experimental Unit Area m<sup>2</sup>

# Results and discussion

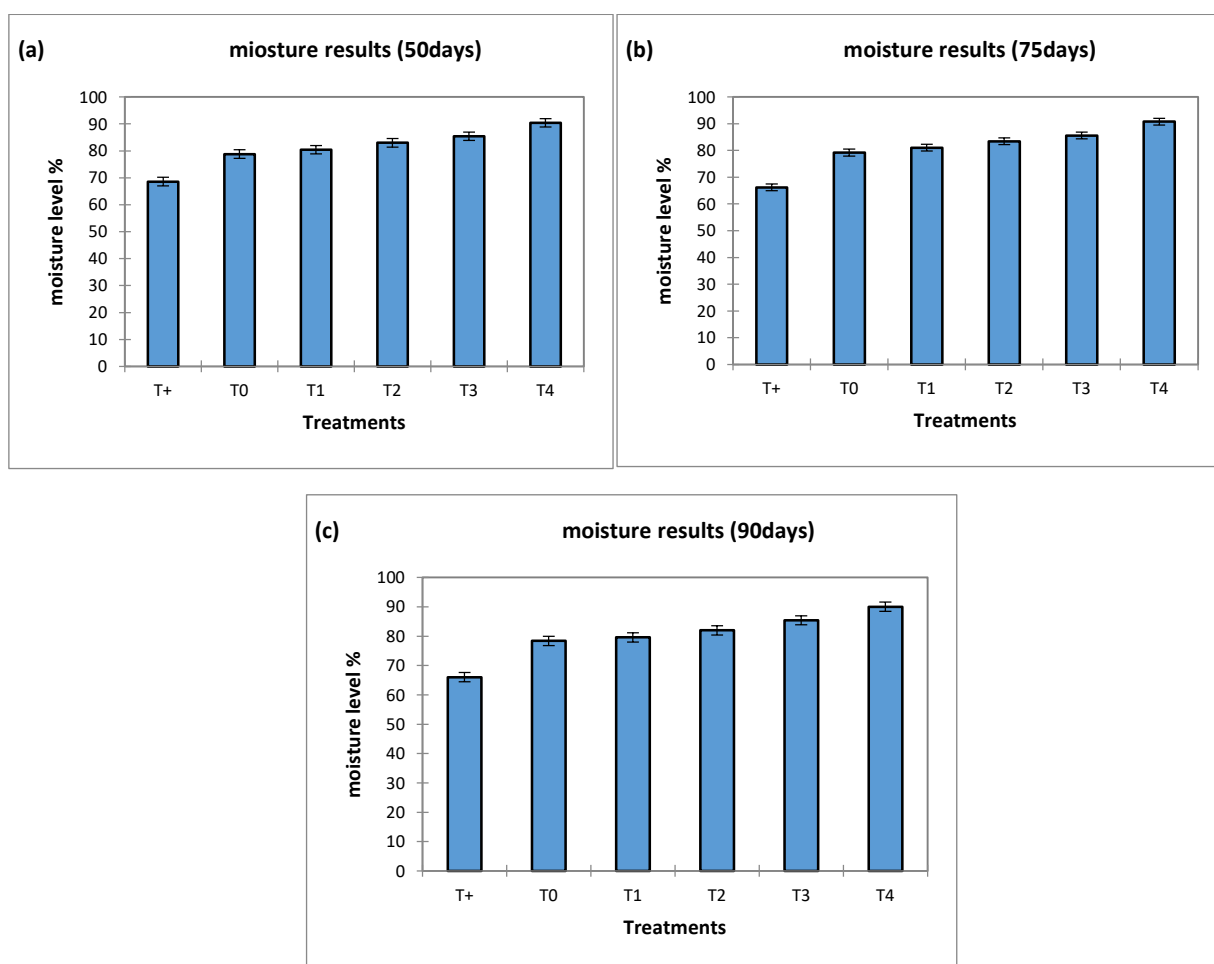
## 6.results and discussions:

In this chapter, we will present the results and discussions based on the data obtained by the evolution of sandy soil with biochar to act on its physical properties, chemical and biological translated by the study of its influence on potato growth.

### 6.1. The parameters studied:

#### 6.1.1. Physical analysis:

##### 6.1.1.1. Result measure moisture:



**Figure 20:** Moisture measurement results (a), (b) and (c) represent respectively (50, 75 and 90 days after planting). **T+** (control) **T0** (100% Poultry manure) **T1** (90% Poultry manure + 10% biochar) **T2** (80% Poultry manure + 20% biochar) **T3** (70% Poultry manure + 30% biochar) **T4** (60% Poultry manure (0.86kg) + 40% biochar).

From the figure 20 we note that there is a correlation between the biochar proportion and the increased to 80 in T3 and almost 90% in T4. The biochar has a positive effect in water retention, this effect was highly significant according to Duncan test ( $p=0.00$ ), (table 04).

## Results and discussion

**Table 04:** Soil measurements moisture data.

	50	75	90
T4	90,400 a a	90,800 a a	90,000 a a
T3	85,400 b b	85,600 b b	85,400 b b
T2	83,000 bc c	83,400 bc c	82,000 c c
T1	80,400 cd d	81,000 cd d	79,600 cd d
T0	78,800 d d	79,200 d e	78,400 d d
T+	68,600 e e	66,200 e f	66,000 e e
Pr > F	0.000	0.000	0.000
Significant	Yes	Yes	Yes

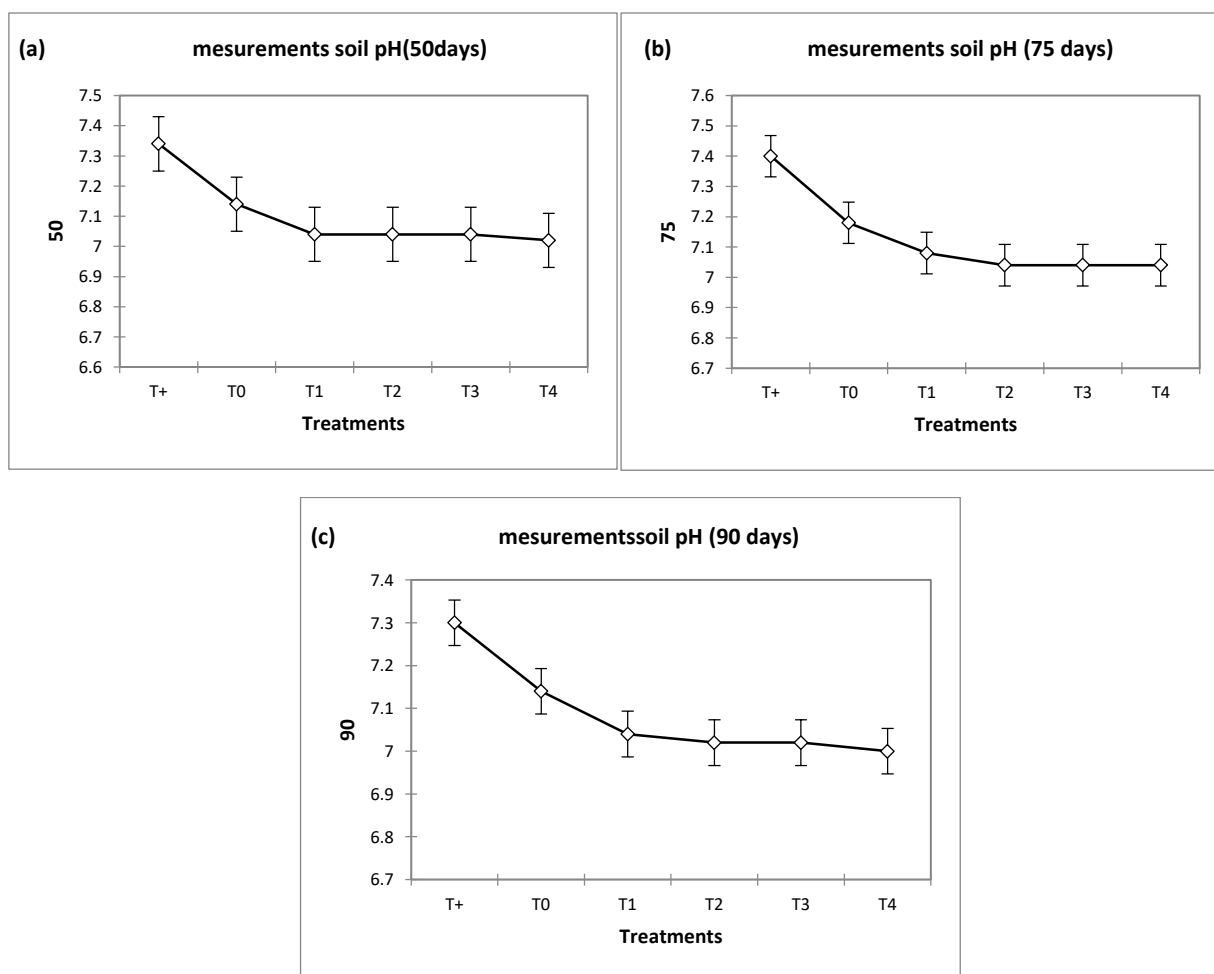
The results in our study show that biochar have a positive effect on moisture of soil because it increases its levels according to (Haidera et al., 2017) generally biochar amendment improved soil moisture contents in the topsoil (0–15 cm where biochar was incorporated) during the experimental period (nine out of thirteen sampling dates) however, not as frequent as expected, a significantly higher moisture content increasing with increasing rate of biochar application for every date of soil sampling. However, the observed improvements in soil moisture contents did not promote a significant yield increase during the study period Agegnehu et al., (2016a); Karer et al., (2013); Liu et al., (2012); Mulcahy et al., (2013); Rogovska et al., (2014); Zhang et al., (2016a) Reported that Biochar amendments also improved soil moisture contents which is in accordance with other studies under different soils, biochar and environmental conditions.

Soil moisture improvement due to biochar addition was mainly attributed to changes in soil bulk density. Biochar retained more water as compared with other carbon sources possibly because of its porous structure and extremely high surface area. This structure changes the physical properties of the soil, creating a reef-like structure (Herath et al., 2013).

### 6.1.2. Chemical analysis:

#### 6.1.2.1. Measurements soil pH:

## Results and discussion



**Figure 21:** Soil pH measurement results (a)(b) and (c) represent respectively (50.75.90. days). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

From the curve in (figure 21) we note that the variation in pH value at different periods as we note that in the absence of biochar the pH is high at 7.4 and decreases when the biochar is high ratio "inverse relationship". Biochar has a clear effect on PH and this effect has statistical significance (Table 05) according to Duncan test (P=0.000).

**Table 05:** Soil pH results data.

	50	75	90
T+	7,340 a a	7,400 a a	7,300 a a
T0	7,140 b b	7,180 b b	7,140 b b
T1	7,040 b b	7,080 b c	7,040 bc c
T2	7,040 b b	7,040 b c	7,020 c c
T3	7,040 b b	7,040 b c	7,020 c c
T4	7,020 b b	7,040 b c	7,000 c c
Pr > F	0.000	0.000	0.000
Significant	Yes	Yes	Yes

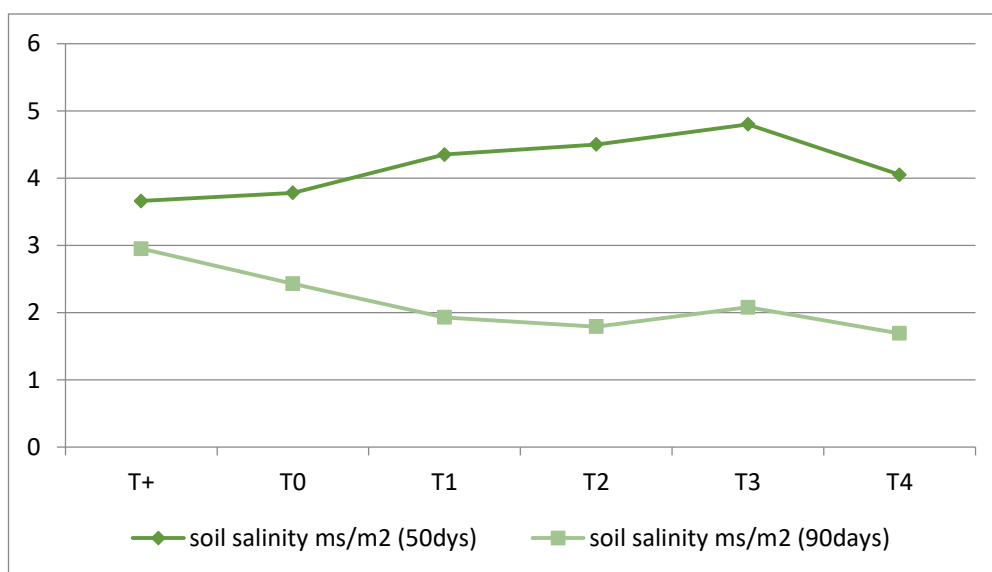
## Results and discussion

Our results indicated that the biochar application decreases the pH level. Similarly, **Khaled et al., (2019)** found that the enriched biochar by rock phosphate and cow manure reduced the soil pH by 0.14 unit but not in the simple biochar. **Khaled et al., (2019)** reported a decrease of 0.2-unit soil pH due to the addition of a date palm residues biochar. In contrast **Streubel et al., (2011)** reported an increase of 0.8–0.1 unit in the soil pH due to the addition of various biochar to the soil.

Although in most studies in literature indicated that BC is alkaline, and therefore its capacity on increasing acidic soil pH was demonstrated whereas its impact on alkaline soil pH is expected to be minimal [5–7]. But in our study, we noted a decrease from 7.4 to 7 by biochar application. Probably this decrease is due to the high CEC of biochar. Similarly, **Amini., (2015)** reported measurable decrease in pH of the salt-affected soils due to the application of acidized biochar.

Increase in soil pH may be related to some chemical oxidation and microbial decomposition of biochar in soil, resulting in acidic compounds being produced and therefore lowering soil pH. This may be more evident with low-temperature biochar which is expected to go through microbial decomposition to some extent. **Khaled et al., (2019)** reported That effect of biochar 300 treatment in this study can support this explanation.

### 6.1.2.2. Soil salinity:



**Figure 22:** Soil salinity ms/m<sup>2</sup> results (50.90days after planting). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure (0.86kg) + 40% biochar).

## Results and discussion

We note from (figure 22) that the salinity level in T3 is high by 4.8 ms/m<sup>2</sup> in duration (50days) followed by T2, T1, T4, T0 and T+ respectively and in duration (90days) we note a decrease in salinity level for each transaction so that T+ is the highest value at 2.95 ms/m<sup>2</sup>.

In our study the biochar has impacted the electrical conductivity (EC), this impact was a decrease in salinity level from 2.95 ms/m<sup>2</sup> to 1.69 ms/m<sup>2</sup>. **Yue et al. (2016)** reported that the biochar-amended columns discharged efflux 24 to 40 days earlier, with that efflux having EC decreased to 5 dS m<sup>-1</sup> 56 to 62 days earlier, than the control without biochar. On the contrary (**Abrishamkesh et al. 2015**) reported that the Soil EC increased in proportion to the biochar application rates. But only the highest rate of the biochar application (3.3%) had significantly higher EC compared to the control soil. The increase in EC can be attributed to high amount of ash in the biochar. **Chaganti et al., (2015)** also noted measurable decreases in (EC) of a saline-sodic soil by 84, 83 and 82% under, respectively, biochar, biosolids compost and green waste compost compared to the non-amended control soil because of improvements in soil hydraulic conductivity facilitating leaching of salts.

Reduction in (EC) and salinity stress with biochar amendments to the adsorption/retention of salts such as Na on the biochar surfaces, or physical entrapment of salts in fine pores of biochar, that decreased salt concentration in soil solution, and biochar-induced reduction in the upward movement of saline water (biochar cover reduced evaporation) resulting in decreased salt accumulation in surface soils. Depending upon biochar type, aging time and strength of salt attraction on biochar, salts adsorbed by biochar or entrapped in fine pores may be released back into soil solution with time (**Akhtar et al., 2015**).

### 6.1.3. Biological analysis:

#### 6.1.3.1. Microbiological Analysis

##### a) The Bacteria:

**Table 06:** Counts of bacterial colonies after 90 days at the end of experiment. **T+**(control) **T0** (100) % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure (0.86kg) + 40% biochar).

	T+	T0	T1	T2	T3	T4
<b>After Experimental CFU/ml</b>	8.5X10 <sup>3</sup>	3.3X10 <sup>4</sup>	5X10 <sup>4</sup>	5.4X10 <sup>6</sup>	5.6X10 <sup>6</sup>	7.5X10 <sup>6</sup>

## Results and discussion

We note from (Table 05) that the number of bacterial colonies is high in T4 compared to other treatment T3, T2 and T1, where each of them has lower by lower biochar ratios, respectively.

### b) The fungi

**Table 07:** Counts of fungal activity after 90 days at the end of experiment. **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

	T+	T0	T1	T2	T3	T4
After Experimental CFU/ml	$6.3 \times 10^3$	$3.2 \times 10^5$	$4.3 \times 10^4$	$7 \times 10^5$	$5.5 \times 10^6$	$5 \times 10^6$

We note from (Table 06) that the number of fungi colonies is high in T3 compared to other treatment T4, T2 and T1, where each of them has lower by lower biochar ratios, respectively.

Biochar application has a positive effect on the increased activity of microorganism. Biochar generally exerts positive effects on soil microbial biomass (**Gul et al., 2015**). It was reported that the increase of soil pH after biochar addition was the main factor affecting microbial abundance and community, rather than other nutrient factors such as total C and N contents (**Nielsen et al., 2014**).

This is consistent with the results of our study which indicated that biochar works to correct the pH ratio. Biochar buffering capacity Increasing the soil buffering capacity reduces the nutrient loss and prevents the nutrients from leaching (**Havlin et al., 2005**).

Biochar affects the soil microbial activity and biomass, changes the soil bacteria to fungi ratio and soil enzyme activity, and reshapes the microbial community structure (**Ahmad et al., 2016**).

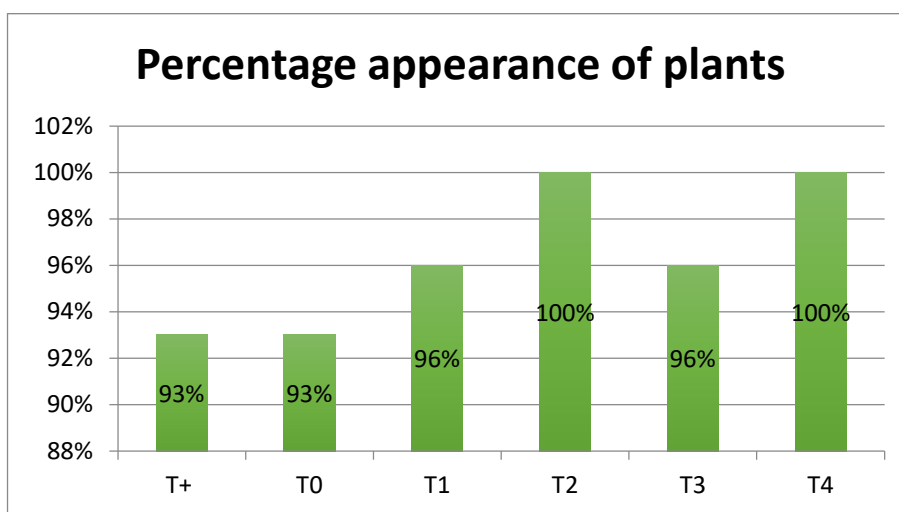
Microorganisms can also change the properties of biochar, especially when causing it to oxidize the surface of particles, which increases the oxygen content (from 7% to 24%). Carbon content decreases (from 91% to 71%) in biochar particles (**Cheng et al., 2008**). These results in the formation of oxygen-containing groups, which form negatively, charged surfaces, leading to a greater cation exchange capacity (CEC) of biochar (**Glaser et al., 2002**)

Hence, there is probably a circular relationship between biochar, pH and microorganisms where organisms affect biochar and in turn affect organisms and each have an effect to buffer the pH level

6.1.4. Development and production parameters of potatoes:

6.1.4.1. Biometric parameters:

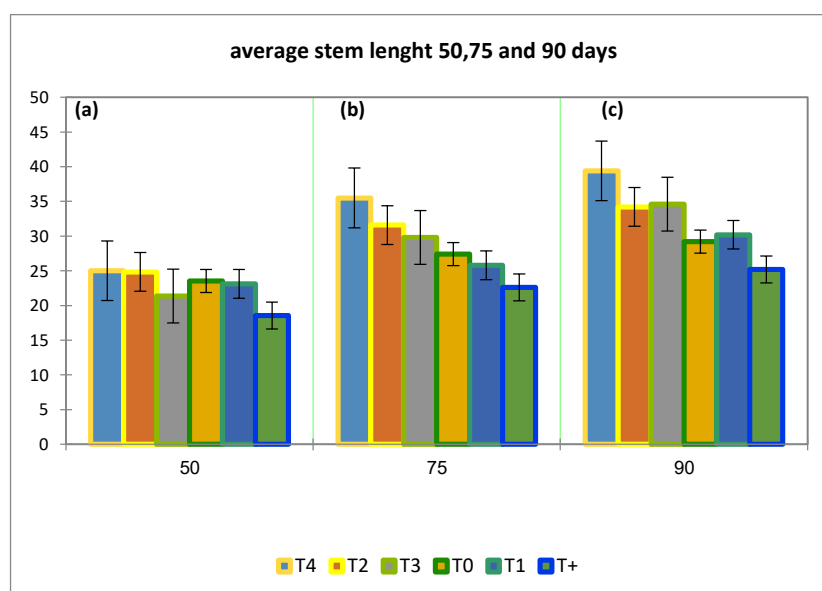
6.1.4.1.1. Percentage appearance of plants:



**Figure 23:** Percentage appearance of plants after 50 days. **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

From the column chart (figure 23) that the rate of plant appearance is 100 % in T4, T2 while less than 100 % in T3, T1, T0, T+ respectively.

6.1.4.1.2. Average stem length (plant height):



**Figure 24:** Average stem length (plant height) (a), (b) and (c) represent respectively (50,75 and 90 days after planting). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

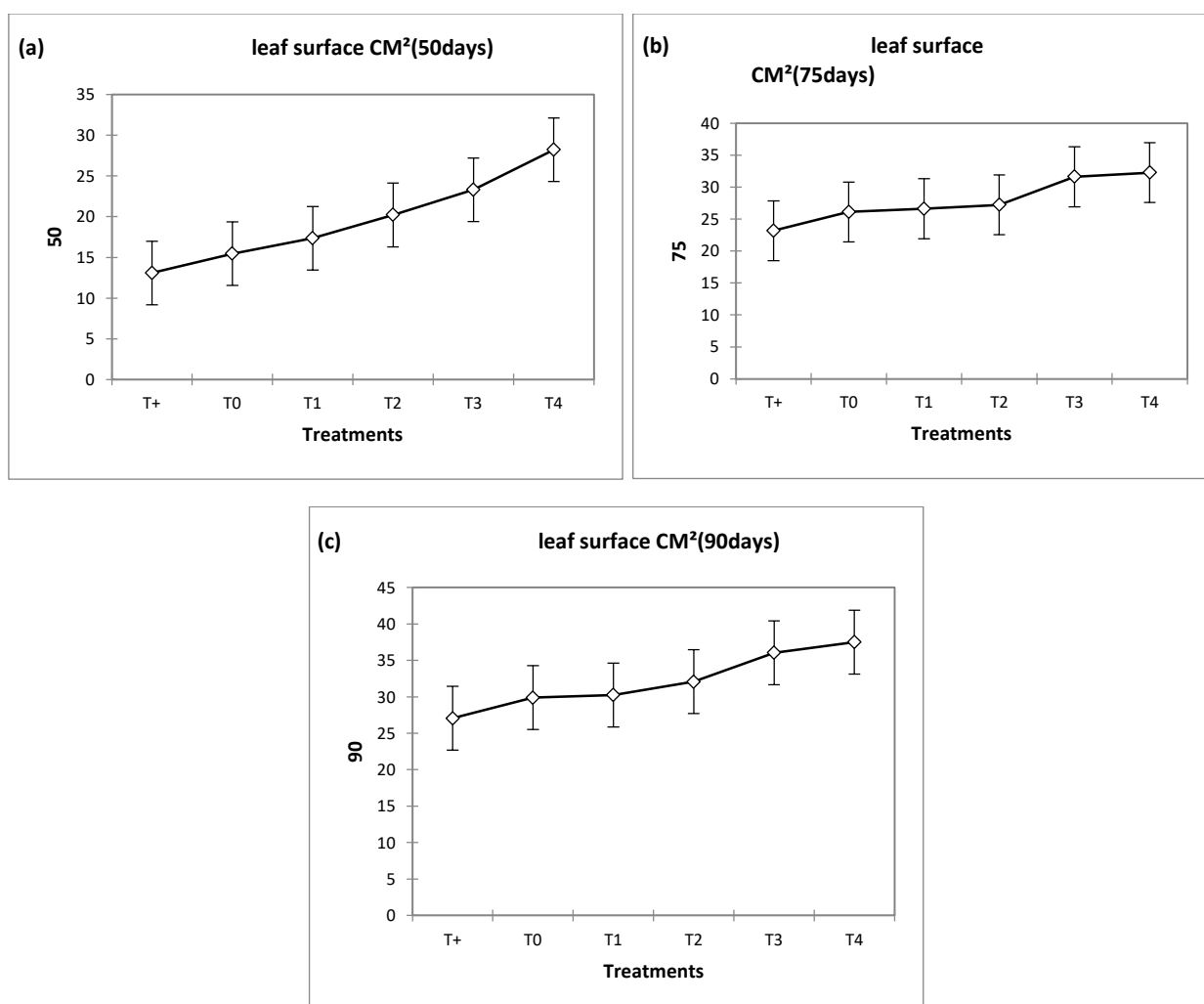
## Results and discussion

We note from the results in (figure 24) that the higher the stem is visibly increased the higher the incidence of biochar at different stages of plant growth 50 .75. 90 .What makes biochar have a positive effect on plant growth, depending on (table 08) it has a statistical significance in the duration ranging from (75 to 90) (P=0.006) and (P=0.000) respectively according to Duncan test.

**Table 08:** Plants stem height (stem length) data.

	50	75	90
T4	25,000 a a	35,500 a a	39,400 a a
T2	24,844 a a	31,600 ab ab	34,200 ab ab
T3	21,360 a a	29,800 ab ab	34,600 ab ab
T0	23,540 a a	27,400 ab bc	29,200 bc bc
T1	23,114 a a	25,800 b bc	30,200 bc bc
T+	18,568 a a	22,600 b c	25,200 c c
Pr > F	0.352	0.006	0.000
Significant	Non	Yes	Yes

### 6.1.4.1.3. Leaf and plants surface CM<sup>2</sup> :



**Figure 25:** Average leaf surface CM<sup>2</sup> (a), (b) and (c) represent respectively (50,75, and 90 days after planting). T+(control) T0(100 % Poultry manure) T1(90 % Poultry manure +10% biochar)

## Results and discussion

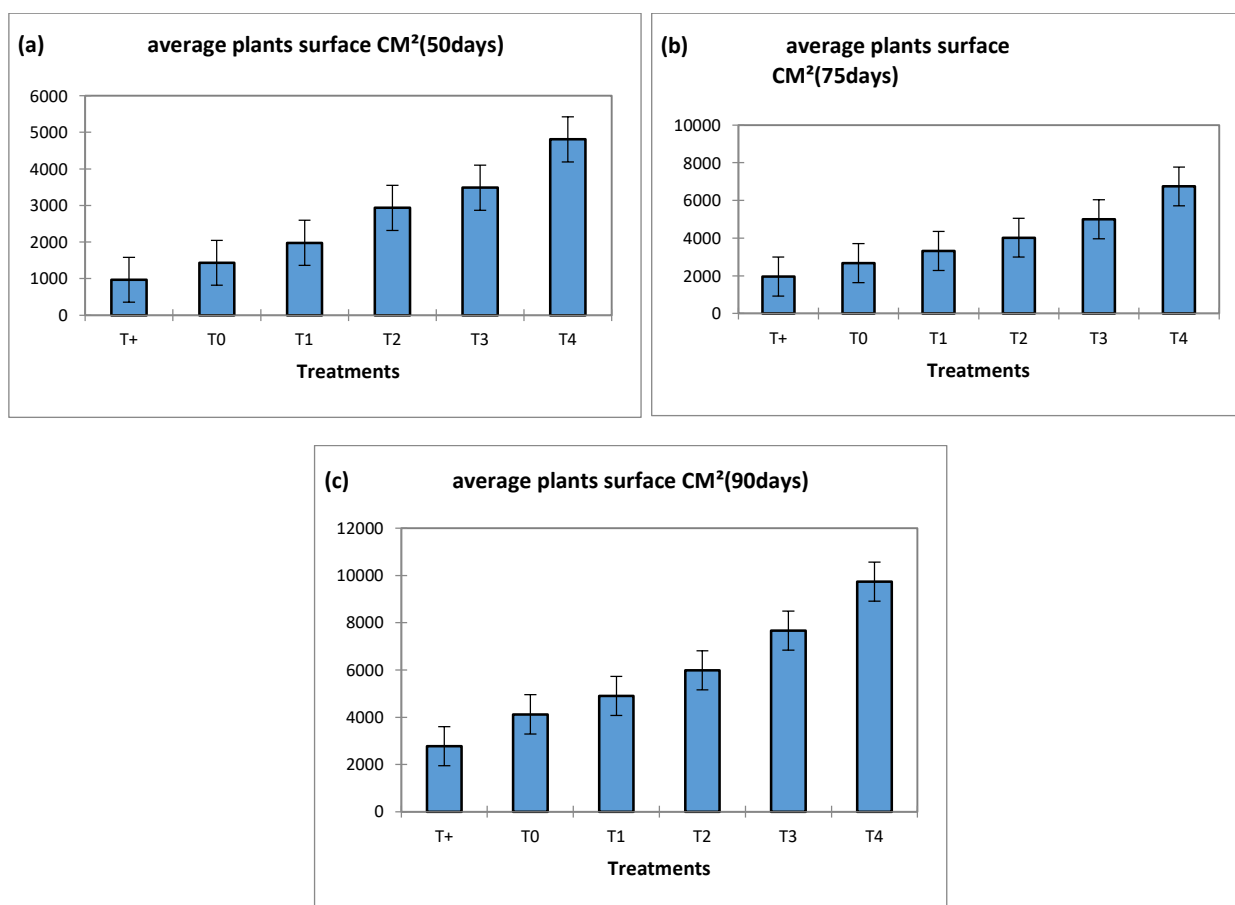
**T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

From the results (figure 25) that the higher the percentage of biochar the greater the size of the paper (positive correlation) where T4 is the highest value at all stages of plant growth according to (Table 09) it has a statistical significance in both (50 days and 90 days) according to (Duncan) test ( $p=0.000$ ).

**Table 09:** Leaf surface measurements data.

	50	75	90
T4	28,222 a a	32,266 a a	37,507 a a
T3	23,312 ab ab	31,616 a a	36,048 ab ab
T2	20,214 abc bc	27,230 a ab	32,070 ab abc
T1	17,350 bc cd	26,612 a ab	30,244 ab bc
T0	15,458 bc cd	26,114 a ab	29,884 ab bc
T+	13,082 c d	23,174 a b	27,052 b c
Pr > F	0.000	0.072	0.016
Significant	Yes	Non	Yes

### 6.1.4.1.4. Average plants surface:



**Figure 26:** Average plants surface CM<sup>2</sup> (50,75 and 90 days after planting). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

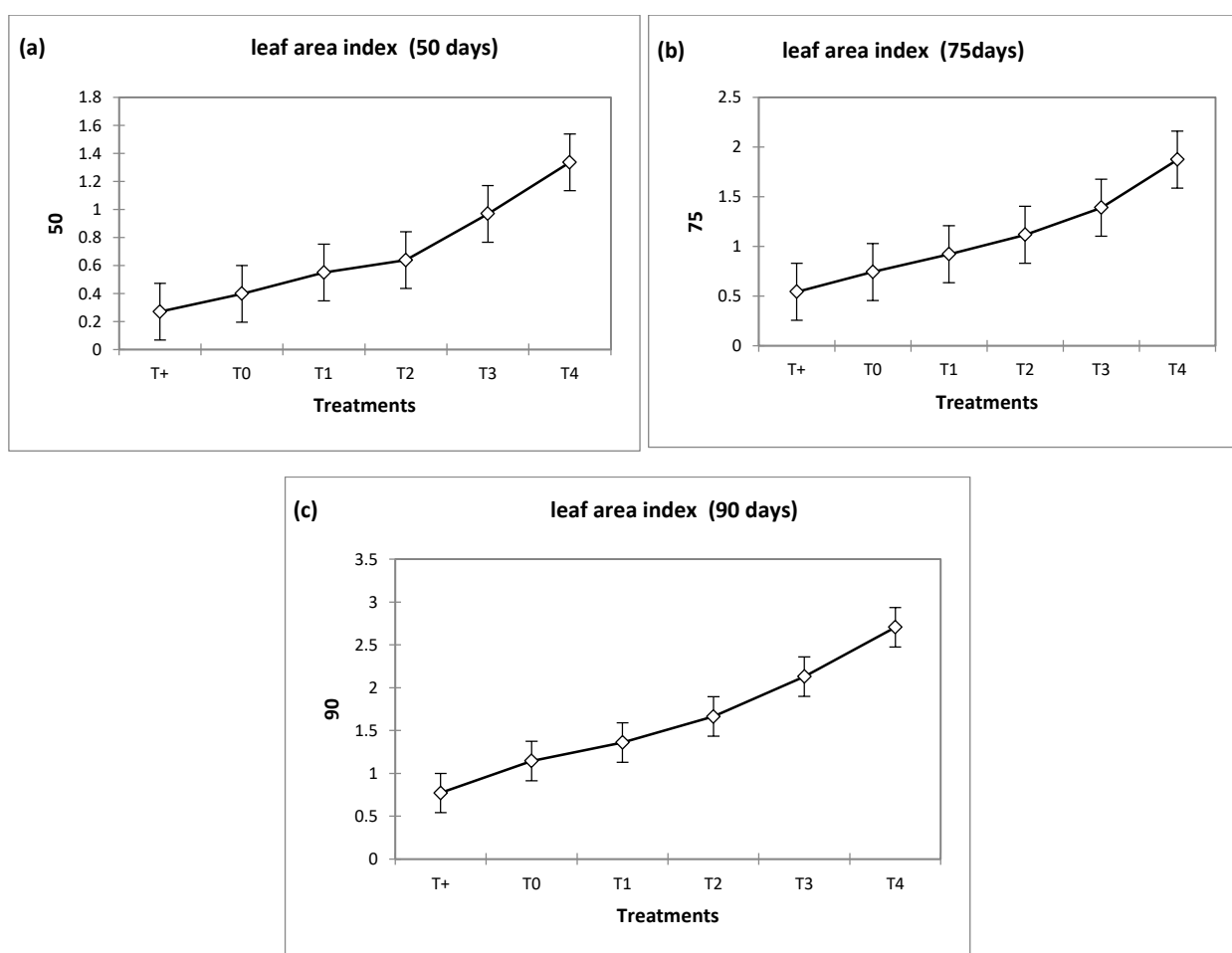
## Results and discussion

We note (figure 26) that the greater the plant area, the greater the incidence of popcorn, the more the biochar has a positive effect on the plant's area. The plant area in T4 is larger and decreases in T3. T2. T1. T0. T+ respectively depending on (Table 10) The effect of biochar has a statistical significance according to the Duncan test ( $P=0.000$ ).

**Table 10 :** Plants surface results data.

	50	75	90
T4	4809,029 a a	6742,540 a a	9743,883 a a
T3	3487,475 b b	5002,080 ab b	7669,608 b b
T2	2935,073 bc b	4022,502 bc bc	5987,705 bc c
T1	1977,900 cd c	3320,240 bc cd	4900,988 cd cd
T0	1434,502 d cd	2675,856 c cd	4121,968 de d
T+	970,684 d d	1955,814 c d	2775,856 e e
Pr > F	0.000	0.000	0.000
Significant	Yes	Yes	Yes

### 6.1.4.1.5. Average leaf index (LAI) :



**Figure 27:** Average Leaf Area Index (LAI) (50,75 and 90days after planting). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

## Results and discussion

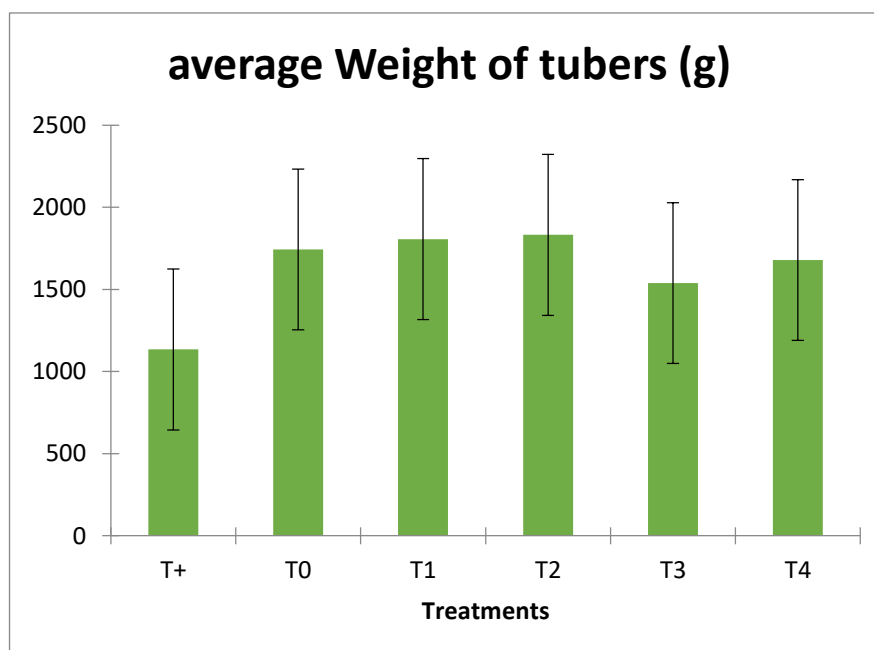
We note from the curve (figure27) that (LAI) increases the higher the percentage of biochar in the soil, where we recorded the largest area acquired by the plant in T4 and decrease in (T3.T2. T0. T+. T1) respectively by (table 11) The biochar has a clear effect and statistical significance so that by Duncan test (P=0.000).

**Table 11:** Leaf area index (LAI) data.

	50	75	90
T4	1,336 a a	1,873 a a	2,707 a a
T3	0,969 ab b	1,389 ab b	2,130 b b
T2	0,638 bc c	1,117 bc bc	1,663 bc c
T1	0,549 bc cd	0,922 bc cd	1,361 cd cd
T0	0,398 c cd	0,743 c cd	1,145 de d
T+	0,270 c d	0,543 c d	0,771 e e
Pr > F	0.000	0.000	0.000
Significant	Yes	Yes	Yes

### 6.1.4.1.6. Average tubers weight (g):

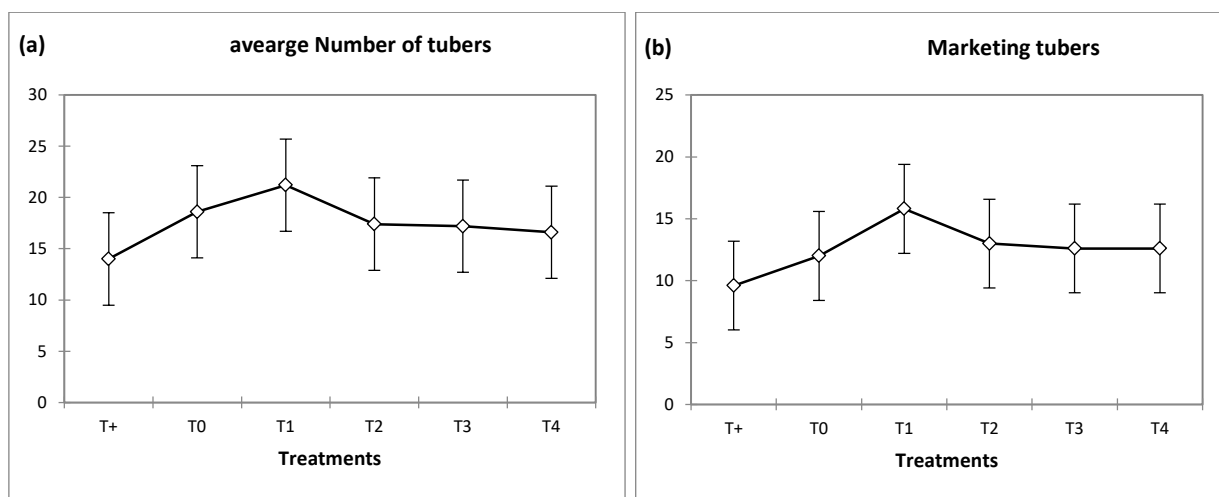
Divide the total weight of tubers in same treatment / number of treatments.



**Figure 28:** Average tubers weight (g). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

We note from (figure 28) that there is a convergence in T2.T1.T0 weight and we record a decrease in tuberculosis weight rate in both (T4. T3. T+) respectively by (Table 12) There is no statistical significance (P=0.334) according to the Duncan test.

6.1.4.1.7. Average tubers production:



**Figure 29:** Average tubers production and marketing tubers per treatment (a) and (b) represent respectively **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

6.1.4.1.8. Number of tubers:

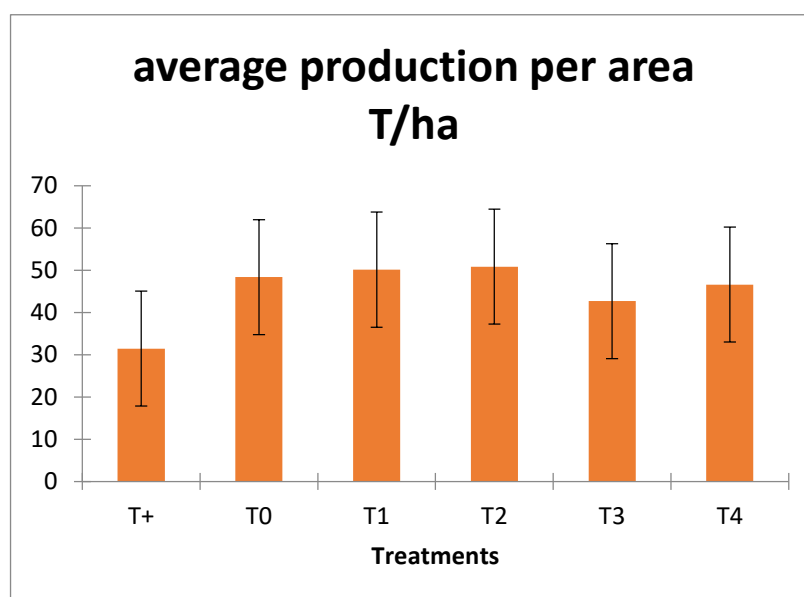
We note from (figure 28) that the number of tubers is the highest value at T1. T0 be close in each of T4. T3.T2.T + respectively by (Table 12) It does not find statistical significance by Test Duncan (P=0.348).

6.1.4.1.9. Marketing tubers:

We note from (figure 29) that the ratio of marketing tubers with converging ratios is greater or equal to 73 % in each of the T4.T2.T1 respectively and is lower at T+. T0 depending on (Table 12) There is no statistical indication significance according to the Duncan test (P=0.294).

## Results and discussion

### 6.1.4.1.10. Average production per area (tons/hectare):



**Figure 30:** Average production per area (tons/hectare). **T+**(control) **T0**(100 % Poultry manure) **T1**(90 % Poultry manure +10% biochar) **T2**(80 % Poultry manure 20% biochar) **T3**(70% Poultry manure + 30% biochar) **T4**(60% Poultry manure + 40% biochar).

From the curve in (figure 30) that the value of each T2.T1.T0.T4 is larger or equal to 46,6 in T3- T+ The value is lower by (table 12) Note that there is no statistical significance ( $P=0.348$ ) according to Duncan test.

**Table 12:** Number, weight, marketable tuber and production per area data

	Number of tubers	Weight of tubers	Marketing	Production per area
T1	21,200 a a	1806,000 a a	15,800 a a	50,140 a a
T2	17,400 a ab	1832,000 a a	13,000 a ab	50,840 a a
T0	18,600 a ab	1743,000 a a	12,000 a ab	48,360 a a
T4	16,600 a ab	1679,000 a a	12,600 a ab	46,600 a a
T3	17,200 a ab	1538,000 a	12,600 a ab	42,694 a a
T+	14,000 a b	1134,000 a a	9,600 a b	31,460 a a
Pr > F	0.348	0.334	0.294	0.335
Significant	Non	Non	Non	Non

From the results we find that biochar has a positive impact on plant development in different levels especially the aerobic part of the plant (plant height, leaves surface, plant surface and leaf area index (LAI) and that impact increases as the amount of biochar in the soil increases.

## Results and discussion

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According to **Jaborova., (2021)** Biochar treatment significantly increased the shoot length by 77%, leaf length by 43%, leaf number by 50%, and leaf width by 45% in potato (*Solanum tuberosum* L.) compared to the control. Ellen **Graber et al (2010)** reported that leaf area in tomato plant (*Solanum lycopersicum* L.) at all biochar treatment levels was significantly greater than in comparable leaves of the control plants, with the leaves from all the biochar treated.

Plant height, number of nodes, and canopy the influence of biochar amendment (0, 1, and 3%) on tomato plant height over time, with results normalized to height at the first measurement (day 35) (**Graber et al.,2010**).

According to **Kalika et al (2020)** all biochar had similar but greater positive effect on plant height and the number of main stems per plant compared to the effect of no biochar. According to **Liu et al., (2022)** Leaf area (LA) was lower in plants grown with 2% biochar amendment compared to those grown with 0% biochar amendment.

Biochar exhibits a projection in crop productivity potential by refining physio-chemical attributes. the variability in responding toward crop yielding potential depends on the chemical as well as physical characteristics of biochar, soil ambient environment, and crop strain (**Yamato et al., 2006**). Likewise, **Chan et al., (2007)** reported that N availability toward cropping systems can also be enhanced by biochar application. Besides this, it also aids for the improvement of N use efficiency due to higher levels of organic carbon and N deposition in soils (**Pan et al., 2016**).

A number of experimental evidences elaborate the effect of biochar application in improving crop yield potential and various soil parameters associated with specific studies reported in literature. biochar application resulted in a higher P availability in comparison with synthetic fertilizer application. A review of the past studies on the use of biochar as soil amendment depicts that, depending upon the feedstock attributes and pyrolytic environments, the nutritional substance of biochar may face variability to distinguished extent with total N and other nutrients in varying patterns (**Ernsting 2011., Hafeez et al., 2017**).

However, we find that biochar has almost no effect on tubers weight, number and marketable tubers in T1, T2 compared to T0 While the results in T3, T4 treatment were low compared to T0. **Liu et al (2016)**. reported the application of biochar generally had negative impacts on growth traits of potato plants. Our results are in contrast to the results of **Akhtar et al (2015)** who reported that incorporation of biochar increased root length and root volume significantly compared to respective non biochar controls at each salinity level. Tuber yield was also

## **Results and discussion**

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positively affected by biochar amendment, but significant increase was found only at 25 mM NaCl treatment.

Probably the increase in the proportion of biochar in the soil appears to had a positive effect in terms of the development and growth of leaves and stem and has no effect on plant in terms of the yield and weight of tubers.

It is possible that the remarkable development in the aerial parts has negatively influenced the development of tubers which led the plant imbalance in terms of growth.

# Conclusion

## Conclusion

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### Conclusion

In the present study the effect of biochar which is produced from date palm residues was mixed with manure at different rates and incorporated on sandy soil. The plant model tested was potato plant and the experiment was conducted under greenhouse conditions.

The findings of this study suggest that biochar influences the physical character of the soil by increasing soil water retention and retaining moisture. So that the more biochar in the soil, the more moisture is preserved. biochar increases moisture levels to 90% in T4 and 80% in T3 compared to T+ 65%.

Biochar affects the chemical properties of the soil by adjusting the percentage of soil pH to reduce it, T4, T3 and T2 was 7.02,7.02 and 7 respectively compared to T+ 7.4 as the greater the amount of biochar in the soil has a greater effect on the pH of soil.

One of the chemical effects of biochar on the soil is also its reduction of soil salinity T4, T2 and T1 has 1.69,1.79 and 1.93 reactively so that an increase in the amount of biochar leads to a decrease in salinity, which in turn has an impact on the plant.

Biochar has the potential to positively affect microorganisms in the soil such as bacteria T4, T3 and T2  $7.5 \times 10^6$   $5.6 \times 10^6$  and  $5 \times 10^6$  colonies respectively and fungi, T3 and T4  $5.5 \times 10^6$  and  $5 \times 10^6$  colonies, providing them with some of their carbon and moisture needs, which in turn (microorganisms) symbiosis and contribute to plant development and growth.

When it comes to the effect of biochar on potato plants, a positive effect was found on the aerial parts. T4 and T3 the stem height results were 39.4 and 34.2 cm respectively, leaf surface was  $37.5 \text{ cm}^2$  in T4 and (LAI) was 2.7.

However, the impact of biochar on the underground organs was not significant. weight and number of tubers was close in T0, T1 and T2 1743,1806 and 1832 g respectively and 18,21 and 17 tubers in T0, T1 and T2 respectively.

Taken together, these results suggest that biochar has a beneficial effect on the soil moisture microorganisms and pH level, in addition to its remarkable positive effect on the aerial parts (leaves, height of plants...) but not on tubers.

## Conclusion

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More broadly, research is also needed to determine:

- The optimal concentration of biochar to mix with manure.
- The relationship between biochar, microorganism and pH level.
- We recommend to test biochar on leafy vegetables such as lettuce, parsley and chard.

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# **Annexes**

Annexes :



**Figure 1: soil before the start of experiments.**



**Figure 2: inside green house after planting potato.**



**Figure 3: the first plants appearances after 20 days of planting.**



**Figure 4: after 40 days of planting.**



**Figure 5: after 60 days of planting.**



**Figure 6: 80days after planting.**



**Figure 7: harvest of potato after 90days of planting.**



**Figure 8: Soil moisture measure device.**