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The impact of mycorrhization on cereals case of durum wheat

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Dédicace

I dedicate this work first to myself,

then to my parents, and finally

to my dear teachers.

To anyone who wants to know,

to learn, to research,

to discover and develop.

Remerciements

First of all I would like to thank ALLAH the Almighty for giving me the courage to complete this memoir. I would like to express all my gratitude and thanks to my supervisor Mrs. Ilias Faiza, for her professional guidance and who supported me throughout this period. I would like to thank also Madam President Mrs. Darreg Zinrb, who gave me the honor and the pleasure to govern this jury,

t as well as Ms. Abdellaoui Hadjira to collaborate in the appreciation of my work.

I obviously thank Mr. Lahbib dardek for his help, his advice, and guidance.

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Abstract :

Wheat cultivation is considered one of the most important agricultural practices in Algeria, especially as it plays a crucial role in human nutrition in general. However, wheat faces many challenges, the most significant of which is drought. This has led to a decline in productivity and problems in agricultural practices. In this study, we attempted to inoculate durum wheat (Simeto variety) with arbuscular mycorrhizal fungi (glomus moreau,glomus intraradices. Glomus etunicatum) and observe its effectiveness in resisting drought and its ability to retain water through morphological and physiological analyses.

The obtained results showed that inoculation with arbuscular mycorrhizal fungi significantly increases the growth of leaves and roots as well as their dry weight, with a particularly clear and strong effect on the roots. This led to an increase in water absorption and retention for a long period, resulting in a higher yield compared to wheat without mycorrhizae.
This is due to the ability of mycorrhiza-inoculated wheat to withstand water stress conditions.
We conclude that inoculation with mycorrhizae is an effective alternative to address the drought problems faced by durum wheat, particularly in Algeria.

Keywords : arbuscular mycorrhizal fungi, water stress, durum wheat.

Résumé:

La culture du blé est considérée comme l'une des pratiques agricoles les plus importantes en Algérie, surtout qu'elle joue un rôle crucial dans l'alimentation humai ne en général. Cependant, le blé est confronté à de nombreux défis, dont le plus important est la sécheresse. Cela a conduit à une baisse de la productivité et à des problèmes dans les pratiques agricoles. Dans cette étude, nous avons tenté d'inoculer le blé dur (variété Simeto) avec des champignons mycorhiziens arbusculaires (glomus mosseae, glomus intraradices. Glomus etunicatum)et d'observer son efficacité à résister à la sécheresse et sa capacité à retenir l'eau à travers des analyses morphologiques et physiologiques.

Les résultats obtenus ont montré que l'inoculation avec les champignons mycorhizes arbusculaires augmente significativement la croissance des feuilles et des racines ainsi que leur poids sec, avec un effet particulièrement clair et fort au niveau des racines. Cela a conduit à une augmentation de l'absorption de l'eau et à sa rétention pendant une longue période, ce qui a donné un rendement élevé en production par rapport au blé sans mycorhize. Cela est dû à la capacité du blé inoculé avec la mycorhize à résister aux conditions de stress hydrique.

Nous concluons que l'inoculation avec la mycorhize constitue une alternative efficace pour tenter de résoudre les problèmes de sécheresse aux quels est confronté le blé dur,

notamment en Algérie.

Mot clés : champignons mycorhiziens arbusculaires,stress hydrique,blé dur,.

الملخص :

تعتبر زراعة القمح احد اهم الممارسات المهمة في الجزائر خاصة انه يلعب دورا رئيسيا في غذاء الانسان بصفة عامة .ولكن يتعرض هدا الاخير الى العديد من المشاكل اهمها هو الجفاف .وهذا ادى الى تدهور الانتاجية ومشاكل في الممارسات الزراعية في هذه الدراسة حاولنا تجربة تلقيح القمح الصلب سيميتو بالفطريات الشجيرية .(glomus mosseae, glomus intraradices Glomus etunicatum).. وملاحظة مدى فاعليته في مقاومة الجفاف وقدراته على الاحتفاظ بالماء من خلال التحاليل المرفولوجية والفيزيولوجية.

أظهرت النتائج المتحصل عليها أن التلقيح بالفطريات الجذرية الشجيرية يزيد بشكل كبير من نمو الأوراق والجذور وكذلك من وزنها الجاف، مع تأثير واضح وقوي بشكل خاص على مستوى الجذور. أدى ذلك إلى زيادة امتصاص الماء واحتباسه لفترة طويلة، مما أدى إلى زيادة كبيرة في الإنتاج مقارنة بالقمح غير الملقح بالفطريات الجذرية. يرجع ذلك إلى قدرة القمح الملقح بالفطريات الجذرية على مقاومة ظروف الإجهاد المائي. نستنتج أن التلقيح بالفطريات الجذرية يشكل بديلاً فعالاً لمحاولة حل مشاكل الجفاف التي يواجهها القمح الصلب، لاسيما في الجزائر.

الكلمات المفتاحية: الفطريات الجذرية الشجيرية، الإجهاد المائي، القمح الصلب

Summary :

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List of abbreviations:

AA : Amino Acid

C : Degrees Celsius

Ca : Calcium

cm : Centimeter

A M : Arbuscular Mycorrhiza

AMF : Arbuscular Mycorrhizal Fungi

AMV : Arbuscular mycorrhiza with vesicule

FAO : Food and Agriculture Organization

Fig : Figure

g : gram

ha : hectare

Kg : Kilogram

Km : Kilometer

Mg : Magnesium

MT : Million tonnes

N: nitrate/nitrogen

pH : hydrogen potential

Pi : inorganic phosphorus.

S : sulfur

GLOSSARY :

- **ARBUSCULE =** refers to a small or tree-like structure found in some mycorrhizal fungi, which helps in the ' exchange of nutrients between fungi and plants. This term derives from the Latin " arbuscula " which means "small tree ".
  (Le Petit Robert, 1 964)
- **ASCOMYCETE** = designates a group of fungi belonging to the division Ascomycota. These fungi are characterized by the presence of reproductive structures called asci, which contain spores. Asci are the distinctive feature of this division, which includes examples such as yeasts, molds, and other fungi of biological and economic importance. (**Larousse French, 2024 edition.**)
- **BASIDIOMYCETE** = is a term used in biology to designate a group of spore-bearing fungi. They are distinguished by the presence of basidia, reproductive structures which carry the spores. This group includes mushrooms such as gill mushrooms and porcini mushrooms. The term is derived from the Greek " basidion " which means " small base ".
  (**Lexico Santé, « Basidiomycete » , consulted in June 2024.)**
- **GLOMEROMYCETE** = are fungi belonging to the division Glomeromycota. They form symbiotic associations with plant roots, known as arbuscular mycorrhizae. These associations improve the ' absorption of ' water and mineral nutrients, particularly phosphorus, by plants. Glomeromycetes are essential for the health of natural and agricultural ecosystems.

  (**Le Robert illustrated and Dixel 2010, Le Robert Dictionaries, Paris** .)
- **HYPHA** = designates a microscopic filament which constitutes the basic structure of fungi. C ' is a fundamental unit of fungi, forming the mycelium, which is the network of filaments that allows fungi to feed and grow. **The Robert**

  (n.d.). *Definition of hypha*. Retrieved from [Le Robert] (https://dictionnaire.lerobert.com/definition/hyphe).
- **MYCELIUM** = is the vegetative part of mushrooms, made up of ' a network of filaments called hyphae. These filaments often grow below the surface of the soil or inside the organic matter on which the fungus feeds . **[Larousse]**

  (https://www.larousse.fr/dictionnaires/francais/mycélium/53462
- **MYCORHIZE** = (from the Greek 'mukês' for mushroom and 'rhiza' for root) Symbiotic association of a mushroom with the roots of a plant **(Pierart, 2012).**

- **SPORE :** reproductive cells unicellular capable s of giving birth to a new organism without fertilization. such as mushrooms, arguments, mosses **.. (encyclopedia the red-spore).**
- **Symbiosis:** organisms of different species. This relationship can be beneficial for both organisms (mutualism), beneficial for one and without effect for the other (commensalism), or beneficial for one and harmful for the other (parasitism).

  https://www.universalis.fr/encyclopedie/symbiose/
- **Coleoptile:** : Primordial leaf forming part of the ' embryo contained in a seed. »

  Photosynthesis is a biochemical process by which plants, algae and certain bacteria transform light energy into chemical energy, in the form of glucose, from carbon dioxide and water. This process takes place primarily in the chloroplasts of plant cells, where the chlorophyll pigment captures sunlight. Photosynthesis also produces oxygen as a byproduct, essential for life on Earth. [Larousse] (https://www.larousse.fr/dictionnaires/francais/photosynth%C3%A8se/60461
- **Photosynthesis :** The process by which plants, algae, and some bacteria convert sunlight into usable chemical energy, stored as organic molecules such as glucose, using carbon dioxide and water . This chemical reaction is catalyzed by chlorophyll pigments present in the chloroplasts of plant cells. Photosynthesis is essential for life on Earth because it forms the basis of the food chain and produces oxygen as a byproduct. ***Reference*** : **"Photosynthesis." Universalize Encyclopedia** . Accessed June 23, 2024, available on

  https://www.universalis-edu.com
- **Coleorhiza :** is a protective sheath that surrounds the radicle of the seedlings, ensuring its protection when ' it passes through the soil at the time of germination. » **[Larousse]**
- **Vesicle :** is a small closed sac filled with liquid or gaz,wich forms in an organic tissue. Biologie on ligne (2023) vésicule définition and exemple Retrieved by :

  https://www.biologyonline.com/dictionary/vesicle**.**

Introduction General

Introduction General :

Cereals play an extremely important role as a food source; they constitute by far a major food resource both for human consumption and for livestock feed. The cereal sector is of crucial importance for global food supplies (**Choueiri, 2003).** However, the production provided by the latter is faced with several biotic and abiotic constraints including drought.

Among large cultivated plants, in particular the major cereals which are wheat, rice and corn, the comparison of the yields in optimal conditions with those observed on average in the field reveals considerable differences.

The explanation for these differences is mainly: climatic, agronomic and also genetic **(Ricroch et al.,2011)**. In Algeria, the climate is characterized by the irregularity of rainfall in time and in space as well as by a tendency towards more aridity and therefore an increased impact of droughts. The latter are considered as factors of a partial or total loss of production, particularly in the case of cereals **(Hassani et al.,2008).**These annual variations in climatic conditions are often an obstacle to any improvement action.

A plant uses most of the water it absorbs to dissipate solar energy that it does not use for photosynthesis. Thus the water needs of a crop are directly linked to the climate. If, due to lack of water, the temperature of the plant rises and becomes higher than that of the air, the energy is then dissipated by convection like a hot plate. The plant's response to water stress is complex because it depends on the severity of the stress, the duration of the stress, the development phase and the state in which the plant was found. when the stress occurred (**Aidaoui, 1994)**. Indeed, the effects of water stress affect all the functions of the plant; A reduction in the amount of water available influences the metabolism and physiological processes that control growth and development of the plant. Difficulties encountered include the extremely dynamic characteristics of the plant's water status and the complex interactions that exist between water stress and other environmental variables **(passiora 1970).**

As for the rhizosphere, it includes a great diversity of microorganisms.

Indeed, the rhizosphere is a highly active zone where many dialogues between the plant and the bacteria. The plant can benefit from these interactions, in terms of growth and/or health **(Richardson& al.,2009)**, and at the same time the microorganisms will benefit from the substrates present in the exudates.

Among the beneficial relationships existing between plants and microorganisms, type of symbiotic interactions is “mutualistic symbiosis”. It is considered as a strong interaction between the two partners, and in the case of mycorrhizal fungi (see chapter I) associated with plants it often involves morphological differentiation in one or both partners **(Bouffaud, 2014).**

The technology of inoculating plants with mushrooms has been among the applications that help in the production of edible mushrooms beneficial for the plant even in conditions of water stress.

The objective of this present work is to test the effect of inoculation of variety simeto of durum wheat by arbuscular mycorrhizal fungi under water stress. The samples will thus be analyzed at the physiological and morphological level.

This dissertation is structured into three main parts:

- **A first part** represents a bibliographical summary on wheat, and mycorrhization

- **The second part** is successively devoted to the description of the plant material, the cultivation conditions, and the analysis methods used.

- **The third part** deals with the different results obtained during this study study**.**

Chapter I

Bibliographic summary

I. Durum Wheat :

1 - General :

Since the birth of agriculture, wheat has been the basis of human food **(Ruel , 2006),** it is a species known since ancient times, including it constitutes the food base of the populations of the globe **(Yves and Buyer, 2000)**. During for several centuries, he was worshiped as a god and associated with rain, agriculture and fertility **(Ruel, 2006).**

The discovery of wheat dates back to 15,000 BC in the Fertile Crescent region, a vast territory including the Jordan Valley and adjacent areas of Palestine, Jordan, Iraq, and the western edge of Iran (**Feldman and Sears, 1981; Mouellef, 2010)**. It was at a time when man was already picking and making his beginnings as a farmer. This period coincided with a dry climatic episode, leading to the cessation of the mode of life of'hunter-gatherer', and leading to the progressive domestication of plants, associated with the creation of the first village communities **(Wadley and Martin, 1993 in Ouanzar, 2012).**

Wheat is one of the main food resources of humanity. The saga of wheat ac companion that of man and of agriculture, its crop precedes history and characterizes Neolithic agriculture, born in Europe 8000 years ago. The oldest crop appears to be durum wheat in the fertile crescent of Mesopotamia **(Feillet, 2000**).

Léon Ducellier (1878-1937) in particular, browsing the wheat, made a census of a little-known flora at the beginning of the century. He discovered and analyzed the numerous varieties which populated the cultivated fields, collected the most characterized samples, the most productive, the most resistant to drought or some diseases. Wheat first evolved without human intervention, then under the selection pressure exerted by the first **farmers (Henry and Buyser, 2001).**

2 - Origin genetic :

It was about 10,000 years ago, in the Near East, in the fertile Croissant region, that wheat was domesticated by hybridization between three species of a wild grass, spelled or wild einkorn: Triticumspelta L. Triticumboeticum and Aegilops longissima. He won Western Europe by two major axes: one on the the Mediterranean from 5000 BC, a bread-making wheat was cultivated in the south of France, on the other hand the Danube valley two species of non-bread-making wheat (emmer and einkorn), old of 4000 years, have been found in the region Parisian, as well as as well as wheat in Brittany and in Normandy. The determination of the origin of each of the wheat genomes is difficult due to the evolution of species **(Cauderon, 1979; Liu &** ***al*** **,1996 in Nadjem, 2012)**.

(Sakamura,1918,cited by Cauderon 1979), was the first to determine the exact number of chromosomes of various species of Triticum of levels of ploidy different :

- *Triticumaestivum* : 42 chromosomes, hexaploid.
- *Triticumturgidum* : 28 chromosomes, tetraploid [2n = 4x = 28] Genome AABB.
- *Triticummonococcum* : 14 chromosomes, diploid**.**

3 - Origin geographical :

According to Vavilové in (**Ounzar,2012),** durum wheat has two origins : Abyssinia and Africa from North. So that for **(Grignac 1978)**, the Middle East is the center generator of durum wheat, where it has differentiated itself in three regions: the western basin of the Mediterranean, the south of Russia and the Near East (Syria and northern Palestine).

4 -Classification botanical :

According to **(Prats, 1960., Crête, 1965., Bonjean and Picard, 1990; Feillet, 2000),** Durum wheat is a herbaceous plant, belonging to the group of straw cereals, which are characterized by particular morphological criteria. Durum wheat is a monocotyledon which obeys the following classification:

Branch	Spermaphytes
S/Junction	Angiosperms
Class	Monocots
Super Order	Commeliniflorales
Order	Poales Family
Family	Grass Triticeae Triticeae
Sub tribe	Triticeae
Gender	Triticeae
Species	TriticumdurumDesf

5- The morphological characters of wheat :

5-1 The vegetative apparatus:

- **The roots :**

There are two kinds of roots: Primary or seminal roots from the seed which develop at the time of germination, a fairly developed fasciculated root system, (adventitious or coronary roots); which are produced by the development of new tillers. They can reach up to 1m50 **(Soltner, 1990)**.

- **The stem :**

Are cylindrical culms, often hollow by resorption of the central pith but in durum wheat is full. They appear as fluted tubes, with long and numerous sap-conducting bundles. These bundles are regularly crisscrossed and contain thick-walled fibers, ensuring the strength of the structure. The culms are interrupted by nodes which are a succession of zones from which a long one emerges. leaf **(Soltner, 1990).**

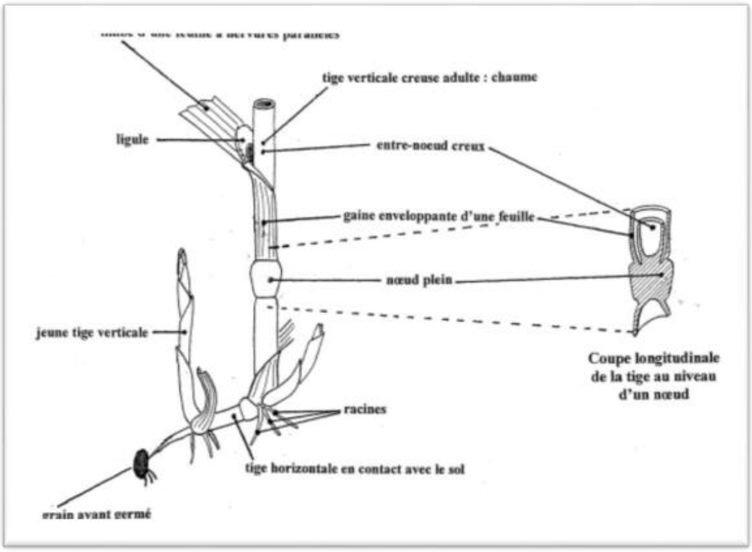


Figure 01: The apparatus vegetative of wheat durum **(Rouibah**,**2021)**.

5-2 oducer :

5-2-1 The flowers: are grouped in inflorescence corresponding to the spike of which the basic morphological unit is the spikelet made up of clusters of flowers enveloped in their glumes and included in two bracts called the glumes (lower and upper) **(Gate, 1995)**

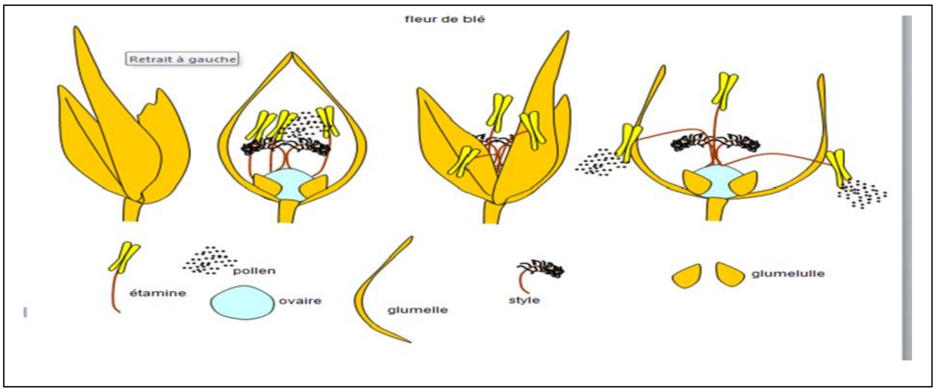


Figure 02 : The reproductive system of wheat durum **(Gate, 1955)**.

5-2-2 The grain :

5-2-2-1 Histological structure of grain of wheat durum :

Wheat grains are fruits, called caryopsis. The latter are ovoid in shape, have on one of their faces a longitudinal cavity "the furrow" and at the opposite end of the embryo of the tufts of hair "the brush". The caryopsis is made up of 03 parts **(Figure 03)**

a) The envelopes :

According to **(Godon and Willm, 1991)** the envelopes give the sound in semolina, they are of thickness variable and are formed of 3 groups of integuments welded :

- The pericarp or integument of the fruit made up of 3 cell bases :

- **Epicarp**, protected by the cuticle and the hairs.
- **Mesocarp**, formed of transverse cells.
- **Endocarp**, constituted by tubular cells**.**

- The testa or integument of the seed constituted of 2 layers of cells.
- The epidermis of the nucellus applied to the underlying albumen.

b) The albumen

Mainly starchy and vitreous in durum wheat, has on its periphery a layer with aleurone rich in proteins, lipids, pentosans, hemicelluloses and minerals **(Godon and Willm, 1991)**.

c) The embryo :

According to **Godon and Willm, (1991)** the embryo comprises :

- The cotyledon unique or scutéllum rich in lipids and proteins.
- The seedling plus or minus differentiated :

- The radicle or root embryonic protected by the coleorhiza.
- The gemmule comprising a variable number of visible sheets, enclosed in a case protector : the coleoptile.

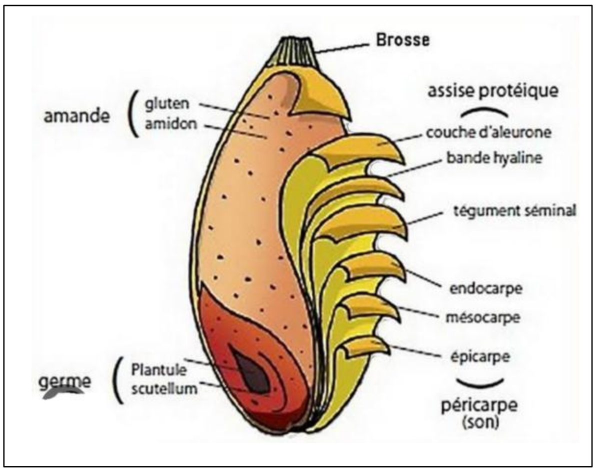


Figure03: Longitudinal section presenting the constituents of the grain of durum wheat **(Paul** , **2007**).

5-2-2-2 Biochemical composition of grain of wheat :

According to **(Cretan and al 1985 , Abed and Bel-abdelouhad 1998)** The grains of cereals are particularly dehydrated plant organs, their content of water is approximately 14%.The cotyledon of wheat represents 82% to 85% of the grain,it accumulates all the nutritional substances necessary: 70 to 80 % of carbohydrates, 9 to 15% protein,1,5 to 2% of lipids, substances minerals and vitamins**.**

During the maturity of the seed the reserve substances are accumulated either in the cotyledon or in the pericarp These substances are mainly metabolites which ensure the nutrition of the seedling during germination **(Godon, 1991)**.

5-2-2-3 Rotation of crops :

It is necessary to plan for a rotation of crops at least on a part of the production areas in compliance with the planned indications. The rotation actually presents various advantages which can be summarized as follows:

- Reduction of parasitic attacks and of risk of fusarium wilt.
- Better control of infestations.

6.Biology of wheat :

Whether perennial or annual, all grasses have an annual vegetation and fruiting rhythm. During its different growth stages, wheat presents variable requirements in water and in mineral materials **(Gate *and al.*, 1997 in Nadjem, 2012)**.

6.1. The biological cycle of wheat :

6.1.1 The growing period:

It is characterized by a strictly herbaceous development and extends from sowing until end of tillering (**Figure 04).**

6.1.1.1 Phase germination-emergence :

Germination of the seed is characterized by the emergence of the coleorhiza giving birth to seminal roots and the coleoptile which protects the exit of the first functional leaf. Lifting is done actually from the exit of the sheets to the surface of the ground.

In a stand, emergence is achieved when the majority of seedling stems are visible **(Gate, 1995)** . During the sowing-emergence phase, the plant's nutrition depends solely on its primary root system and seed reserves. The realization of this phase depends on heat, ventilation and humidity **(Eliard, 1979 in Nadjem, 2012)**.

6.1.1.2 Phase lifting-tillering :

The production of tiller begins at the completion of the development of the third leaf, approximately 45 days after the date of sowing **(Moule,1971 in Nadjem, 2012)**.The secondary tillers may appear and be likely to emit tertiary tillers.

The number of tillers produced depends on the variety, the climate, the mineral and water supply of the plant, as well as the seeding density **(Masale, 1980 in Nadjem, 2012)**.

6.1.2 The reproductive period :

6.1.2.1 The rise-inflation :

Bolting begins at the end of tillering. It is characterized by the elongation of the internodes and the differentiation of the floral parts. At this phase, a certain number of herbaceous tillers begin to regress while others are crowned by ears. During this active growth phase, nutrient requirements, particularly nitrogen, are increased. The bolting will end at the end of the emission of the last leaf and the manifestations of the swelling that cause the ears in the seed **(Clement-Grancourt and Prats, 1971 in Nadjem, 2012)**.

6.1.2.2 Heading - fertilization :

It is marked by the meiosis pollen, the bursting of the sheath with the emergence of the ear. It is during this phase that the formation of the floral organs (anthesis) is completed and fertilization takes place. This phase is reached when 50% of the ears are half out of the sheath of the last leaf **(Gate, 1995).** It corresponds to the maximum growth of the plant which will have produced three quarters of the total dry matter and depends closely on mineral nutrition and transpiration which influence the final number of grains per cob **(Masale, 1980)**.

6.1.2.3 The magnification of the grain :

This phase marks the modification of the functioning of the plant which will then be oriented towards filling the grains from the biomass produced. At the beginning, the grain is organized, the cells multiply, The needs of the grains are lower than what provides the aerial parts (more than ¾ of the dry matter is stored at the level of the stems and leaves). Subsequently, the needs increase and the weight of the grains in the ear rises, while that the matter dries of the parts aerial decreases gradually. Only 10% to 15% of the grain's starch can come from reserves prior to flowering **.**

At the end of this phase, 40 to 50% of the reserves have accumulated in the grain which, although it has reached its final size, is still green and soft, this is the stage“ Grain milky ” **(Hoppenot &** ***al,*****1991 in Boulelouch, 2002)**.

6.1.2.4 Ripening of grain :

The maturation phase follows the pasty stage (45% humidity).It corresponds to the phase during which the grain will gradually lose its moisture by passing through various stages **.** It begins at the end of the water level marked by the stability of the water content of the grain for 10 to 15 days beyond this period, the grain will only lose the excess of water it contains and will gradually pass through the stages “scratchable at the corner” (20% humidity)then “ brittle under the tooth » (15-16% humidity) **(Gate, 1995)**

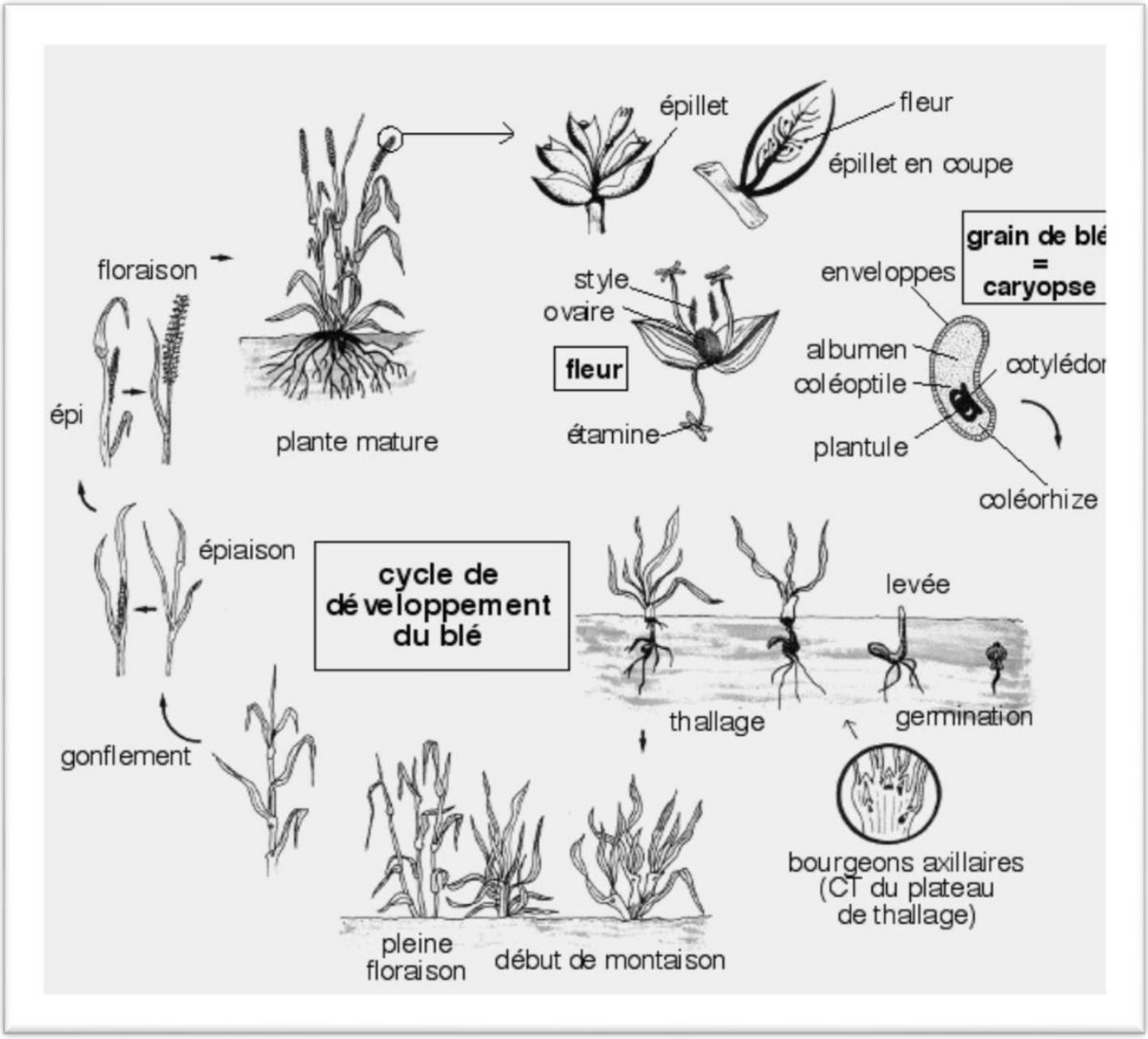


Figure 04: Cycle of development of wheat durum **(Gate, 1955)**.

6−2- Cycle of development of wheat :

The cycle of development of a cereal to straw includes three major periods **(Figure 5)**

a) High :

The date of lifting is defined therefore the appearance of the first sheet which crosses the coleoptile, a rigid and protective sheath enveloping the first leaf. The lifting stage encompasses therefore three successive stages of different nature :

- The germination which corresponds to the entry of the seed in life active and at the very beginning of growth of the embryo.
- The elongation of the coleoptile, first organ of the aerial system to emerge to the surface of the ground.
- The growth of the first leaf which pierces in its top the coleoptile..

b) Stage 2-3 leaves :

This stage is characterized by the number of leaves on the seedling. After emergence, the leaf primordia piled up in alternate positions from the base to the middle third of the apex grow and emerge the one after the others according to a regular rhythm.

c) Stage start tillering :

The plant has three to four leaves. A new stem appears on the main strand at the axil of the oldest leaf.The emergence of this first tiller out of the sheath of the first leaf constitutes the conventional mark of the start tillering stage.

d) Stage full height :

The stage full tillering is not defined by precise characteristics. It is more a period than a particular state insofar as the notion of full height implies that we know a priori the abundance of final tillering, variable depending on sowing dates, temperature and variety. However, the full-tiller stage is conventionally defined when the plants have two to three tillers

e) Stage ears at 1 Cm :

The plants becomes upright, and the stem main as well as and the tillers the more begin to lengthen following the elongation of the internodes previously stacked under the ear. The other stems more young will regress: their speed of growth becomes reduced, they commit towards senescence then die.

f) 1-2 nodes :

The tiller, a short knotted stem, essentially made up of initially stacked nodes, grows by the elongation of the first internodes. Each internode begins its growth after the previous without waiting until the last has reached its final length.

g) Stage meiosis pollen :

Pollen meiosis occurs when the top of the young spike touches the ligule of the penultimate leaf. This stage therefore takes place a little before swelling; on average the meiosis stage pollen occurs 10 days before heading for wheat.

Stage heading :

Just after the swelling stage, the sheath of the last leaf gradually deviates following the lengthening of the last internodes of the stem: this is the burst sheath stage. Then in the day or days that follow, the top of the ear emerges from the last sheath which has then reached its final length : this is the start of heading.

h) Stage flowering :

At this stage, the stem and the ear have almost completed their growth. In general, the maximum weight of the ear is reached 3 days after flowering.

i) The formation of the grain :

This period includes 3 essensial stages:

- **The milky grain stage:** from fertilization, a stage identified by flowering to the milky grain, the envelopes of the future grains are put in place. These envelopes which determine the potential weight of the grains have reached their maximum size at this stage for all cereals with straw with the exception rice.
- **The pasty grain stage :** from the milky stage to the pasty stage, there is expansion of the cells of the envelope and filling of these cells in a dominant manner with sugars which are stored essentially under form of starch. The quantity of water contained in the grain is stable: this is the water level, the characteristic phase of filling of the grain.
- **Physiological maturity:** Physiological maturity occurs when there is no longer any migration of dry matter towards the grain. This stage follows a few days (2 days on average) after the pasty stage. At this stage the dry weight of the grain has reached its maximum and final value. After this stage, a rapid desiccation phase takes place and the grain becomes harder and harder and can be harvested by machine: this is harvest maturity**. (Kalarasse.,2018)**

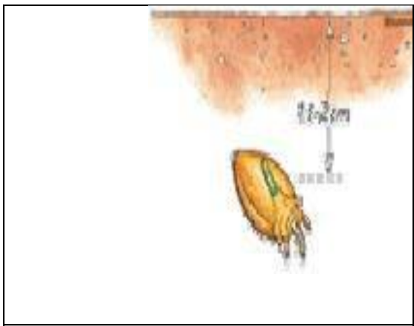
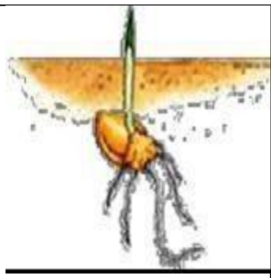
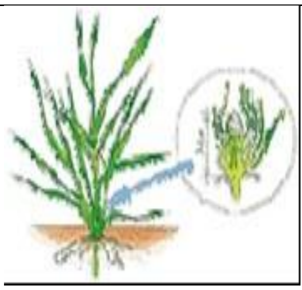
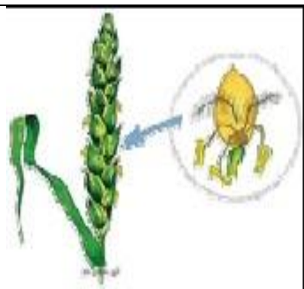
		
1-Germination	2-The lifting	3-Three leaves
		
4- Start of tillering	5- Ear at 1 cm	6-A knot
		
7– Swelling	8- Heading	9- Flowering
		
10- Yawn.	11- Grain formed	12- Ripe ear

Figure 05: Different stages of development of wheat. **(Casnin et al., 2013)**

7. wheat requirement :

7-1. The pedoclimaticrequirement:

7-1-1. The Temperature :

(Mekhlouf & al.2001) locate the following requirements in temperature for the following stages:

- Stage lifting : The sum of the temperatures =120°C.
- Stage tillering : The sum of temperatures =450°C.
- Stage full tillering : The sum of the temperatures =500°C.
- Stage cob 1cm : The sum of the temperatures = 600°C.

7.1.2.Light :

Light is the factor that acts directly on the proper functioning of photosynthesis and the behavior of wheat. Good tillering is guaranteed if the wheat is placed in the optimal lighting conditions **(Latreche,2011)**.

7.1.3.The Soil :

The soil is the support of vegetation, its pantry and its water reservoir **(Girard et *al* , 2005)** . Indeed, the soil acts through its physical, chemical and biological properties. It intervenes by its composition in elements minerals, in organic matter and by its structure, and plays a important role in the nutrition of the plant, thus determining the expected grain yield. The plant, through its growing root system, behaves like a set of spatially distributed underground sensors playing the role of an exchange surface with the soil, and a transport system of l waterup to the collar, to the surface of the soil **(Olioso , 2006)**.

7.1.4.Water :

Wheat requires constant humidity throughout the development cycle, water is required in variable quantities. Water requirements are estimated at around 800 mm **(Soltner, 2000)**. In arid zones, needs are greater given unfavorable climatic conditions. It is from the 1 cm ear phase to flowering that the water needs are the greatest. The critical water period is 20 days before heading until 30 to 35 days after flowering **(Loue, 1982)**.

7.2.The cultural requirement:

7.2.1.Preparation of soil

Wheat requires well-prepared and loosened soil to a depth of 12 to 15 cm for patent soils (generally loamy) or 20 to 25 cm for other soils. The soil must be slightly clod and sufficiently compacted in depth, a fine structure in surface to allow regular and shallow sowing **(Ouanzar, 2012)**.

7.2.2.Sowing :

The sowing date is a limiting factor with regard to yield, this is why the date specific to each region must be seriously respected to avoid climatic harm, in Algeria it can start at the end of October with a row spacing of 15 to 25 cm and a seeding depth of 2.5 to 3cm. **(Latreche, 2011)**.

7.2.3.Fertilization :

Nitrogen-phosphoric fertilization is very important in the Saharan regions where the soils are skeletal, it will be in function of the potentialities of the varieties, the fractionation of nitrogen is a necessity of makes of the great mobility of this element. **(Ouanzar, 2012)**

a) Nitrogen :

It is a very important element for the development of wheat **(Viaux, 1980)**, durum wheat must absorb 3.5 units of nitrogen to produce 1 quintal of grain at 13-14% of proteins. Until the start of the crop, the needs are quite modest 40 at 45Kg/ha then until flowering all the nitrogen is absorbed, the plant must have from the start of the rise all the nitrogen necessary for its development.

(Remy and Viau, 1980, in Ouanzar, 2012).

b) The phosphorus :

It promotes the development of roots, its presence in the soil in quantities sufficient is a sign of increased yield. Theoretical phosphorus requirements are estimated at approximately 120Kg of P2O5/ha **(Balaid, 1987 in Ouanzar, 2012)**.

c) potassium :

The potassium requirements of cereals may be greater than the quantity contained at harvest 30 to 50 kg of K/ha **(Balaid, 1987 in Ouanzar, 2012)**.

7.2.5. Weed control:

Weeds compete with cereals for water and mineral nutrition and also for light, affecting yield. For weeds, there exist two means of control **(Ouanzar, 2012)**.

a) Mechanical weeding:

From September onwards, irrigate the plots to encourage germination of weed seeds and previous crops. After their removal, proceed to bury them**(Ouanzar, 2012)**.

B) Chemical control :

Is done to using multi-purpose weedkillers **(Ouanzar, 2012)**.

7.2.5.Rotation of crops :

It is necessary to plan a rotation of crops at least on a part of the production areas in compliance with the planned indications.The rotation actuallypresents various advantages which can be summarized as follows:

- Reduction of parasitic attacks and of risk of fusarium wilt.
- Better control of infestations.
- Improvement of structure and of soil fertility.
- Better protection of the environment **(Ouanzar, 2012)**.

7.3. climate change :

a) The drought :

In agriculture, drought is starting to have very negative impacts on agricultural production in the Mediterranean region. Drought results in a prolonged absence with a poor distribution of precipitation, in relation to a so-called normal value it should note that cereals are faced with several types of drought which affect them over the course of their cycle of development, they 'acts of :

- The drought at the beginning of vegetative cycle and which affects the installation of the crop
- Drought in the middle of the vegetative cycle mainly affects the fertility of the reproductive organs of the plant.
- The drought of end of vegetative cycle which affects the formation and the filling of grain.

Drought is the cause of water and heat stress. (**Alismail et al., 2017)**

b) water stress :

Water stress can be defined as the ratio between the quantity of water necessary for the growth of the plant and the quantity of water available in its environment, knowing that the reserve of useful water for the plant is the quantity of soil water accessible by its root system. The plant's water demand is determined by the level of transpiration or evapotranspiration, which includes water loss both from the leaves and from the ground level. **(anonyme 2007)**

When the quantity of water captured by the plant is less than the quantity of water lost by evapotranspiration, a water deficit appears.The effects of this deficit depend on stage, the organ considered, the intensity and duration of stress. Overall and for all plants, water deficit causes a reduction or even a cessation of growth, wilting of the aerial parts and, if the stress is too intense or too long, the death of the plant. Not all the plants present the same strategies in the face of stress. **(Y Despinase ,2015)**

The water deficit settles in the plant when the absorption does not satisfy the perspiration of the latter. Part of the physiological processes begins to be affected.

It causes the establishment of a state of water regulation in the plant which is manifested by the closure stomatal and by a regulation of the potential osmotic.

However, this closure of the stomata, which constitutes a means of resistance, has the consequence of a reduction in gas exchange which results in a reduction in production in the culture **(Alismail et al, 2017).**

b) Stress thermal :

The sensitivity of plants to extreme temperatures is very variable, some are exterminated or weakened by moderate drops of temperatures, while that other perfectly acclimatized, are capable of following frost (tens of C° below zero), stress caused by high temperatures induces the synthesis of a group of particular proteins**. (Douaer & al.,2018).**

8. Situation of wheat in Algeria :

Wheat production in Algeria does not keep pace with the demographic rate and is hardly sufficient to meet the growing demand for this product. Low yields are attributed, essentially, to climatic hazards and inadequate cultivation techniques. This production also suffers from underexploitation of the land reserved for this speculation. Average yields which do not exceed 12 q/ha are due, in large part, to a lack of mastery of production techniques **(Hamou & al, 2009).**

According to **(Yalloui *& al*. 2013)** the average cereal productions of the 1980s compared to that from the last decade, have evolved by mannered spectacular, in effect the production average has increased from 21.528.824 qx to price from the period 1987-2001 to 36.710.066 qx over the period from 2001-2013,i.e.a rate of changeof 71%. However, this development still remains unstable, and considerable fluctuations in cereal production in Algeria were recorded from one year to the next between 2010 and 2015 **(MADR /DSA Guelma, 2018).**

9. Importance and production of wheat in the world and in Algeria :

9.1. In world :

FAO 's current forecast for 2017 projects global cereal production at 2.594 billion tonnes, down 5 million tonnes from May's estimate and down 14.1 million tonnes. tonnes (0.5%) year-on-year. The monthly decrease is explained mainly by of less good prospects in this which concerns coarse grains and, to a less extent, rice.

Indeed, wheat production in the world increased in February compared to forecasts for January 2016 (1 million tonnes), an increase of +3 million tonnes, in Turkey, Russia and in Australia and a drop in India of 2.4 million tonnes. Similarly, global durum wheat production in 2015/16 during the month of February 2016 is up by 1.7 million tonnes compared to January of the same year, reaching 39.7 million tonnes, a jump of 15% compared to the result of the previous year. Stocks of the four main exporters (Canada, United States, Mexico and European Union) are expected to rise by around a third, to 3.4 million tonnes. **(Yaiche.,2017).**

9.2. In Algeria :

Algeria before the 1830s exported its wheat to the whole world.Currently Algeria imports its wheat and finds itself dependent on the international market. Through its position as a major importer of wheat, Algeria buys more than 5% of world cereal production annually. This situation risks continuing for several years, due to insufficient yields and ever-increasing consumption needs in the face of strong developments. demographic. Indeed, a very insufficient production of 2.7 Mt to cover the needs of the national market and supply stocks pushes us to systematically resort to imports **(Douaer et al., 2018).**

10. Production strategy :

Under temperate conditions, repeated cultivation of wheat is common in conventional agriculture. Continuous wheat cultivation, however, leads to greater competition with weeds, the appearance of diseases in the soil (rot of the foot and roots), depletion of nutrients and reduction of _> yields. A rotation of appropriate crops allows for successful wheat crops.

A cereal crop must not be planted more than twice in a row on the same land. Wheat should only be reseeded once every three years on the same plot. It should be grown in rotation with plants that do not attract the same pests and diseases as wheat and that help control weeds. The most effective partners for wheat rotation are legumes because they do not transmit diseases to wheat, they cover the soil densely and they provide nitrogen to subsequent crops.

The best crops for precede the bé are the legumes and the tubers. The wheat benefits the nitrogen provided by the legumes. The tubers leave small trail this which facilitates the preparation of ground for the wheat. The crop of wheat in second position after a legume is also recommended. Growing wheat after another cereal crop increases the risk of pests and of diseases.

Wheat can also be grown as intercrops. Good partners for wheat in intercropping are chickpeas, barley, mustard, peas, long-maturing pigeon peas, lentils, or safflower. Wheat can also be planted with crops at short maturation (pea chickpea, lentil or lentil d 'Spain) at the end of its growing season, if the soil is still sufficiently moist. A cover crop can also be planted after the second crop weeding, before the wheat comes out. successive passes with a cereal harrow,
a weeder or feeder mixes the seeds and improves germination **(http://www.agriguide.org)**

11. Import and consumption :

11.1.Production and consumption of wheat in Algeria :

Each year, approximately 3.3 million hectares are devoted to cereal crops of which approximately 1,5 million hectares are planted of wheat hard,600 000 hectares of wheat soft, the cereal harvest reached 4 MT of which bread wheat represented 1% of total production.Wheat being the basic consumer product, the inhabitants of the Maghreb countries are the largest consumers of this commodity in the world, particularly Algeria with nearly 600 grams per person per day.

This wheat consumption has increased slightly in recent years due to increased urbanization, population growth and increased milling capacity, but is expected to remain more or less stagnant.

According to the FAO during the year 2014, Algeria is ranked in fourth position at African level and in seventeenth position at world level with a wheat production of 2.4 million tonnes, collared is made up on average of hard wheat 58.7%, soft wheat 33%. **(Zettal, 2017).**

11.2.Import of wheat into Algeria :

On the world market, Algeria still remains among the major importers of cereals (particularly durum and soft wheat) due to the low capacity of the national sector at satisfy the growing consumption needs of the population.

Algeria imported 6 to 7 Mt per year of total wheat over the past five years, soft wheat accounted for about 80 percent of total wheat imported in 2015, while imports of durum wheat accounted for only 20 percent, because it is produced less wheat soft than wheat hard and than the production domestic is still mainly focused on time and does not yet meet demand despite the increase in yields due to agricultural strategy.

France remains the main supplier of wheat to Algeria, representing 54 percent of imports in 2015, mainly soft wheat. And it imports durum wheat from Canada, Mexico and the United States. **(Zettal,2017).**

II. Mycorrhizal :

1. General information on mycrohizae :

It is only in recent decades that botanists and mycologists have realized that almost all land plants live in symbiosis with soil fungi **(Mosse, 1956).** The term mycorrhiza, which results from the combination of two Greek words 'mukès' (mushroom) and 'rhiza' (root), designates the symbiotic association between beneficial soil fungi and plant roots and is the base, a bidirectional nutrient exchange interface. (**Smith & Read, 2008).**

Mycorrhizal fungi are heterotrophic for carbon, so they need carbon resources that are produced by the photosynthetic activity of the plant. In return, the fungus takes and transports mineral nutrients and water to the plant **(Honrubia, 2009).** Used for the first time by Frank (1885), the term “mycorrhizae” today includes several types of mycorrhizal symbiosis. depending on the fungus involved and the symbiotic structures formed. Wheat forms late arbuscular mycorrhizae (AM) **(Trouvelot et al.,1982),** so we were interested in their study.

2. The different types of mycorrhiza :

According **to (Tacon 1985and Durrieu 1993)**; mycorrhizae are distributed between three large main morphological types:

ectomycorrhizas, endomycorrhizas, ectendomycorrhizas

2.1 The ectomycorrhizas :

About 3% of plants have only established this kind of mycorrhiza (**Mousain,1997).** These are associations where the fungus surrounds the living cells of the roots, but does not penetrate them; the mycelia progresses between the cells of the root cortex to form the intercellular hartig networks, the ectomycorhises develops a mantle, formed by hyphae that cover the surface of the root; Mycelial cords spread from the mantle toward the surrounding soil, usually absorbent hairs do not develop on ectomycorrhizae, and the roots are short and often branched **(Selosse, 2007; Raven & al., 2007 and Duloux and Nicole, 2004).**

2.2 The endomycorrhizae :

Almost all plants form at least one type of endomycorrhiza, generally vesicular and arbuscular endomycorrhiza. They associate with more than 90% of land plants. This type of mycorrhizal symbiosis is characterized by the absence of a fungal coat. In this association, fungal hyphae penetrate the outer cortical cells of the plant roots, where they grow intracellularly and form balls, swellings and small branches **(Prescott & *al*, 2003).** According to **(Durrieu, 1993),** there are three main types of endomycorrhiza:

- Endomycorrhizae to platoons of septate hyphae
- endomycorrhizae ericoid
- The endomycorrhizae of orchids

2.3 The endomycorrhiza to arbuscule and to vesicle:

MA fungi belong to the Phylum of Glomeromycota.They are widespread across the world and genus Glomus is the most ubiquitous and the often encountered They are non-specific and an MAV fungus isolated from the roots of a plant or from the spores of its rhizosphere can be easily associated not only to of plants of the same genus (**Molina & *al*,1978)** , but also to other plants of different families and genus (**Plenchettes & *al* , 1982).**

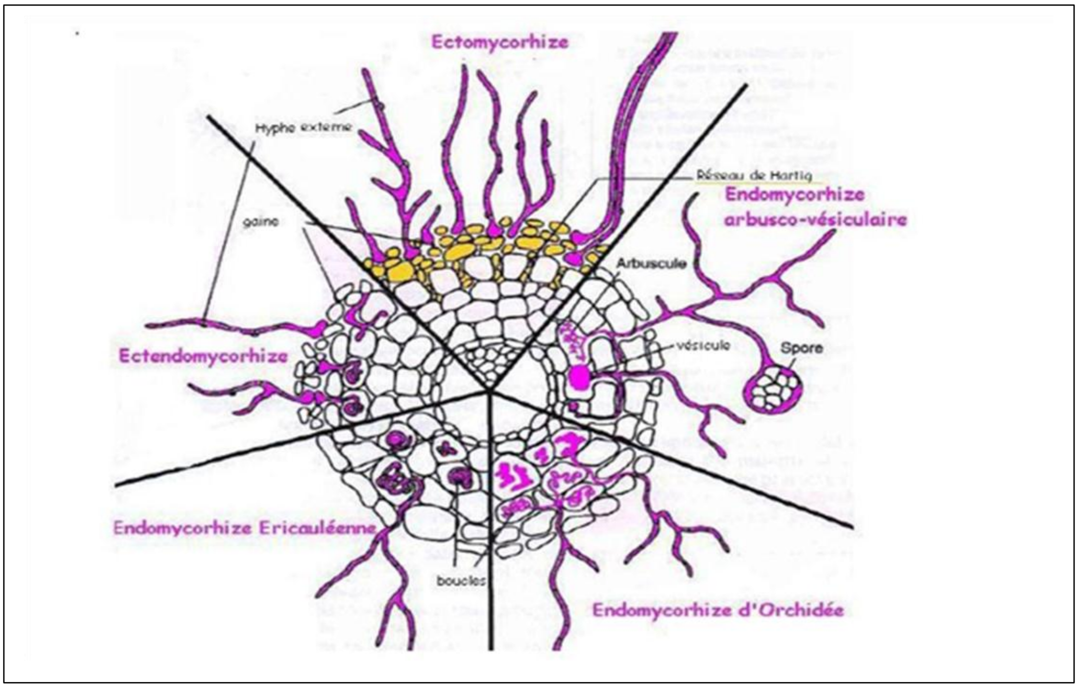


Figure06 : Schematic representation of different types of mycorhizea **(Peterson & *al*.,2004)**

3. Mycorrhizal symbiosis :

towards the end of the 1880s, these associations called mycorrhiza, the term mycorrhiza is a term used for the first time by the German plant pathologist **(Frank, 1885).**

Mycorrhizal associations between roots and fungi are common in almost all natural ecosystems; approximately 90% of terrestrial plants are in fact capable of establishing a symbiosis to mutually exchange nutrients and elements necessary for their proper development. Heterotrophic fungi provide mineral elements to the plant such as nitrogen and it receives carbon molecules from photosynthesis **(Duhoux and Nicole 2004 and Redon 2009)**

The root plays a role from a health point of view, because it stimulates the defenses of its plants hosts. For the mushrooms, the symbiosis their allows food

carbonaceous substances via the root system of plants **(Damas, 2013 in Smaali 2013)**

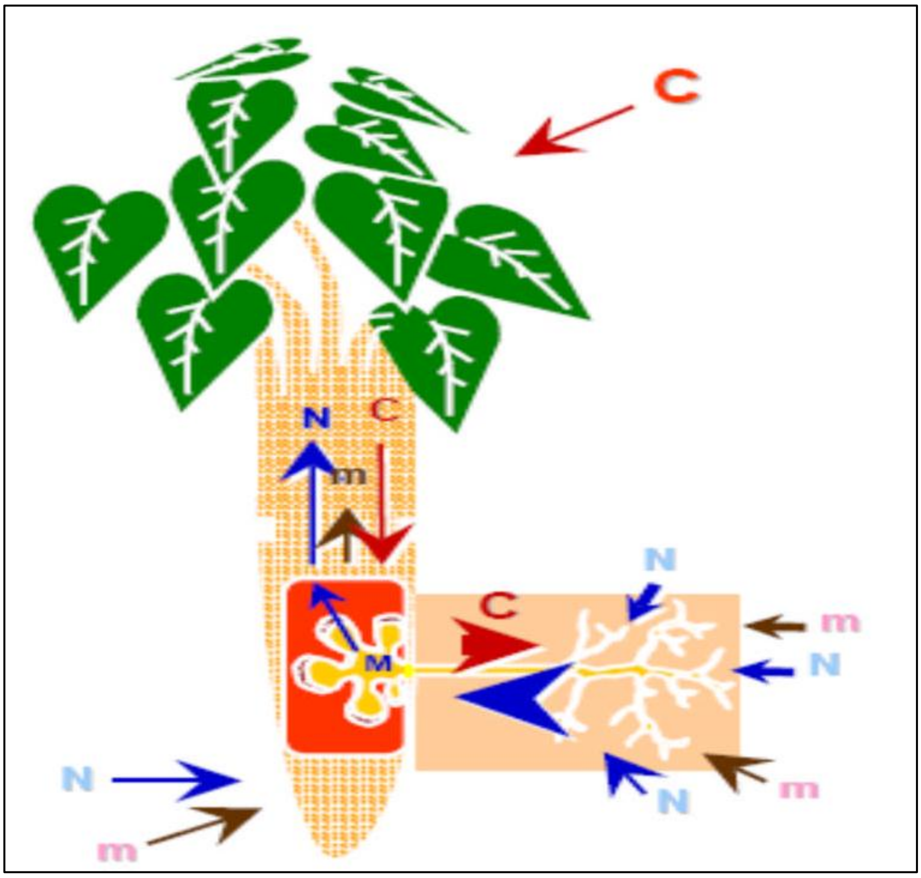


Figure7 : diagram of mycorrhizal symbiosis **(From Rougemont,2007).**

4. Reproduction endomycorrhizal fungus :

The reproduction of the endomycorrhizal fungus only occurs when the symbiosis is established: the mycelium extends in the rhizosphere and the spores form at the hyphal branching end. Any endomycorrhizal fungal AM system can include a host plant **(Gianinazzi et *al*, 2002).**

4.1 Protection against pathogens :

The mycorrhizal association is a biological means of combating telluric pathogenic organisms, by reducing the carbonaceous substrate of the rhizospheric environment by the use of root exudates, or by forming mechanical obstacles difficult for certain microorganisms to overcome, by synthesizing inhibitors of the development of certain soil micro-organisms. Finally, by producing antibiotic substances (chloromycorrhizin A,mycorrhizin A) which can protect the plant.**(Dalpé, 2005).**

4.2.Protection against pollutants :

Mycorrhizae protect trees from the toxic effects of pollutants; heavy metals such as: lead, nickel, mercury or chromium and radioactive substances such as strontium and cesium; retaining them in the fungal coat thus reduces their concentration inside the plant **(Egli and Brunner; 2002).**

4.3.Process of infection of the endomycorrhizal symbiosis:

Infection occurs from of (spores, fragments of hyphae of mycorrhizae).

There are several routes of penetration, the hyphae of the fungus penetrate the root either through root hairs **(Boullard,1968)**, or directly into the cortical cells **(Scannerini and Bonfante -Fasolo, 1982)** and more rarely between the cortical cells **(Jacquelinet, 1986).**

After penetration, hyphae form of structure s very branched s called arbuscules and into some cases, of bulge s terminal or vesicles. Arbuscules do not penetrate into the protoplasm, but cause a strong invagination of the plasma membrane, this which increases its surface and facilitates exchanges between symbiotic partners **(Ravenet *al.*, 2007).**

The entire process of penetration and of the formation of the endomycorrhiza is carried out in three phases :

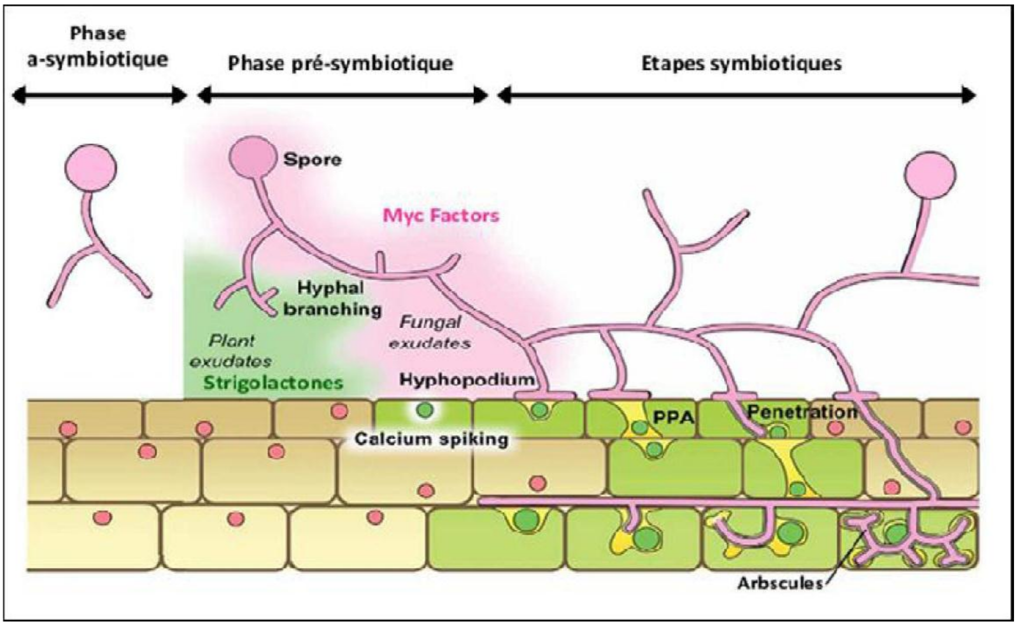


Figure 08: Diagram of different stages of colonization of fungi MA, adapted from **(Bonfante et Genre, 2010).**

After spore germination(asymbiotic stage); (2) The presence of mycorrhizogenic fungi near the rootsof host plants leads to an exchange of signals between the two symbionts, this is the presymbiotic phase; (3) The symbiotic stage begins with contact with the root surface, thus the fungal hyphae form a structure called "appressorium".

From this recognition structure, the fungus develops intraradicular hyphae and penetrates the root tissues until they reach the inner layer of cortical cells;(4) The fungus then penetrates the cortical cells where it forms intracellular structures called "arbuscule" because of their shape.

This structure, which is lined with the host plasmalemma, constitutes the active site for the bidirectional exchange of nutrients: water and mineral elements towards the plant,and carbohydrates towards the fungus; (5) The periarbuscular space (PAS) refers to the interface that forms between the fungal membrane and the periarbuscular membrane (PAM) of the plant. In addition to nutrient uptake, root colonization by AM fungi can lead to plant protection against a wide range of root pathogens; (6) the life cycle of AM fungi is completed by the formation of spores at the extraradical mycelium, which can enter into another colonization process **(Tisserant, 2011)**

5.development of symbiosis :

5.1.Cycle of development of the fungus and formation of mycorrhizae :

The putting in place recognition the symbiosis MA can be in vised as a programmed sequence recognition phenotypic changes, corresponding to distinct recognition events which lead both partners, host plant and fungal symbiont, to a high degree of morphological and physiological integration.

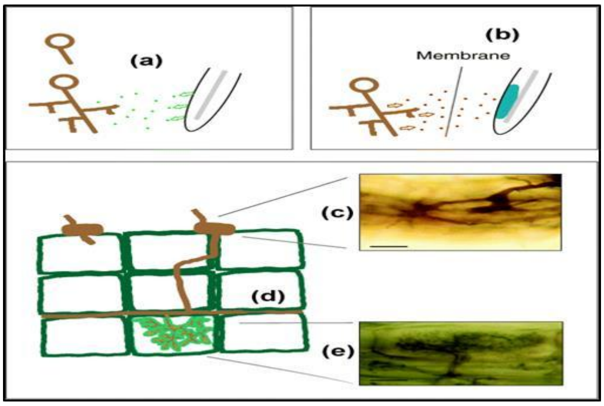


Figure 09: Stages of root colonization by an arbuscular mycorrhizal fungus (AM). **(anonymus 2006)**

(a) Hyphal branching occurs upon perception of strigolactone released by the plant;

(b) expression of pENOD11:GUS during of the perception of the oudes factors Myc;

(c) F ormation of appressorium setpassage through the layers cellular external roots;

(d) longitudinal spread of the fungus Apo plastic; formation of arbuscules in the cortex internal.

Photomicrographs show rice roots stained with chlorazole black and colonized by intraradices of *Glomus.* Bars, 25 mm. **(Paszkowski,2006)**.

5.2.Reactions fungal salts signals of plant origin:

For two symbionts, the period preceding physical contact (evaluation training) involves recognition and attraction of partners appropriate and other s events promoting an alliance. The survival of the biotrophic fungus is enhanced by germination and rapid colonization of host plants. AM fungal spores persist in the sol and germinate spontaneously, independently of signals of plant origin. However, root exudates and volatiles can promote or suppress spore germination, indicating the existence of spore “receptors” sensitive to alterations. After germination, the hypha germ tube grows into the soil.

In the absence of a potential host (phase a symbiotic) **(Paszkowski, 2006).**

This constitutes the pre-symbiotic phase and its success is very dependent on two conditions: soil properties (e.g. pH, humidity and temperature), and the host plant (e.g. root exudates, such as flavonoids, CO 2, and unknown cationic duramification factors) **(Buee et al., 2000; Besserer et al., 2006; Zsögön et al., 2008).**

These conditions are capable of modifying the metabolism of AMF, thus stimulating the growth of mycelium and of hyphal branches **(Buee & *al*,2000;Campelli & *al*,2005; Requena & *al.*, 2007).**

After the establishment of physical contact with the surface of the root, the cells extra radicular hyphae differentiate into appressorium cells, and the symbiotic phase begins

(Brundrett, 2004; Ramos *&* ***al*** **, 2009 a, b; Kiriacheck &** ***al.*****, 2009) (Souza,2015).**

From the moment when a hypha enters in contact with the wall of a epidermal cell, the interaction passes into the symbiotic phase **(Genre and Bonfante,2016).**

The fungi appear to colonize the root tissues of the host plant by via a combination of mechanical and enzymatic processes and the coordinated of the cell host, this which facilitates the penetration of fungi mycorrhizal in the cortex of the root **(BonfanteetPerotto,1992)** by the action of enzymes which dissolve the walls cellular **(Linder man ,1994) (Mekahlia,2014).**

The morphology of the symbiotic intra-root structures was classified into two types, Paris and Arum, according to the two plants where they were described for the first time. In Arum-type colonization, the fungus proliferates along the root in the intercellular spaces and the arbuscule enters the cells through the resulting axes. In the Paris type, the fungus diffuses from cell to cell, and in many cases pellets of hyphae are formed without or with arbuscules **(Bonfante and Genre, 2008).** Most plants form an intermediate structure between these two models, which leads to the formulation of the term "Arum-Paris type continuum " **(Dickson, 2004) (Driai , 2016).** A brief description of different phases of development of the mycorrhizal symbiosis of AMF shown in **Figure 9**

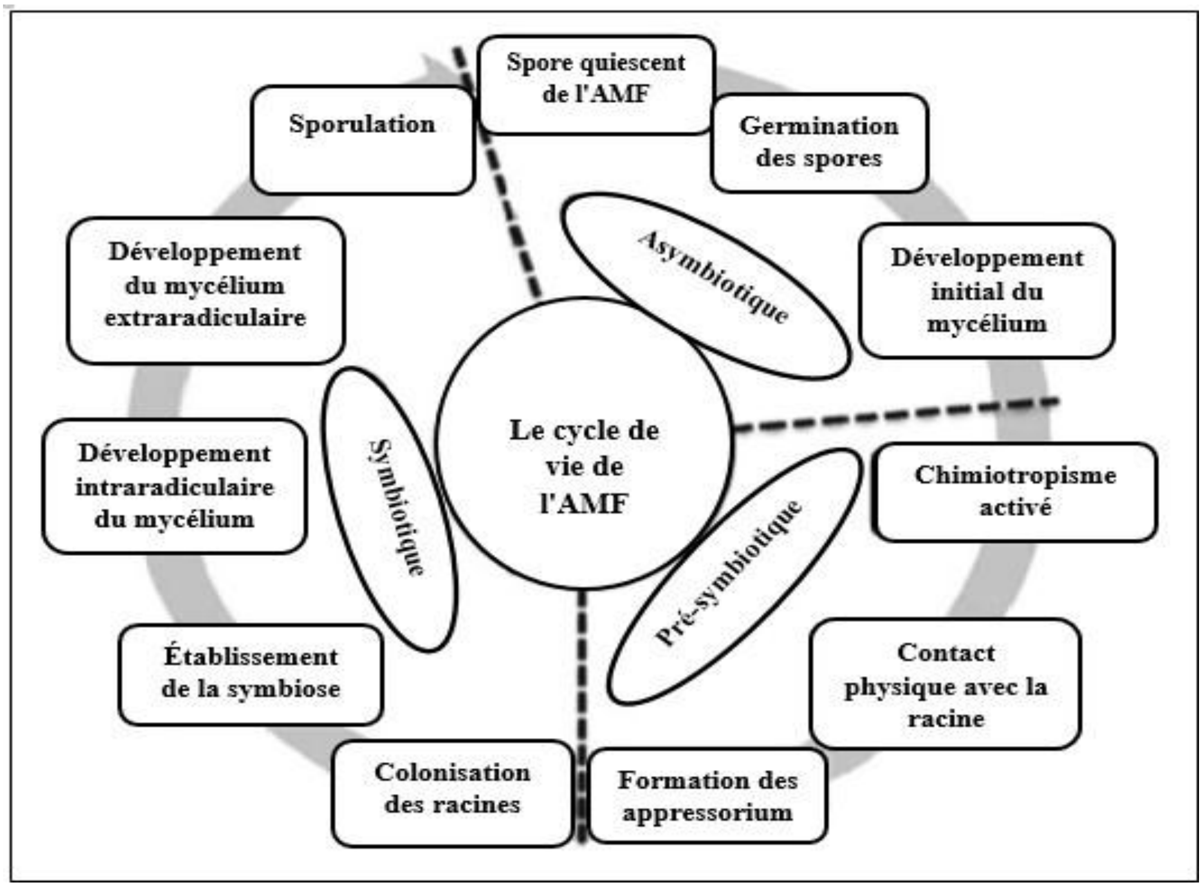


Figure 10: Main processes during during cycle of life of MFA **(Souza, 2015).**

6. The Role and importance :

According to (**Gianinazzi,2013)** the fungus smycorrhizal are considered as:

- Bio fertilizer, improvement nutrition of plant in particular in phosphorus;
- Bio regulators, controls the growth and yield of plants (increased size and productivity but also their development (more dichotomized root architects and more abundant flowering).
- Bio stabilizer; promotes the retention of soil aggregates, thereby stabilizing its structure and quality.

We call the specificity of an interaction between two organisms the possibility or not that two given species have of contracting this interaction. In the case of mycorrhizal symbiosis, we have just seen that not all plants associate with just any fungus. In some cases, well-defined groups of plants only form mycorrhizae with an equally well-defined group of fungi, such as Ericales with only a few Ascomycetes genera. Conversely, most species of sarbuscular endomycorrhizal fungi seem to be able to colonize the roots of practically all plants likely to host Glomeromycetes, that is to say more than 80% of known species (**Garbaye, 2013).**

10.1 Role of mycorrhizas :

The fungi mycorrhizal arbuscular (MA), being that organic trophs obligate, depend for their growth and their activity on the carbon provided by their host plant and, in exchange, they improve the mineral nutrition of the plant, in particular the acquisition of phosphorus and, to some extent, nitrogen and other minor nutrients. This exchange of nutrient its place to through the symbiotic interfaces which is develop when the fungus colonizes the root system **(Ferrol and Pérez-Tienda, 2009).**

10.2 water supply:

Even if the more share of the work carried out with the CMA 'is concentrated on their effects on mineral nutrition in plants, there is also growing interest in drought resistance of plants mycorrhizae **(Allen and Boosalis, 1983).** AMF are important in sustainable agriculture, because they improve the water relations of host plants and increase if their resistance to drought **(Allen andAllen, 1986;Nelsen,1987;Mekahlia, 2014).**

10.3 Nutrition mineral :

mushrooms MA have extraordinary importance in that they facilitate the absorption of nutrients by the plant and give it resistance to biotic and abiotic stresses **(Barea & *al.* 2002).** Due to its ability to improve the nutrition of the plant, this association is very useful for the plant because it maintains its growth in an environment with content limited in nutrients **(Nadeem & *al* ,2017).** mycorrhizal fungi are capable of absorbing almost all nutrients at different rates. However, fungi are able to absorb P at the highest efficiency, which is due to production of enzymes such as phosphatase .

Although it has been indicated that fungi are capable of absorbing mineral and organic nitrogen from the soil, the question of how fungi can affect nitrogen uptake by their host plant is still under investigation. 'a debate. This may be due to the chemical differences that exist between these elements.

salt stress conditions, increased absorption of nutrients such as K, Mg and Ca Fungi are also able to absorb K, Mg, Ca and the S .

.' absorption of nutrients by mushrooms is also important under of conditions of stress, where mushrooms can significantly increase the absorption of nutrients by the plant. For example, in by fungi can help the plant tolerate stress **(Miransari, 2013).**

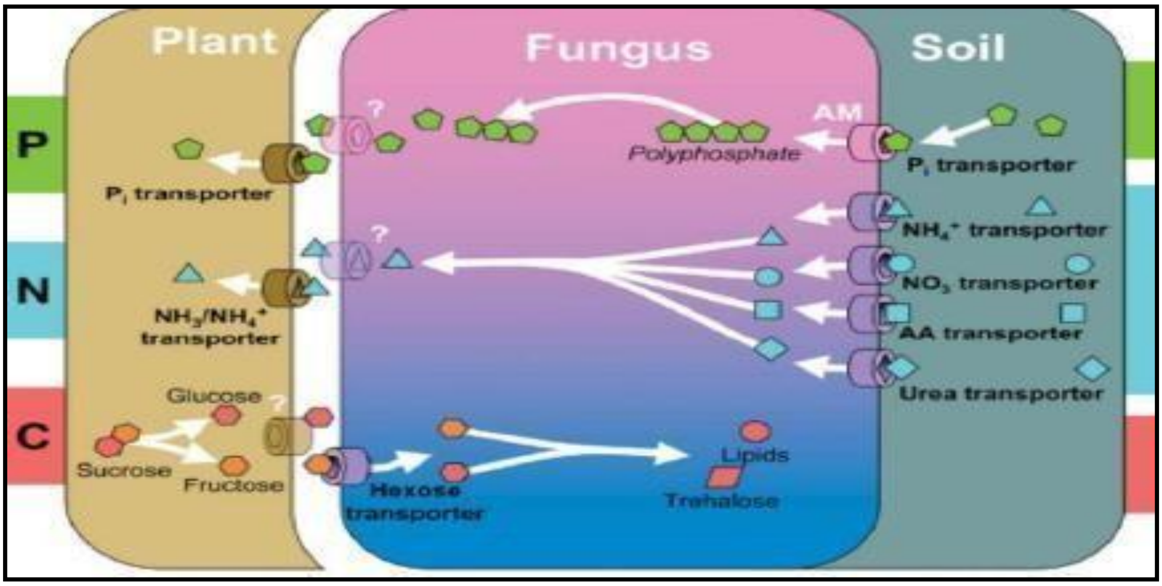


Figure 11 : Diagram summarizing the main processes of exchanges of nutrients in all of mycorrhizal symbioses **(BonfanteetGenre,2010).**

The interfaces between the three compartments soil, fungus and root are represented. Inorganic P (Pi) and forms of organic or inorganic N, such as NH4+, NO3- and amino acids (AA), are collected in the soil by specific hexose transporters located in the mycelium extra-root.NH3/NH4+ and Pi (after hydrolysis of the poly groups -phosphate (Poly-P) in CMA) are imported at level from the inter face symbiotic at level specific arbuscules in the CMA towards the cells plant thanks to to specific hexose.The hexose transporters import the carbon © from the plant to the fungus **(Driai, 2016).**

Some selected examples have been reported in **(Table1)** which indicate the potential of mycorrhizal fungi to improve plant nutrition. Mycorrhizal fungi are involved in facilitating phosphorus uptake by plants. Mycorrhizal fungi have a phosphate transporter for the transport of Pi (inorganic phosphate) from soil to plant (**Harrison and Van Buuren, 1995**)

mushrooms MA increase the concentration of P in plants in facilitators we absorption increased to from the soil thanks to growth hyphalextensive which allows plants to explore a greater volume of soil than plants non mycorrhizal**(Ruiz -Lozano and Azcon ,2000;Nadeem &** ***al*****, 2017).**

When the hypha penetrates a root cortical cell to form an arbuscle, the fungal cell wall becomes thinner. Chitin, a major component of the cell walls of AM fungi, exhibits an amorphous structure in these walls compared to the thin, fibrillar structure of chitin in the extraradicular cell hyphae. As a result of the fungus penetrating the host cell, the host plasma membrane is closely invaginated along the penetrating hyphae to surround the arbuscular hyphae. The plant plasma membrane that surrounds the arbuscular hyphae is called the peri-arbuscular membrane, like the peri-bacterial membrane that surrounds the bacterial in the legume root nodule. The plant cell wall is almost absent around an arbuscule, so that the peri-arbuscular membrane closely faces the wall fugitive through the interfacial matrix. The interfacial matrix is rich in B-glucan, hydroxy-proline-rich glycoproteins and polysaccharides with N-acetyl galactose and galactose residues. Thus, the arbuscule gives the two symbionts a large surface area in which the two membranes are in close contact through a fine interfacial matrix.

From such the micro-morphological characteristics of the arbuscule are adapted to the transfer of nutrients between symbionts **(Saito, 2000).**

AMF hyphae contribute to soil structure. Indeed, mycorrhizal fungi are a major component of soil organic matter and would make a grand contribution for the storage of carbon in the soil.

These shyphes represent also of pipelines that can transport carbon from plant roots to other soil organisms involved in the processes of the cycle of elements nutrients **(Brundrette and Abbott,2002).**

mycorrhizal fungi can help plants survive in soils affected by acid precipitation **(Malcova et *al*,1998)** and may sometimes be necessary for _> rehabilitate habitats or the conservation of rare species **(Koske and Gemma,1995)** and even play the role of bio indicators **(Oehl and *al* , 2011b).**

Additionally, these mushrooms are an important source food for certain s animals **(Mc Gee and Baczocha,1994;Janos & *al* ,1995;Mekahlia,2014)**

Nutrient	Culture	Mycorrhizae	References
Nitrogen(N)	Great Britain(Cajanuscajan)	Glomusmosseae	**(Garget Manchanda, 2008)**
	Chanvres of river (Sesbania) aegyptiaca)	Glomusmacrocarpum	**(GirietMukerji, 2004)**
	White Clover (Trifoliumrepens)	Glomusmosseae	**(Medinaet*al.*,2006)**
Phosphorus (P)	Soja(Glycinemax)	Glomusetunicatum	**Sharifiet *al*., (2007)**
	Coton(Gossypiumarboretum)	Glomusmosseae	**(Tian et *al*., 2004)**
	Corn (Zeamays)	Glomusmosseae	**(Fenget*al*., 2002)**
	Tomate(Lycopersiconesculentum)	Glomusmosseae	**(Al-Karaki, 2000)**
	White Clover (Trifoliumrepens)	Glomusmosseae	**(Medinaet*al.*,2006)**
	White Clover (Trifoliumrepens)	Glomusmosseae	**(Medinaet*al.*,2006)**
Potassium(K)	Soja(Glycinemax)	Glomusetunicatum	**(Sharifiet *al*., 2007)**
	White Clover (Trifoliumrepens)	Glomusmosseae	**(Medinaet*al.*,2006)**
Calcium(Ca)	Soja(Glycinemax)	Glomus etunicatum	**(GirietMukerji, 2004)**
Magnesium (Mg)	Chanvrederivière (Sesbaniaaegyptiaca)	Glomusmacrocarpum	**(GirietMukerji, 2004)**
Sulphur(S)	Locust (Robiniapseudoacacia)	Rhizophagus intraradices	**(Yanget*al.*,2016)**
Chloride(Cl)	Cotton (Gossypiumarboretum)	Glomusmosseae	**(Tian et *al*., 2004)**
Zinc(Zn)	Glycinemax	Glomusetunicatum	**(Sharifiet*al*., 2007)**
	Sauleàcorbeille(Salixviminalis)	Glomusintraradices	**(Bissonnetteet*al.*,2010)**
	Tomate(Solanumlycopersicum)		**(Watts-Williamset*al.*, 2013)**
Copper	Elsholtziasplendens	Gigasporamargarita,G.decipiens,Scutellosporagilmori, Acaulosporaspp.	**(Wanget*al*., 2005)**

Table 01: Improved plant nutrition through mycorrhizae **(Nadeem & al.,2017).**

Chapter II

Material and methods

1.Objective of the experiment :

This research was undertaken with the aim of demonstrating the impact of mycorrhizae on the development and yield of durum weat simeto variety. To do this, we inoculated a product composed of three arbuscular mycorrhizal fungi on durum wheat in order to evaluate their resistance especially water stress.

2. presentation of the study area : (wilaya of Ain Temouchent)

2.1. Geographic description of the experimental site:

The wilaya of Ain Temouchent is located between latitudes 35° and 37° nord and longitudes 0° and West.

It is limited by the wilaya of Oran to the east, the wilaya of Tlemcen to the west, the wilaya of Sidi Bel Abès to the south and the Mediterranean Sea to the north.

2.2 climate :

It benefits from a temperate Mediterranean climate, with mild, rainy winters and hot, dry summers.

2.3. Economy :

The wilaya's economy is largely based on agriculture, with crops such as wheat, barley, grapes and olives.

2.4. presentation of the study stage:

The experiment was carried out within the grounds of the University of Ain Temouchent, the GPS coordinates of the site of which are as follows:35°17’33.3 north latitude and 1°07’16.3 longitude

Figure12 : the Temouchent University study area **(Abdelkader.2024)**

3. Plant material:

The plant material used is a durum wheat grain, variety <simeto> Take from the cereal and legume cooperative **(Annex 1)**.

Simeto is a semi-precocious to precore variety known for its amber color and hardness which makes it an ideal raw material for mills and pasta makers.

Figure 13: durum wheat seed <simeto> **(Abdelkader.2024)**

4. Material fungal:

The inoculated material is a product imported under the trade name "**Biocult ML45**", it is mainly composed of three fungi: Glomus mosseae, Glomus intraradices and Glomus etunicatum.
These mushrooms are arbuscular types **(technical sheet in Annex 3)**

.5 Experimental apparatus :

The device consists of two batches with four repetitions each. Each bucket contains 13 durum wheat seeds. A group inoculated with mycorrhizae and a control group. see **(Figure14).**

Figure14 : the two groups of wheat used **(Abdelkader.2024)**

6. Material used:

Our experiment took place in two phases:

Phase I: on the open field

The material used is as follows:

• University topsoil • durum wheat seeds <simeto>

• Inoculum ML45

• Plastic buckets

• glove, scale

Phase II: In the laboratory :

For the determination of mycorrhizae, the equipment used is as follows:

• Root fragments of durum wheat plants

• Methylene blue

• Acetic acid

• Microscope, slide, coverslip • Water bath • KOH (10%),

• Distilled water, beaker, pipette, wash bottle, graduated cylinder, forceps and petrie dishes

7. Crop management:

7-1 - Germination of seeds of wheat:

We used 8 pots then we put 13 grains of durum wheat (S imeto) in the soil of each pot (**Figure 15-16),** and then we put 1g of mycorrhiza in 4 pots and the other 4 pots are used as a control (Nonmycorrhizal)(**Figure 17/18)** For watering we watered with 1.5 liters of water (**Figure 19)** twice in the first period: During planting then after 15 days with a second inoculation of mychorize **.**

Figure 15: preparation of grains

(Abdelkader.2024)

Figure 16: Quantity of grains

(Abdelkader.2024)

Figure 17: method of adding mycorrhizae to a pot **(A.hanane.2024)**

Figure 18: First watering 01/31/2024 **(A.hanane 2024)**

Figure 19: Second inoculation of mycorrhiza **(A.hanane. 2024)**

In order to know the effect of mycorrhizales, we stopped watering in order to achieve water stress (**Stade of three sheets**).

7-2 Parameters measured:

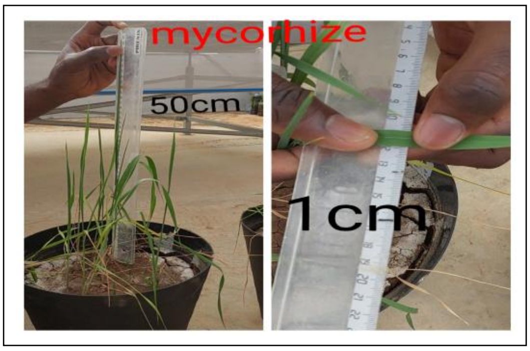
7-2-1. Morphological parameters:

7.2.1.1.Measurement of the length and width of the leaves: L length of the leaves was measured

,

root length root weight

a-



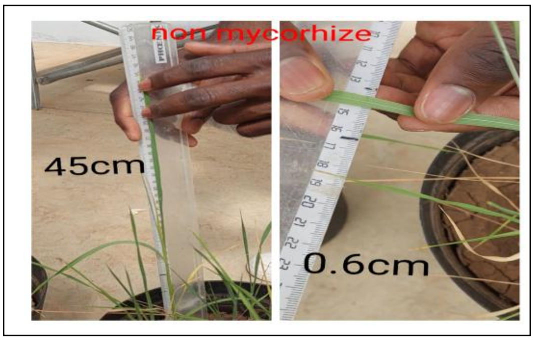


Figure 20: Mourning of languor and dropping leaves (**hanane.mohamed.2024)**

B-

After one month of cultivation, root measurements were taken in order to see the effect of mycorrhization on the roots (**Figure 21**) and after 3 months (**Figure 22)**

Figure 21: observation the roots

(Abdelkader.2024)

Figure22 : observation the roots after a me

after 3 months **(Abdelkade.2024)**

7.2 1.2- Messuring root dry weight:

The dry weight of wheat roots was measured with and without mycorrhizae

Figure 23: the dry weight of roots with and without mycorrhizae **(Abdelkader.2024)**

-7.2.1.3Messuringleaf cont:

The number of leaves was counted before and after water stress.

Figure 24: calculating the number of leaves (**Abdelkader.2024)**

Messuring wheat brain yield and Quality:

The number of spikes has been counted and their quality assessed

7-2-2. Microscopic parameters:

Microscopic observation of the roots :

The roots of the seedlings (mychorized and non-mychorized wheat) detected are colored with T rypan blue according to the technique of **(Philips and H ayman, 1970),** which allowed us to highlight the difference between the two samples.

A-Root collection and preparation:

1- Choose the seedling.
2- Rinse the roots to remove all soil **(Figure 25)**
3- Cut the most non-lignified parts into segments approximately 1cm **(Figure 26)**

B- coloration:

1- Prepare the potash solution (10g potash for 90 ml of water) **(Figure 27)**
2- Put the solution in a container and put the roots in it
3- Place everything in a bin at 90° for 10 min to allow the potash to settle **(Figure 28)**
4- Take the roots and put them in another container containing white vinegar.
5- After 5minutes, the roots are ricinized in the5% methylene blue bath with vinegar **(Figure 29)**
6- Then in the Marie bath like the other time in May for 5 min
7- Place the root fragments on a slide and apply the coverslip on them, pressing gently

C- observation:

1- Install the slide without a binocular magnifier or microscope so you can observe it on one hand.
2- Fungal hyphae transport nutrients and explore the soil

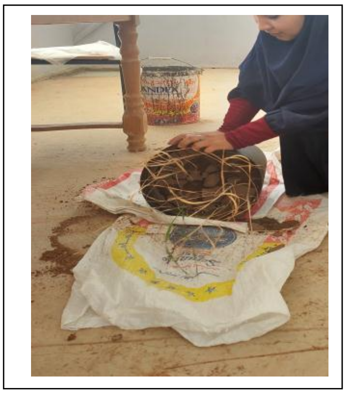


Figure 25: choose weight **(Abdelkader .2024)**

Figure 26: Rinse the roots (**Abdelkader.2024**)

Figure27: Cut the thinner parts **(Abdelkader.2024**)

Figure 28: Potash solution **(Abdelkader.2024.)**

Figure 29: Roots bathed at 90° in vinegar **(Abdelkader. 2024)**

Figure 30: methylene blue solution **(Abdelkader.2024)**

Chapter III

Results and discussion

Results:

I. Morphological parameters:

1- Measurement of the length and width of the leaves:

After 35 days of planting durum wheat, we obtained a certain number of leaves. The average length of the leaves of mycorrhizal durum wheat s was longer (50 cm) than that of the leaves lles without mycorrhiza (45cm).

The width average of leaf mycorrhizal s reached 1cm while leaf without mycorrhizae reached 0.6 cm **Figure 31**

It can be inferred that mycorrhizae have a positive effect on leaf growth in wheat.

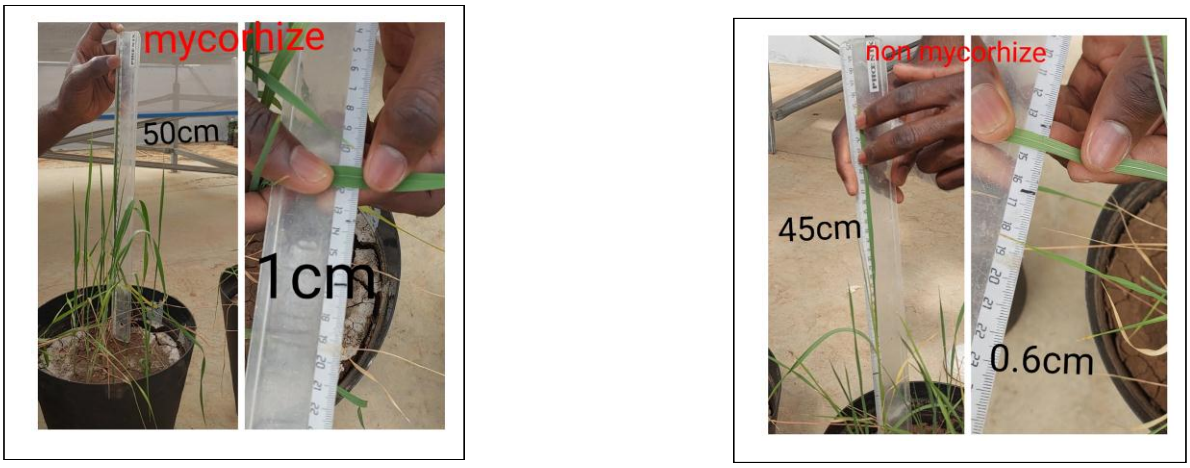


Figure31 : Length and width of leaves mycorrhizal and without mycorrhiza

(Abdelkader, 2024)

- Measure of the length of the roots:

Mycorrhizal and non-mycorrhizal roots are observed after 35 days of growth and see the differences in length and branching **Figure32**

Figure 32: L roots after 1 months

Figure 33: L roots after 3 months

(Abdelkader.2024)

Figure 34: the roots after 3rd months and a half **(Abdelkader.2024.)**

3- Measurement of numbers of sheets l :

After tracking the number of leaves in a few weeks for three months We noticed that the number of mycorrhizal leaves is always high by app or t leaves without mycorrhiza (**Figure 35/36)**

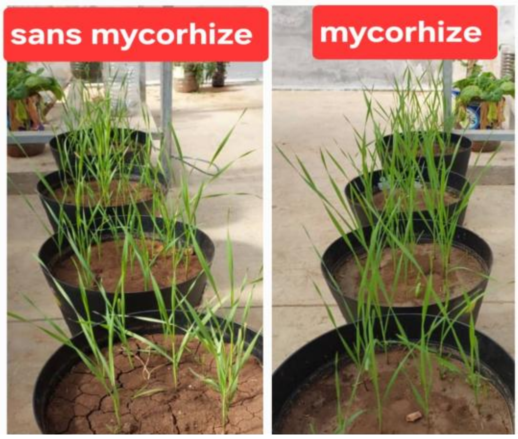


Figure 35: The After 1st month

Figure 36 : The After 3rd month

(Abdelkader.2024)

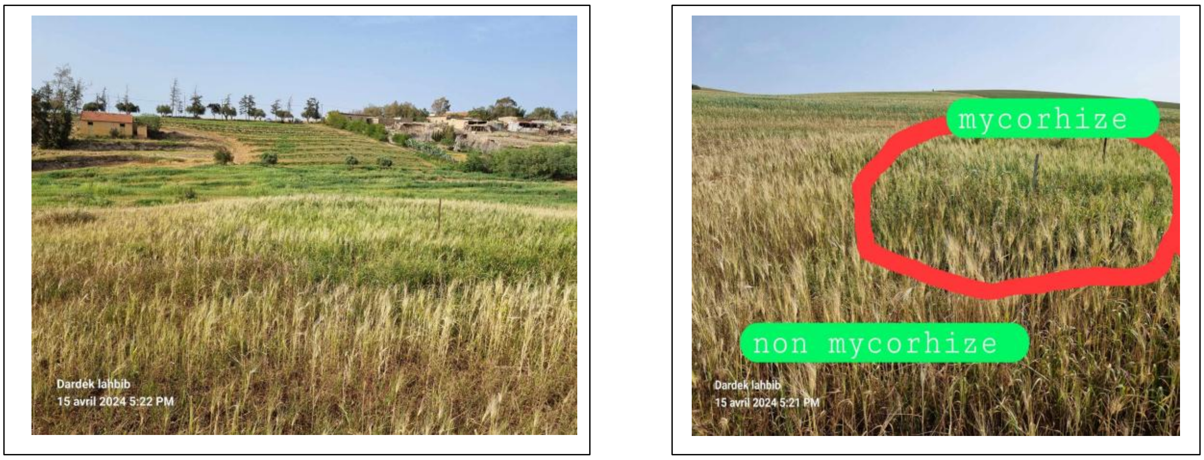
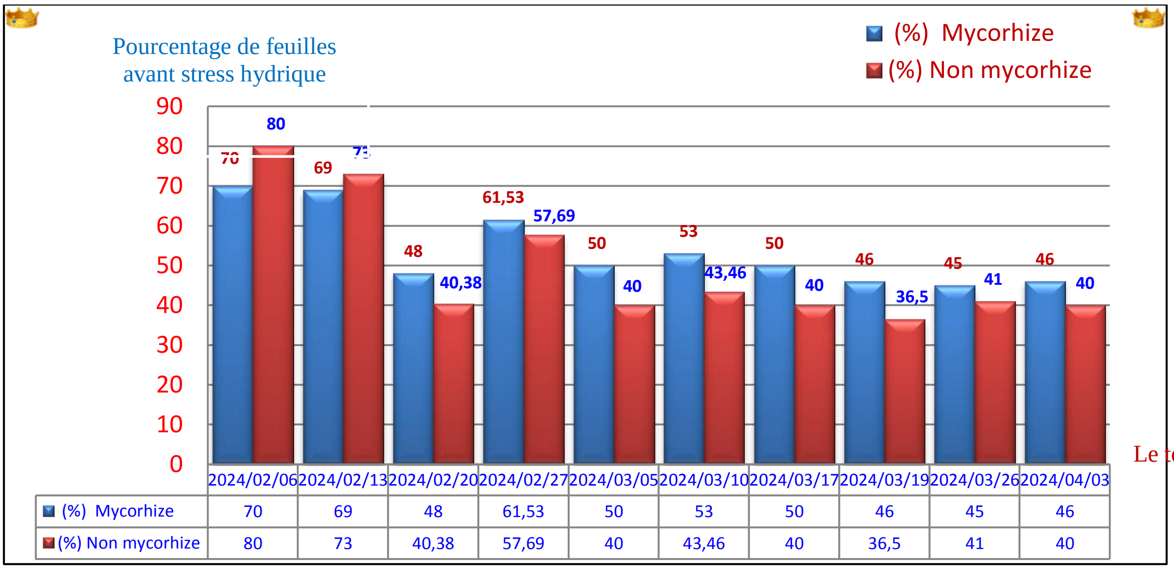


Figure 37: the difference between mycorrhizal and non-mycorrhizal wheat in terms of number and length of leaves and greenery in the orchard **(dardak.2024)**



	2024/02/06	2024/02/13	2024/02/20	2024/02/27	2024/03/05	2024/03/10	2024/03/17	2024/03/19	2024/03/26	2024/04/03
(%) Mycorhize	70	69	48	61,53	50	53	50	46	45	46
(%) Non mycorhize	80	73	40,38	57,69	40	43,46	40	36,5	41	40

Figure 38: Percentage variation of well-developed leaves between mycorrhizal and non-mycorrhizal plants before water stress **(Abdelkader.2024)**

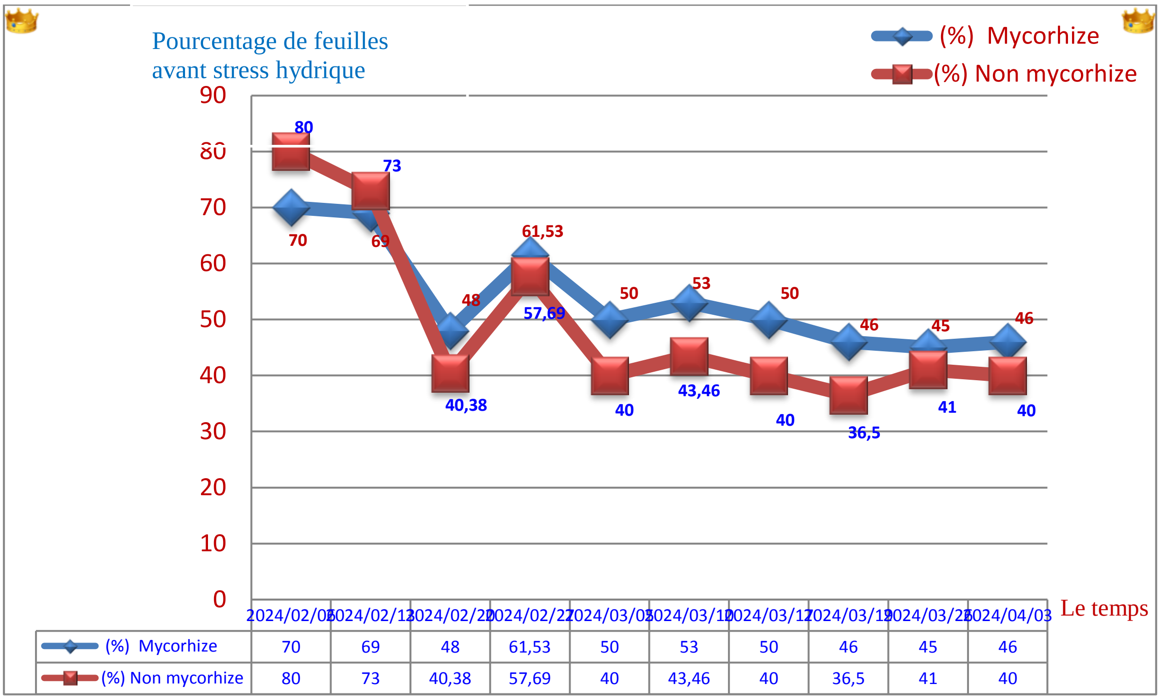


Figure39: The difference in leaf development over time before water stress between mycorrhizal and non-mycorrhizal plants **(Abdelkader.2024)**

Analysis :

Before water stress, we noticed that the number of mycorrhizal leaves developed in greater numbers than non-mycorrhizal leaves with variable proportions.

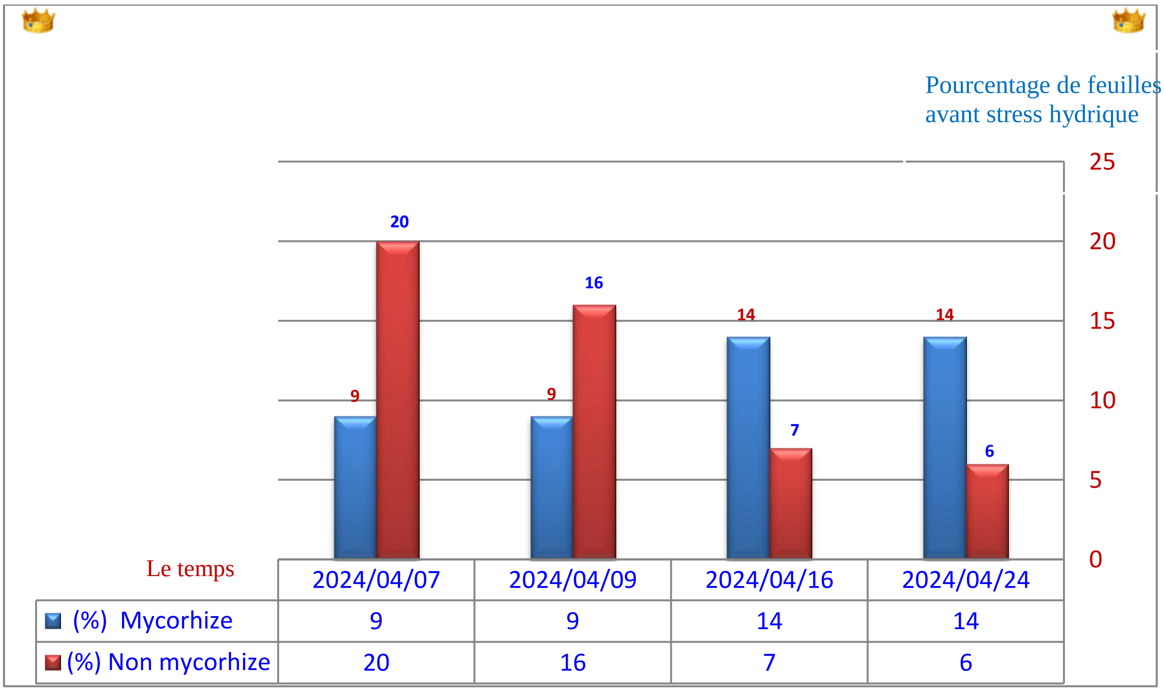


Figure 40: The number of resistant leaves after water stress between mycorrhizal and non-mycorrhizal plants. **(Abdelkader.2024)**

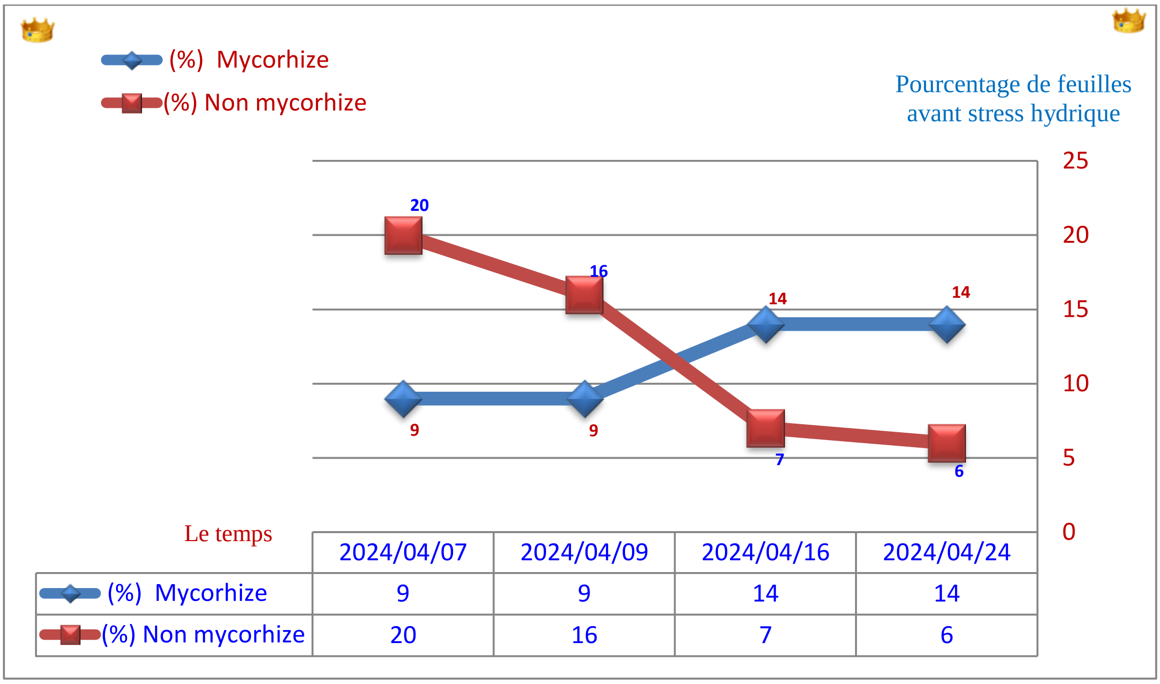


Figure 41: The difference in the evolution of the number of leaves after water stress between mycorrhizal and non-mycorrhizal plants . **(Abdelkader.2024)**

Analysis :

After water stress, the leaves resumed their development and growth, with the mycorrhizae they were wide, whereas without mycorrhizae they were almost narrow.

4- Root dry weight measurement:

After weighing the roots, the results were as follows:

The weight of 3 roots mycorrhizal was 0.10g and the weight of 3 roots without mycorrhizae was 0.02 g (**Figure42/43)**

Figur e 42: the dry roots **(Abdelkader .2024)**

Figure 43: weight of dried roots **(Abdelkader 2024)**

5- Performance measure:

After 3 months of planting durum wheat and 1 month of water stress we obtained the following results (**Figure44**)

Figure44: macroscopic observation of the ears **(Abdelkader.2024)**

	Mycorrhizal wheat				Non-mycorrhizal wheat			
Pots	1	2	3	4	1	2	3	4
Number of leaves	/	/	6	7	/	/	/	2
Number of spikes	/	/	4	7	/	/	/	2

Table02 : N shade of mycorrhizal and non-mycorrhizal ears and leaves After water stress **(Abdelkader.2024)**

Figure 45: Number of ears in mycorrhizal and non-mycorrhizal wheat**(Abdelkader.2024)**

Analysis :

The number of ears in mycorrhizal wheat is much more (13 ears) than in non-mycorrhizal wheat (4 ears)

Figure 46: Ear quality in mycorrhizal and non-mycorrhizal wheat **(Abdelkader.2024)**

Analysis :

The quality of the grains from mycorrhizal wheat ears is good and their weight is greater than that of other grains from non-mycorrhizal ears.

6- Root coloring:

After 3 and a half months, we carried out the coloring of the roots, the aim of which was to confirm the presence of mycorrhizae.

The presence of arbuscular mycorrhizae was manifested at the roots by a blue coloring. This is a structure clearly visible under an optical microscope in the tissues of the root cortex of wheat. The vesicles show the beginning of colonization of intraracian hyphae.

We observed that there is a large amount of s vesicles in all root fragments observed. Which shows the beginning of root colonization.

While the arbuscules (lateral branches of the fungal hyphae in the cells of the cortex) were not observed under the microscope. It can be concluded that the species of fungi mycorrhizens existing in the root system vesicles in the host root tissues.

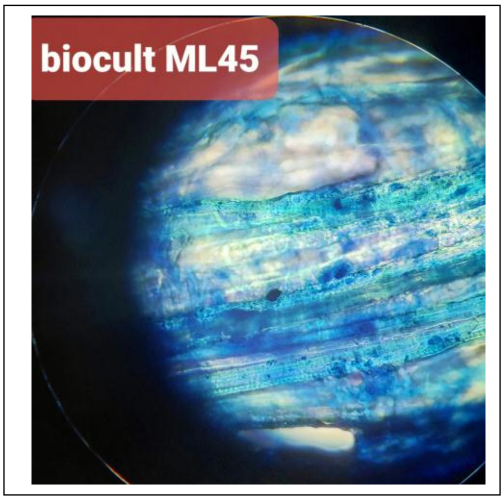


Figure 47: Structure of mycorrhizal and non-mycorrhizal fungi in durum wheat magnification 40x **. (Abdelkader.2024)**

Discussion:

After having studied the impact of mycorrhization on durum wheat Simeto, we noticed a positive and effective effect of mycorrhizae on durum wheat Simeto with water stress, this confirmed the previous data.

The studies of **(Simard, 2014)** demonstrating that a good number of mycorrhizal plants present stimulation of leaf growth so he confirmed this in carrots (*Daucus carro*). Indeed, the mycorrhizal symbiosis allows more efficient assimilation of water and nutrients,

In case of water stress regime, it was noticed that wheat presents the lowest values of leaf length.

(Sh & al,1990) worked on *Prunus persica* , and showed that leaf growth is sensitive to drought since the limiting effect of stress > water appears early and with intensity.

Mycorrhizal fungi are key to resistance to water stress by controlling the synthesis of a plant hormone, abscisic acid (ABA),which is involved in the closure of plant stomata to limit evapotranspiration. Researchers have thus shown that plants with mycorrhizal symbiosis have better hydraulic conductivity and a reduced transpiration rate in drought situations thanks to their ability to regulate their ABA level better and more quickly than plants without mycorrhizal symbiosis. This establishes a better balance between transpiration of the leaf and water movement during dry periods **(Hirissou, 2020).**

Therefore, the study showed that mycorrhizae play a major role in increasing the length and branching of roots as well as leaves which leads to large absorption and retention of water (humidity), also great resistance to drought, as well as resistance to certain observed infections, such as yellowing, rust le and wilting.

Mycorrhizae are biological control agents that allow a large number of plants to protect themselves against mainly root pathogens. Reduction of disease symptoms has been described for pathogens such as Phytophthora, Footrot, Pythium, Rhizoctone, Aphanomyces or nematodes such as Rotylenchus, Meloidogyne. To act, the mycorrhizae must be installed in the root system of the plant before the attack because they are not capable of taking over a pathogenic fungus gene already installed. The following mechanisms are implemented to reduce or even eliminate the progression of pathogens **(Hirissou, 2020).**

Wheat yield components begin to develop at the six-leaf stage **(Hay, 1999)**. As a result, wheat varieties that mycorrhize late could be limited in their ability to benefit from the advantages of mycorrhizal symbiosis (**Singh et al., 2012**), which is not the case for Siméto.

Conclusion

And

perspective

Conclusion :

By studying the effect of mycorrhizae on durum wheat, we were able to conclude that the use of mycorrhizae in agriculture is extremely important because of their benefits and its positive aspects on production yields and control e drought and diseases ,especially the effective effect on the length and branching of roots to absorb the greatest amount of water.

Also, its role also in the length, width of the leaf and their wrapping so as not to lose an amount of water during the transpiration process.

The use of mycorrhizae as a biological fertilizer helps improve plant health and increase their resistance to pollutants and environmental conditions, especially water stress.

In conclusion that mycorrhizae are essential for agriculture.

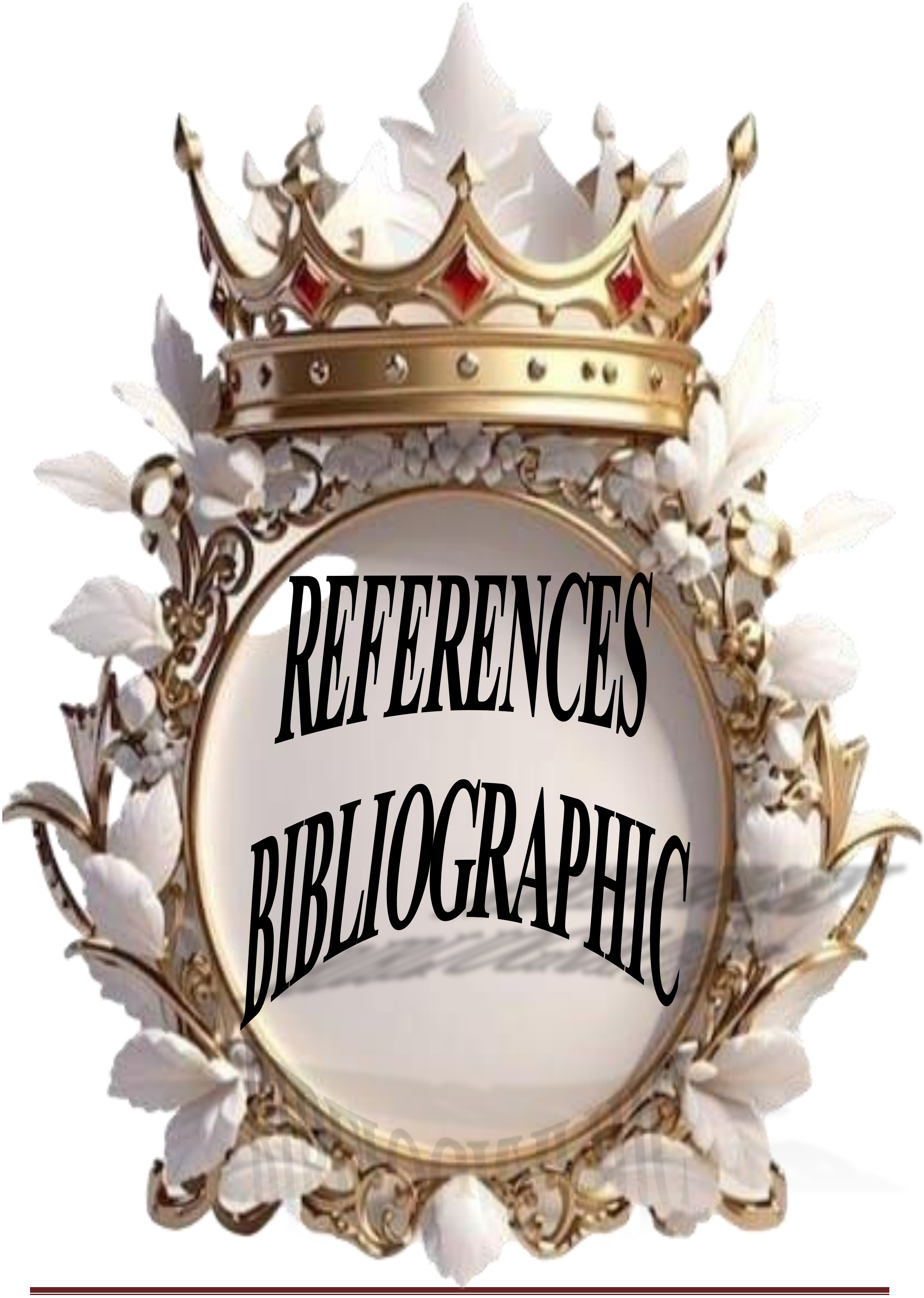
Perspective :

-The use of mycorrhizal networks in plots through the practice of mycorrhizogenic cultivation and in particular plant cover, and their diversification over time.

-Taking into account mycorrhizal symbioses, in the full extent of their interaction with other components of the soil system and cultural practices, is very productive in supporting change in the quality and quantity of durum wheat

-The diagnosis of the population of mycorrhizal fungi is a relevant tool to better manage and guide cultural practices favorable to microbial life.

- Intensify studies and research on the importance of integrating mycorrhizas in agriculture and globally raise awareness among farmers of the need to adopt them in the future.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Annex

Appendix 1 : Commercial label of the variety simeto

Appendix 2: Description of the variety simeto

Name: simeto Botanical name: tritium turigidum subsp durum.
Applicant/holder: the cereal and wheat cooperative in Ain temouchent.
The simeto reference wheat variety is a variety commonly grown in several regions of the world, simeto is known for its resistance to diseases and variable environmental conditions, as well as for its high quality.
Description: Simeto wheat is a type of hard winter wheat, characterized by its small and hard grains which have a high gluten content, it is generally used for the manufacture of breads due to its good kneading and baking properties and can also be used in the production of biscuits and pasta.

Appendix 3: Technical sheet of the mushroom

CULTURE	TAUX D'APPLICATION	MÉTHODE D'APPLICATION	REVENDICATIONS
Groupe 1 de l'UE sur les biostimulants (Broadacre)			
Céréales (blé, orge, avoine, seigle, maïs, seigle, sorgho, riz, millet, doux mais, mais souffle, triticale)	100g/ha ou maximum 3g/kg de semences	Appliquer comme traitement des semences ou application dans un sillon.	• Améliore la disponibilité des nutriments confiné dans le sol et la rhizosphère • Améliore l'établissement des semis • Améliore la croissance des racines et des plantes • Améliore l'efficacité de l'utilisation des nutriments • Améliore la tolérance des cultures au stress abiotique • Augmente le rendement - et le potentiel de qualité du rendement
Légumineuses (haricot sec, haricot vert, soja, pois, lentilles, lupins, trèfle, luzerne (Lucerne), trèfle, kudzu, vesce, Arachides, pois chiches, fèves, guar, pois d'Angole)	100g/ha ou maximum 3g/kg de semences	Appliquer comme traitement des semences ou application dans un sillon.	
Graines oléagineuses (tournesol, lin)	100g/ha ou maximum 3g/kg de semences	Appliquer comme traitement des semences ou application dans un sillon.	
Groupe 2 de l'UE sur les biostimulants (noix et arbres fruitiers)			
Fruits à pépins et à noyau (pommes, poires, kakis, cerises, prunes, pêches, nectarines, coings, abricots, pruneaux)	200g/600 arbres	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 50 ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	• Améliore la disponibilité des nutriments confinés dans le sol et la rhizosphère • Améliore l'établissement • Améliore la croissance des racines et des plantes • Améliore l'efficacité de l'utilisation des nutriments • Améliore la tolérance des cultures au stress abiotique
Agrumes (citron, clémentine, tangelo, nadorcott, pomelo, raisin, mandarine Satsuma (mandarine), orange, calamondin, citron d'agrumes, Chaux, Kumquat)	200g/600 arbres	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 50 ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Grenades	200g/1200 plantes	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 25ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Vignes (raisins de table, raisins de cuve, kiwis, fruits de la passion, granadilla)	200g/1200 Vignes	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 25ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Olives	200g/600 arbres	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 50 ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Arbres à noix (amandier, pacan, macadamia, noisette, pistaches, noix, pignons de pin, châtaignes, noix de cajou)	200g/600 arbres	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 50 ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Baies (framboises, baies noires, cassis, fraises, groseilles à maquereau, baies de Goji)	200g/1200 plantes	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 25ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Houblon	200g/1200 plantes	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 25ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Fruits tropicaux et subtropicaux (mangues, avocats, litchis, goyave, figue, datte, fruit du dragon, figue de barbarie)	200g/600 arbres	Dissoudre les 200g de Biocult Mycorrhizae WS dans 30L d'eau. Appliquer 50 ml de suspension par plante, directement sur les racines avant de fermer le trou de plantation **Remarque:** Maintenir la suspension dans une agitation constante	
Vergers établis			
Fruits à pépins et à noyau (pommes, poires, kakis, cerises, prunes, pêches, nectarines, coings, Abricots, pruneaux)	200g/ha	Appliquer via l'irrigation ou comme trempage de sol. Appliquer le premier traitement au début d'une nouvelle saison de croissance (2 semaines avant la première chasse attendue des pousses) et répéter l'application après un mois ou après la récolte.	• Améliore la disponibilité des nutriments confinés dans le sol et la rhizosphère • Améliore la croissance des racines et des plantes • Améliore l'efficacité de l'utilisation des nutriments • Améliore la tolérance des cultures au stress abiotique • Augmente le rendement - et le
Agrumes (citrons, clémentine, tangelo, nadorcott, pummelo, raisin, satsuma, mandarine (mandarine), orange, calamondine, citron d'agrumes, Chaux, Kumquat)	200g/ha	Appliquer via l'irrigation ou comme trempage de sol. Appliquer le premier traitement au début d'une nouvelle saison de croissance (2 semaines avant la première chasse attendue des pousses) et répéter l'application après un mois ou après la récolte.	
Grenades	200g/ha	Appliquer via l'irrigation ou comme trempage de sol. Appliquer le premier traitement au début d'une nouvelle saison de croissance (2 semaines avant la première chasse attendue des pousses) et répéter l'application après un mois ou après la récolte.	
Vignes (raisins de table, raisins de cuve, kiwis, fruits de la passion, granadilla)	200g/ha	Appliquer via l'irrigation ou comme trempage de sol. Appliquer le premier traitement au début d'une nouvelle saison de croissance (2 semaines avant la première chasse attendue des pousses) et répéter l'application après un mois ou après la récolte.	
Olives	200g/ha	Appliquer via l'irrigation ou comme trempage de sol. Appliquer le premier traitement au début d'une nouvelle saison de croissance (2 semaines avant la première chasse attendue des pousses) et répéter l'application après un mois ou après la récolte.	

Abstract :

Wheat cultivation is considered one of the most important agricultural practices in Algeria, especially as it plays a crucial role in human nutrition in general. However, wheat faces many challenges, the most significant of which is drought. This has led to a decline in productivity and problems in agricultural practices. In this study, we attempted to inoculate durum wheat (Simeto variety) with arbuscular mycorrhizal fungi (glomus moreau,glomus intraradices. Glomus etunicatum) and observe its effectiveness in resisting drought and its ability to retain water through morphological and physiological analyses.

The obtained results showed that inoculation with arbuscular mycorrhizal fungi significantly increases the growth of leaves and roots as well as their dry weight, with a particularly clear and strong effect on the roots. This led to an increase in water absorption and retention for a long period, resulting in a higher yield compared to wheat without mycorrhizae.

This is due to the ability of mycorrhiza-inoculated wheat to withstand water stress conditions.

We conclude that inoculation with mycorrhizae is an effective alternative to address the drought problems faced by durum wheat, particularly in Algeria.

Keywords : arbuscular mycorrhizal fungi, water stress, durum wheat.

Résumé:

La culture du blé est considérée comme l'une des pratiques agricoles les plus importantes en Algérie, surtout qu'elle joue un rôle crucial dans l'alimentation humai ne en général. Cependant, le blé est confronté à de nombreux défis, dont le plus important est la sécheresse. Cela a conduit à une baisse de la productivité et à des problèmes dans les pratiques agricoles. Dans cette étude, nous avons tenté d'inoculer le blé dur (variété Simeto) avec des champignons mycorhiziens arbusculaires (glomus mosseae, glomus intraradices. Glomus etunicatum)et d'observer son efficacité à résister à la sécheresse et sa capacité à retenir l'eau à travers des analyses morphologiques et physiologiques.

Les résultats obtenus ont montré que l'inoculation avec les champignons mycorhizes arbusculaires augmente significativement la croissance des feuilles et des racines ainsi que leur poids sec, avec un effet particulièrement clair et fort au niveau des racines. Cela a conduit à une augmentation de l'absorption de l'eau et à sa rétention pendant une longue période, ce qui a donné un rendement élevé en production par rapport au blé sans mycorhize. Cela est dû à la capacité du blé inoculé avec la mycorhize à résister aux conditions de stress hydrique.

Nous concluons que l'inoculation avec la mycorhize constitue une alternative efficace pour tenter de résoudre les problèmes de sécheresse aux quels est confronté le blé dur,

notamment en Algérie.

Mot clés : champignons mycorhiziens arbusculaires,stress hydrique,blé dur,.

الملخص :

تعتبر زراعة القمح احد اهم الممارسات المهمة في الجزائر خاصة انه يلعب دورا رئيسيا في غذاء الانسان بصفة عامة .ولكن يتعرض هدا الاخير الى العديد من المشاكل اهمها هو الجفاف .وهذا ادى الى تدهور الانتاجية ومشاكل في الممارسات الزراعية في هذه الدراسة حاولنا تجربة تلقيح القمح الصلب سيميتو بالفطريات الشجيرية .glomus mosseae, glomus intraradices) ..(Glomus etunicatum وملاحظة مدى فاعليته في مقاومة الجفاف وقدراته على الاحتفاظ بالماء من خلال التحاليل المرفولوجية والفيزيولوجية.

أظهرت النتائج المتحصل عليها أن التلقيح بالفطريات الجذرية الشجيرية يزيد بشكل كبير من نمو الأوراق والجـــذور وكذلك من وزنها الجاف، مع تأثير واضح وقوي بشكل خاص على مستوى الجذور. أدى ذلك إلى زيادة امتصاص الماء واحتباسه لفترة طويلة، مما أدى إلى زيادة كبيرة في الإنتاج مقارنة بالقمح غير الملقح بالفطريات الجذرية. يرجع ذلك إلى قدرة القمح الملقح بالفطريات الجذرية على مقاومة ظروف الإجهاد المائي. نستنتج أن التلقيح بالفطريات الجذرية يشكل بديلاً فعالاً لمحاولة حل مشاكل الجفاف التي يواجهها القمح الصلب، لاسيما في الجزائر.

الكلمات المفتاحية: الفطريات الجذرية الشجيرية، الإجهاد المائي، القمح الصلب