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EFFECT OF FIRE ON SOIL PROPERTIES BENEATH QUERCUS CALLIPRINOS IN LEBANON ANT ITS IMPACT ON REGENERATION AND LEAVE COMPONENTS.

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This thesis is dedicated to the soul of my Mom Nassab

For her love, endless support and encouragement even during her sickness before her lately death.

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Abstract

The purpose of this research was to investigate the effects of fire on physiochemical soil properties beneath the Quercus calliprinos forested areas and to determine its regeneration capacity in three representatives burned plots of Mediterranean forests: Obeidat, Hakel and Batroun in the North of Lebanon; the leaves content was also studied during the three growing seasons of 2012.

On average, the soil organic matter content after the fire decreased strongly and varied between 9.8 and 7% with highest fall (38.2%) in Obeidat plot; one year after the fire, it did not vary substantially, while it increased slightly during the following two years until the end of experiments in the unburned plots.

So significant difference was detected in pH between the burned and unburned plots and varied between 7.6 and 7.7; pH increased immediately after fire and decreased progressively to initial values; while the parameter time after fire highly influenced the pH significantly and varied between 6.9 and 7.6 in the burned plot of Obeidat. The oxidation of soil organic matter and the release of cations after high fire intensity also contributed to an increase in pH.

The electrical conductivity was higher in the burned than the unburned plots with 0.23 in Batroun followed respectively by Obeidat (0.16) and Hakel (0.13). For the $CaCO_3$ and active $CaCO_3$, status influenced significantly their amount and varied between 26.8 and 28.3% for the first while the content of active $CaCO_3$ decreased from 6.56 and 1.83 in Hakel plots.

For the nitrogen content, neither the year nor the status influenced its content. The N decreased in the burned sites with the highest loss in Hakel (38.4%). For the phosphorus content, in the unburned plots, it acted normally and increased while it decreased in the burned plots. The biggest loss was in Hakel from 22.2 to 0.63ppm. The potassium varied between 155 and 498ppm in the burned plots. Concerning the cations, sodium and magnesium wasn't influenced by the status of the plots; iron was highly influenced and almost a total loss was detected in Hakel (99%), while calcium content increased by 41.5% in Batroun.

Only small variations in clay content have been observed; it slightly decreased from 40.6 to 35% in Batroun. Post-fire erosion processes might have contributed to the decrease in clay content. Lime and sand content were influenced neither by the status nor by the number of years after fire.

The aim of the second part of the study was to analyze the regeneration of Quercus calliprinos after wildfire in term of length and number newly developed leaves during the third year after fire. The twigs elongation was highly influenced by season ($p<0.001$) and status ($p<0.001$). Concerning the leaves, it was also influenced by the same parameters and best results were detected during July 2012.

The chemical constitutions of the aqueous extract were analyzed by GC/MS which resulted in the identification of eighteen constituents, representing 82.3% of the extracts; 1-deoxy-inositol (11.9%), cyclotrisiloxane hexamethyl (10.15%), cis-13-docosenamide (6.21%), silicic acid (3.96%) and pyrogallol (3.87%) being the main components.

Keywords: Quercus calliprinos, physiochemical properties, regeneration, GCMS, Obeidat, Hakel, Batroun

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Abbreviations List

Al	Aluminium
a.s.l	Above sea level
°C	Celsius degree
Ca	Calcium
$CaCO_3$	Calcium carbonate
CO_2	Carbone dioxide
cm	Centimeter
EC	Electrical conductivity
EDTA	Ethylene Diamine Tetra Acetic acid
et al.	and colleagues
eV	Electron volt
Fe	Iron
G	Gram
GCMS	gas chromatography coupled with mass spectrometry
ha	Hectare
H_2SO_4	Sulfuric acid
i.e.	That is to say
IAA	Indole Acetic Acid
IBA	Indole Butiric Acid
K	Potassium
Kg/ha	Kilogram per hectare
µg	Microgram
µm	Micrometer
M	Meter
Ml	Milliliter
ml/min	Milliliter per minute
Mm	Millimeter
mg/kg	Milligram per kilogram
M.	Molarity
Meq/l	Milli equivalent per liter
Mg	Magnesium
Mn	Manganese
mS/cm	Milli Siemens per centimeter
MoA	Ministry of Agriculture

MoE	Ministry of Environment
N.	Normality
N	Nitrogen
Na	Sodium
NaOH	Sodium hydroxide
$NH4^+$	Ammonium
Nm	Nanometer
$NO3^-$	Nitrate
OH	Hydroxide
OM	Organic matter
P	Phosphorus
pH	Hydrogen potential
ppm	Part per million
Q.	Quercus
SOM	Soil Organic Matter

1. Introduction and Problematic.

Fire is the most important natural threat to forests and wooded areas of the Mediterranean basin. It destroys many more trees than all other natural calamities: parasite attacks, insects, tornadoes, and frost (Alexandrian *et al*., 1998) and increases the risk of soil erosion and desertification. Large areas of forest are being destroyed by wild fire every year around the Mediterranean regions (Rashid, 1987).

Mediterranean maquis are dense forests dominated by short (2–5m high), multi-stemmed, evergreen, sclerophyllous trees that covers most of the northern and central mountainous region (300–900m a.s.l.) in the East Mediterranean region (Di castri *et al*., 1981). This vegetation includes about 15 evergreen and 15 deciduous tree species but is strongly dominated by the evergreen sclerophyllous Quercus calliprinos Webb, which accounts for 80–90% of the tree coverage (Zohary, 1973). Today, the average annual number of forest fires throughout the Mediterranean basin is close to 50 000, twice as many as during the 1970's (Alexandrian *et al*., 1998).

According to the newly produced map of the forest classification in Lebanon (2001), the green cover is estimated of about 20 % of the Lebanese territory (Masri, 2004). The forested areas illustrated in the agricultural map produced at 1960 upon aircraft imaging, with similar ones detected by satellite images taken in 1998 have shown that the forested lands in Lebanon decreased up to 32 % (Masri *et al*., 2002). Forest fires, among other natural and human threats, have a major cause of this decline.

The different Lebanese forested areas are threatened by deforestation, road enlargement, urban sprawl and industrial development. To these facts, the frequency and intensity of forest fires are a real threat on the sustainability of the forest ecosystems. They usually occur at the end of the summers and are followed a few weeks later by the heavy showers of rain, which cause severe soil losses (Masri, 2004).

The main forest species of Lebanon are *Quercus calliprinos* Webb*, Q. infectoria* Oliver*, Q. cerris* L.*, Juniperus excelsea* Bieb*, Cedrus libani* Rich*, Abies cilicica* Carr.*, Pinus pinea* L.*,* *Pinus brutia* Tenore, and *Cypressus sempervirens* L.. The bulk of the forest area consists of oak and pine stands (Asmar, 2003). Oak Forests are one of Lebanon's most important natural assets. They have many uses and provide a range of valuable products and benefits. They offer not only environmental protection but also income and livelihood options for forest-dependent communities.

Despite all the measures taken, no country has shown an improved situation. The annual cumulated burnt area in the Mediterranean countries can be estimated to be approximately 600.000 ha, almost twice as much as during the 1970's (Alexandrian *et al*., 1998).

The natural differentiation of the soil profile into horizons creates a stratification of the physical, chemical, and biological soil properties. Understanding this stratified arrangement is necessary in order to accurately assess the effects of fire and soil heating on the different soil properties (De Bano and Neary, 2005).

The most extreme temperatures generated in forest soils during fire are largely restricted to the upper soil (Macadam, 1989). The soil properties near the soil surface are the most directly exposed to heat that is radiated downward during a fire. Soil heating generally decreases rapidly with soil depth in a dry soil because dry soil is a poor conductor of heat (De Bano and Neary, 2005). During wildfires, only a small part of the heat generated is transmitted to the first centimeters of the soil profile.

The main changes in the characteristics of the soil are usually more easily detected on the surface (0-5 cm of mineral soil) and in the first months after the fire (Marcos *et al*., 1994). Yet, because the bulk of nutrients and the activity of soil organisms are concentrated in the first 10cm of the surface organic layer and the upper 15cm of mineral soil, any heating of this soil region can have serious repercussions on post-fire forest productivity (Bitterroot National Forest, 2000). These effects may be fleeting or may linger for years. Fire alters physical and chemical properties, organic and mineral reserves, and the microbial population of soil (De Bano and Neary, 2005).

When the vegetation and surface litter are burned, ash usually provides an increase in the pH of soil, as well as an increase in nutrients available to plants (Marcos *et al*., 1994). Kutiel and Naveh (1987) showed that fire modifies the levels of soil nutrient, resulting mainly in the loss of total nitrogen, but also in the increase of available forms of nitrogen and other nutrients. This increase is considered to be the major factor promoting rapid growth of herbaceous plants after fire.

Quantitative changes in the proportion of mineral soil particles (sand, silt, and clay) after fires are not usual, unless high temperatures occur at the mineral soil surface. Temperatures above 300°C can affect soil texture, as reported by several researchers (Iglesias *et al*., 1997; Ulery and Graham, 1993).

In order to follow the changes that took place over time in the burned Lebanese forests, and to study the effect of fire on the soil properties in oak forests and provide qualitative and quantitative information on the losses; soil texture, $CaCO_3$, pH, organic matter, nitrogen, available phosphorus and soluble cations (K, Mg, and Ca) will be determined from soil samples collected under these trees, in a burned and adjacent unburned forest.

Rapid resprouting and regrowth from secondary buds is the main adaptation of Mediterranean trees to major disturbances such as fire, cutting and grazing (Bond and Midgley, 2001). Quercus *calliprinos*, a typical resprouter, regenerates from shoots on the rhizome or the stem of subterranean roots. The seasonal influence on the recovery capacity of Quercus *calliprinos* will be studied by measuring the length and number of leaves of the burned and unburned plots on monthly basis during the growing seasons of 2012.

Vitamin E, a principle lipid-soluble antioxidant in both plant and animal systems, is a necessary nutrient in ruminant diets. This study examined also the concentrations of different components in the leaf tissue of the Quercus *calliprinos* to assess the value of these plants as a source of vitamin E for goat diets. The components are detected by GCMS.

This work will be divided into three parts.

In the first part, the bibliographic review, will be cited different characteristics of the Quercus genus (cultural and genetic), the multiplication methods that can be applied in the conservation and reforestation of Q. *calliprinos*. The Mediterranean and Lebanese ecosystems, the status of Oaks forests in Lebanon and different components of the soil are also studied

The second part, material and methods, includes different techniques and treatments that are used.

- Tests concerning different soil characteristics (structure and texture, mineral composition).
- GCMS to study the leaves components and variations all around the year.

The third and last part will include results and analysis of the different collects in order to study the influence of the season on the power of regeneration of the oaks trees and leaves components to choose the best time for the collect of the plant material; and the speed of recovery and difference between the burned and the unburned plots in oaks forests.

2. Bibliographic review.

2.1. Botanical Classification.

Since the beginning of the linean taxonomy, the classification within the genus Quercus has raised conflicting opinions, and more than 20 classifications were proposed. Disagreements were due to the characters to be used for the classification, the intrageneric subdivisions adopted (sub genus or sections), and species delineation.

The most complete classification, as much for it's geographic as specific cover, was that of Camus (1954). Classifications criteria used by Camus were mostly based on foliar and fruit characteristics. In Camus' classification the genus Quercus is subdivided in two sub genera: sub genus Cyclobalanopsis and sub genus Euquercus.

There are about 150 species belonging to Cyclobalanopsis which exist only in South Asia, whereas species belonging to Euquercus are the more familiar oak species. The sub genus Euquercus has been further subdivided into 6 different sections by Camus (1936-1954).

Trees of the Quercus genus are among the most important trees in the world. The genus contains 450 woody and perennial species of diverse habit and leaf shape that ranges in size from shrubs to tall trees. Some oaks are quite tall, with broad crowns and are long-lived. Oak species are common as the dominant trees in deciduous forests of cool-temperate regions in the Northern Hemisphere, and in evergreen forests in Mediterranean regions (Aloni and Livne, 2008).

Quercus calliprinos is one of the most common trees in the wild flora of Lebanon. It regrows after cutting or fire or grazing, but grows in the form of a low, multi-trunk, branched and dense shrub. It is native to eastern Mediterranean region and southwest Asia, from northern Algeria and Turkey east across the Middle East.

The oak tree has a preference for loamy or medium and clay (heavy) soils, but they are able to grow in heavy clay soil too. The plant also has a preference for basic (alkaline), acid and neutral soils. The plants need an arid or moist soil and are able to grow in sunlight as well as semi-shade conditions as in the slightly forested areas. Although the oak plant is able to endure strong winds, they do not survive well when exposed to maritime conditions.

Palestine Oak is a tall evergreen tree with a height that can reach 15 meters, a diameter of 2 meters, a crown with a diameter of 30 meters and an age of up to 850 years. The Palestine Oak is closely related to the Kermes Oak (*Q. coccifera*) of the western Mediterranean which is distinguished from it by its smaller size (usually shrubby, not over 10 m) and smaller acorns that have a diameter less than 2 cm.

The oak has 2n=24 chromosomes. The different species are very similar to each other. The difficulty in differentiating the species is the great diversity in the shape of the leaf, the trunk and the fruit within populations of the same species (Aloni and Livne, 2008). The genus has a wide geographical distribution.

In the Americas, it is found from the far north down into the tropical western parts of South America. It is also native to temperate and tropical Eurasia and both north and South Africa. Prior to widespread felling for agricultural purposes, oaks were a major component of many European forests. It appears that oaks are issued from a natural hybridization, at least between some European species, and synonymy seems to have resulted from imperfect genetic isolation of species (Mabberly, 1987).

The Quercus genus is classified into two subgenera based on leaf characters, cone and seed.

2.1.1. Subgenus Quercus

2.1.1.1. Section Cerris: found in Europe, Asia, North Africa. Styles are long. Acorns mature in 18 months and they are very bitter, the inside of acorn shell is hairless or slightly hairy. This section includes Quercus calliprinos (Palestine Oak) from the Southwestern Asia.

2.1.1.1.1. Leaves

Leaves are small, with a length of 1.5-4 cm. They are dark green and stiff. It is a typical example of the Mediterranean arboreal trees and shrubs characterized by small and rigid leaves. The leaf arrangement is alternate and is sometimes undulating over their entire surface. They are glabrous and shiny on both sides. Their margins are dentate-thorny. The young leaves are soft, and light and fresh green in color. The leaf persists for 2-3 years, and then abscises (Aloni and Livne, 2008).

Trees may be either evergreen or deciduous but where they lose their leaves in autumn, they produce well developed winter buds (Paterson, 1994).

In a mature oak, the ground is covered by a soft thick carpet of dead leaves, which decay slowly until they turn into fertile forest soil. Great diversity in the shape of the leaf within the population is prominent. The bark of the branches is light gray and the bark of the trunks is dark and grooved. The plant usually appears as a tall shrub, but after proper pruning it grows into a tall tree with an erect trunk and a round crown (Aloni and Livne, 2008).

2.1.1.1.2. Flowering

Quercus calliprinos blooms in early spring during March-April, concomitantly with the sprouting of leaves. The flowers are single-sex, the trees are monoecious. The male flowers are arranged in groups which disperse their pollen in the wind. The female flowers are tiny and appear singly or in pairs on small branches in the axil of the sprouting leaves (Aloni and Livne, 2008).

The fruit contains a single large seed and takes the form of an acorn (Kingsbury, 1964), enveloped in its lower part by a lignified cup-like structure called a cupule. Fruits ripen in the following autumn or in the autumn of the following year (Aloni and Livne, 2008). The acorns mature over either one (white oaks) or two (black oaks) years after the fruit set (Paterson, 1994).

A year later, the acorns become ball-shaped with a diameter of 2-3 mm. They are gray, similarly to the bark of the branches, and ripen only after another six months, during autumn, into small brown acorns that sit within deep light green cupules. Less than half of the acorn protrudes out of the cupule. The scales of the cupule are erect.

There is great diversity in the details of the fruit shapes. The acorn germinates easily when it is buried in moist soil in the first weeks after it has ripened. The seedling develops slowly, but rapidly sends a vertical root into the soil (Aloni and Livne, 2008).

2.1.1.2. Section Quercus: The white Oaks (synonym sect. Lepidobalanus or Leucobalanus) are found in Europe, Asia, North Africa, North America. Styles are short and acorns mature in 6 months, they are sweet or slightly bitter, inside of acorn shell hairless. This section includes Quercus ilex, known also as the Holly Oak, and dispersed in the Southern Europe and Northwestern Africa forests.

2.1.1.3. Section Mesobalanus: Europe, Asia, North Africa. Styles are long and acorns mature in 6 months; they are bitter, and the inside of acorn shell is hairless; this section is closely related to sect. Quercus and sometimes included in it.

2.1.1.4.Section Lobatae: The red Oaks (synonym sect. Erythrobalanus). These oaks are found in the North, Central and South America. Styles are long and acorns mature in 18 months; they are very bitter, and the inside of the acorn shell is woolly

2.1.2. Subgenus Cyclobalanopsis

The ring-cupped Oaks (synonym genus Cyclobalanopsis) are found in Eastern and Southeastern Asia. They are distinct from subgenus Quercus in their acorns that have distinctive cups bearing concrescent rings of scales; they commonly have densely clustered acorns, though this does not apply to all of the species.

2.2 Multiplication.

Oaks commonly sprout vigorously from the stumps or root collar after aboveground portions of the plant are killed by fire (Kruger and Reich, 1989). Stem density is often increased as fire promotes sprouting and reduces competition (Crow, 1988). Seedling sprouts are particularly important in post-fire reestablishment (Jhonson, 1976). Hannah (1987) showed that the "best" sprouts often originate from buds located at, or below, ground level. Large oaks that survive fire frequently could serve as seed sources (Hannah, 1987) and could produce a massive seed crop. Acorns often germinate well on mineral soil, and establishment may actually be favored in burned areas (Rouse, 1986).

Three multiplication methods are used for oaks.

2.2.1. __Cutting__

Cutting is the best suited multiplication method for the production of vegetative clones. Leafy cuttings are taken from newly developed branches and treated by IBA. These cuttings are then introduced under plastic tunnels equipped with a mist system. The choice of substrate is also an important success factor (Cornu *et al*., 1977).

In species like Oaks, where delays in flowering are very long, controlled crosses are difficult and seed production is irregular, this is why vegetative propagation can overcome these problems by:

- Enabling the creation of stocks that are necessary for the mobilization and distribution of genetic resources in order to improve the quality of the populations.

- Regulating the supply of seedlings which can lead to a rapid availability of genetically improved products.

2.2.2. __Grafting__

The vegetative propagation by grafting is used in cultivars that are resistant, important from the ecological point of view and have interesting forms. It is also used for propagation of valuable introduced woody species when their seed is not available (Obdržálek and Jílková, 2006).

Oaks grafting is usually performed in a propagation house in January or February, however spring grafting outdoors is also possible. Grafting takes place at the top of the rootstock of the same species during spring; if scions and rootstocks are of good quality success can reach over 80%. Scions retain the characteristics of the branches on which they were collected.

2.2.3. In vitro methods

There are three main methods for the propagation *in vitro*; propagation by axillary buds (microcuttings), proliferation by adventitious buds and somatic embryogenesis. Regarding the Oaks, the latter two methods are the most used (Seckinger *et al*., 1979, Srivastava and Steinhauer, 1982; Gingas and Lineberger, 1989). These techniques require the use of juvenile tissues, which is unfavorable to a strict genetically assessment of the multiplied material.

Studies on micropropagation are more advanced and this propagation method can be successfully applied to the three main species of deciduous native oaks (*Quercus* robur, *Quercus* petraea, *Quercus* pubescens) (Chalupa, 1984; Favre and Juncker, 1987). All stages (conditioning ortets, initiation, subcultures, rooting, and acclimatization) were made from juvenile and adult material. The multiplication rate varies from 2 to 4 during a subculture of six weeks.

2.2.4. Sprouting

Sprouting is a means by which many plants recover after fire. Shoots can originate from dormant buds located on plant parts above the ground surface or from various levels within the litter, duff, and mineral soil layers (Brown and Smith, 2000).

The Mediterranean Landscape is composed chiefly by sclerophyllous phanerophytes and dominated by *Quercus calliprinos.* Most of these sclerophyll trees and shrubs are distinguished by dual root systems that can spread horizontally and penetrate deeply into rock cracks, vigorously resprouting from their roots after fire, grazing, or cutting (Naveh and Carmel, 2003).

Many woody plant species have dormant buds located in the tissue of stems, above or below the surface of the ground. These plants sometimes sprout from the root collar, the point where roots spread out from the base of the stem. Such species include turkey oak, northern red oak, and paper birch (Brown and Smith, 2000).

Epicormic sprouts develop in species such as eucalyptus, pond pine, and pitch pine from buds buried in woody tissue of tree stems, or from bud masses present in branch axils. Lignotubers, burls, and root crowns are names for masses of woody tissue from which roots and stems originate, and that are often covered with dormant buds (James, 1984). These buds may be deeply buried in wood, and may be located far below the surface if the tissue mass is large. Plants with this commonly occurring structure include white sage (Keeley, 1998), chamise, willow and tanoak.

Dormant buds are often located on laterally growing stems or roots of woody plants. Some woody species have dormant buds or bud primordia located along roots from which new shoots can originate. Rhizomes are the horizontal underground stems that have a regular network of dormant buds that can produce new shoots and adventitious roots (Welsh *et al*., 1987; Zasada *et al*., 1994). Woody rhizomatous species include thimbleberry, white spirea, Gambel oak and Labrador tea.

If resprouting from suckers is prevented they soon attain the stature of small trees. In this way closed, one-layered, very fire-prone, and unproductive shrub thickets can be converted into rich, multilayered, park-like groves and woodlands (Naveh and Carmel, 2003).

If fire occurs during the growing season, death of the apical meristems removes inhibition of subsurface buds and new shoots form. If a fire occurs when herbaceous plants are seasonally dormant, fire does not remove the source of inhibition because aboveground leaves and stems are cured and sometimes already decomposed (Brown and Smith, 2000).

2.3. Mediterranean ecosystems.

Biological diversity, or biodiversity, is the variability of living systems at several levels, including the diversity of ecosystems, species within ecosystems, and genes within species (ECODYT, 2009).

Vegetation in Mediterranean-type ecosystems is characterized by dense forests dominated by short (2–5m high), multi-stemmed, evergreen, sclerophyllous trees (Di Castri *et al*., 1981). This complex vegetation type is termed ‘maquis’ in the Mediterranean basin. In the absence of human interference, the natural succession will turn this open landscape into closed, dense and shady woody vegetation with low biodiversity (Perevolotsky, 2005). Since the early pre-historical period, the Mediterranean maquis has been widely affected by intensive human activities. Fires, cuttings and grazing were the traditional exploitation techniques of the natural woody vegetation, which greatly affected the evolution of plants and the landscape (Naveh, 1990).

2.4. Lebanese ecosystems.

Lebanon’s ecosystem diversity results from the country’s dramatic topographic and altitudinal diversity, combined with its location at the far eastern end of the Mediterranean Sea (ECODYT, 2009).

Forests in Lebanon constitute an important natural resource. The main forest species widespread in Lebanon are *Quercus calliprinos, Quercus infectoria, Quercus cerris var. pseudo-cerris, Juniperus excelsa, Cedrus libani, Abies silicica, Pinus pinea, Pinus halepensis, Pinus brutia* and *Cupressus sempervirens* (MoA, 2010).

In addition, Lebanese forests contain a wide range of aromatic, wild and medicinal plants (Asmar, 2005). The bulk of the forest area consists of Oak and Pine stands (Asmar, 2009). Oak woodlands (Quercus spp) constitute the major parts of Lebanese forests with 41.61%, while pine forests (Pinus spp) occupy 20.28% (MoA, 2005).

Climate influences the vegetation cover in Lebanon (CAS, 2008). The country consists of two major Mediterranean climate zones, the Mediterranean zone and the Pre-steppe areas, harboring ten bioclimatic regimes and 22 vegetation associations (Asmar, 2009). The biological diversity of the Mediterranean Eco-region, of which Lebanon is part, has been more influenced by humans than by any of the other 24 eco-regions selected by Conservation International (CI) as biodiversity hotspots (ECODYT, 2009).

2.4.1. The Mediterranean mountains

Mediterranean mountains in their seaward aspects can be differentiated along the altitude into the Thermo-Mediterranean, Eu-Mediterranean, Supra-Mediterranean, Mountainous Mediterranean and Oro-Mediterranean zones (Fig.1). A belt of evergreen maquis and garrigue characterizes the formers, while the later are respectively covered by summer-green forest climax and dwarf thorny vegetation characterizing the alpine and sub-alpine zones (Asmar, 2009).

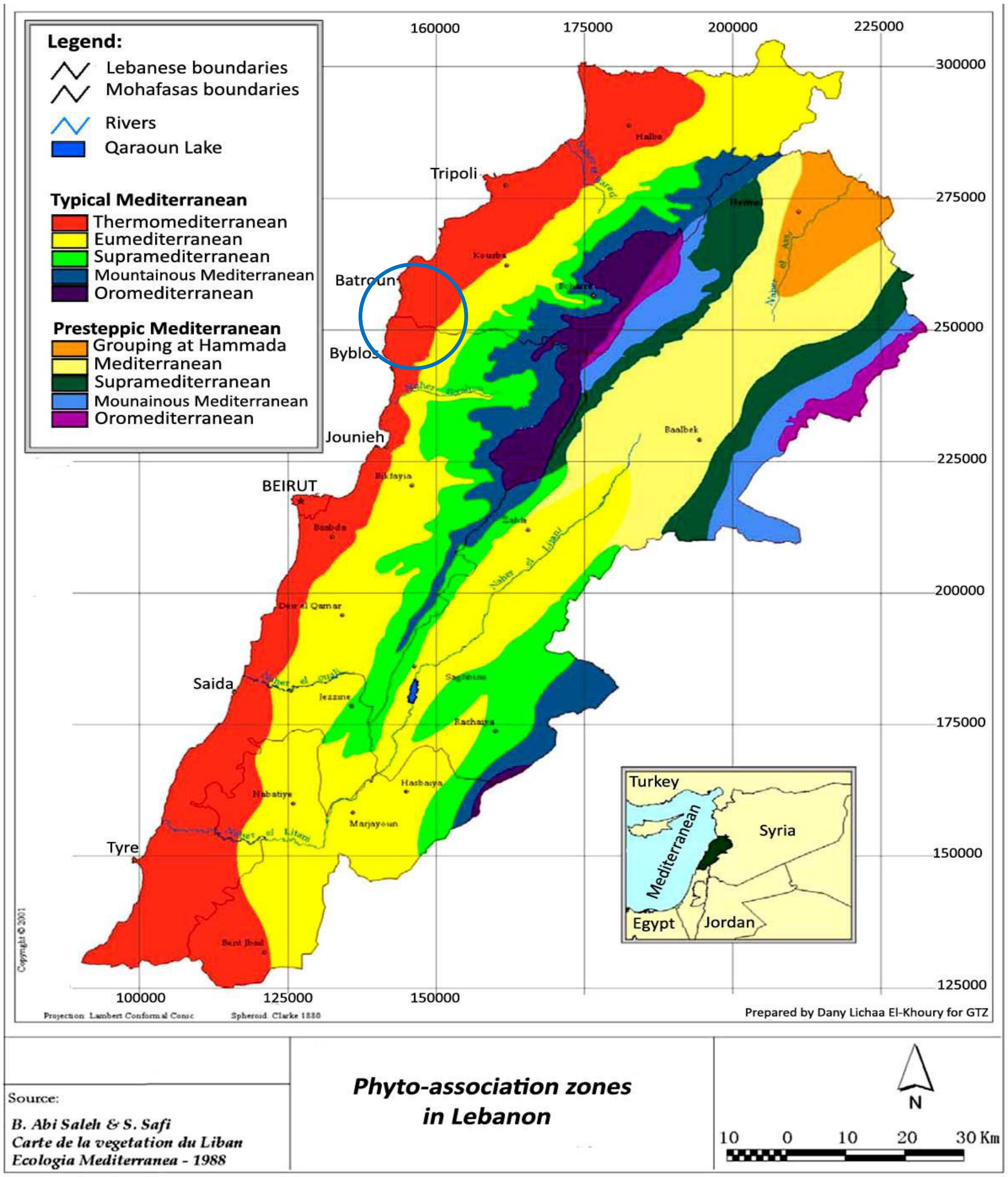


Fig.1. Phyto-association zones in Lebanon (Abi Saleh & Safi, 1988).

The Thermo-Mediterranean zone, ranging from 0 to 500 m altitude, comprises, at the sea level, a coastal strip harboring two plant communities currently severely degraded (Beirut as well as the western slope of Mount-Lebanon). Plant community degradation is also shown in the upper vegetation characterized by an evergreen garrigue. In this zone *Ceratonia siliqu*a, *Pistacia lentiscus* and *Pistacia palaestin*a trees grow along with their accompanying flora (Asmar, 2009; CAS, 2008).

At an altitude ranging from 500 to 1,000 m, lays the Eu-mediterranean zone, mainly covered by maquis vegetation dominated by *Quercus calliprinos* and *Pistacia palaestina*. The climax oak maquis has almost disappeared and has been replaced by a degraded garrigue. Additionally, Pine forests (*Pinus pinea* and *Pinus brutia*) are largely found in these areas together with the associated species to the oak maquis like *Cercis siliquastru*m, and *Styrax officinali*s (Asmar, 2009).

The Supra-Mediterranean zone (1000-1500) situated above the evergreen vegetation is characterized by a deciduous forest climax. In this zone, the vegetation cover is denser as the population density is lower and major human settlements are more recent. At present, this zone is occupied by *Quercus calliprinos* and *Quercus infectoria*, *Pinus brutia* and *Pinus pinea* formations (Asmar, 2009). This zone is located in Ehden, Sir ed-Dinniyeh, highlands of Qadisha, piedmonts of mount Mekmel and Aakkar (CAS, 2008).

A higher zone of coniferous forest climax, ranging from 1500-2000 m altitude (Asmar, 2009), replaces usually the zone of the summer-green forest (Bsharreh, Ehden, Qadisha, Hadath ej-Jebbeh, Tannourine, Baruk) (CAS, 2008). This mountainous Mediterranean zone harbours relic formations of *Cedrus libani, Abies cilicic*a and *Juniperus excelsa*. Plant communities encountered comprise *Quercus cedrorum*, *Q. calliprinnos*, *Ostrya carpinifolia*, *Sorbus flabellifolia*, *Malus trilobata*, *Prunus ursina* and *Pyrus syriaca* (Asmar, 2009).

In the high summit dominating the Mount Lebanon chain, lie the Oro-Mediterranean zones (Talaat Moussa on the high altitudes of Anti-Lebanon) (CAS, 2008). where the leading plant community is xerophytes vegetation comprising a formation of cushion-like dwarf thorn shrubs and *Juniperus excelsa*, the only tree present at this altitude. In these alpine uplands, a high endemism level is marked as the result of the isolation effect (Asmar, 2009).

2.4.2. The pre-steppic vegetation

The pre-steppic vegetation zone ranging between 1000 and 1500 m is mainly composed of heavily grazed forestlands of *Quercus calliprinos*. In the Supra-Mediterranean zone, *Quercus calliprinos* and *Quercus infectoria* are found. Then follows sparse *Juniperus excelsa* stands, which extends to higher altitude and figures as sporadic tree mixed with dwarf thorny shrubs. However, the dominant formation on these slopes is a degraded garrigue used for grazing. On the Western slopes of the Anti-Lebanon chain, the pre-steppe vegetation is similar to the one present on the eastern slopes of the Mount Lebanon chain (Asmar, 2009).

2.5. Lebanese climatic conditions.

The climatic characteristics of the Mediterranean (warm dry summers and relatively wet winters) varies from the mild, maritime, moist characteristics in the west, to the more continental characteristics of the east. Most rainfall is associated with depressions, with 70–80% of rain falling between October and March (i.e. autumn to early spring) following generally dry summer conditions, when most wildfires occur (Shakesby, 2010).

Lebanon’s climatic conditions are determined by its geography and physiography (Asmar, 2009). The climate of Lebanon is typically Mediterranean, humid to sub-humid in the wet season to sub-tropical in the dry season. (Karam, 2002). In fact, there are two mountain chains expanding perpendicularly to the atmospheric circulation and constituting the core of the country. They are at the origin of a climatic variability at small distances (CAS, 2008).

The wet season coincides with winter period that lasts from November till April. The dry season coincides with summer period, which starts in June till the end of September. During this period, no rain is recorded and a state of high pressure dominates the whole country, with a general tendency toward Northeast (Karam, 2002).

Climatic conditions vary from Mediterranean climate along the coastal plain and in the middle mountain range, to reach the sub-alpine or mountain Mediterranean climate on the highest slopes, covered by snow during most of the year; they become sub-deserted and almost too dry for agriculture in some of the northern plains (Asmar, 2009).

The average annual rainfall on the coastal zones varies between 700 and 1000 mm and increases towards the N-S direction. The Mount Lebanon forms a barrier against the rain movement and the precipitations can reach more than 1400 mm per annum (the majority of which is snow) (CAS, 2008) (Fig.2).

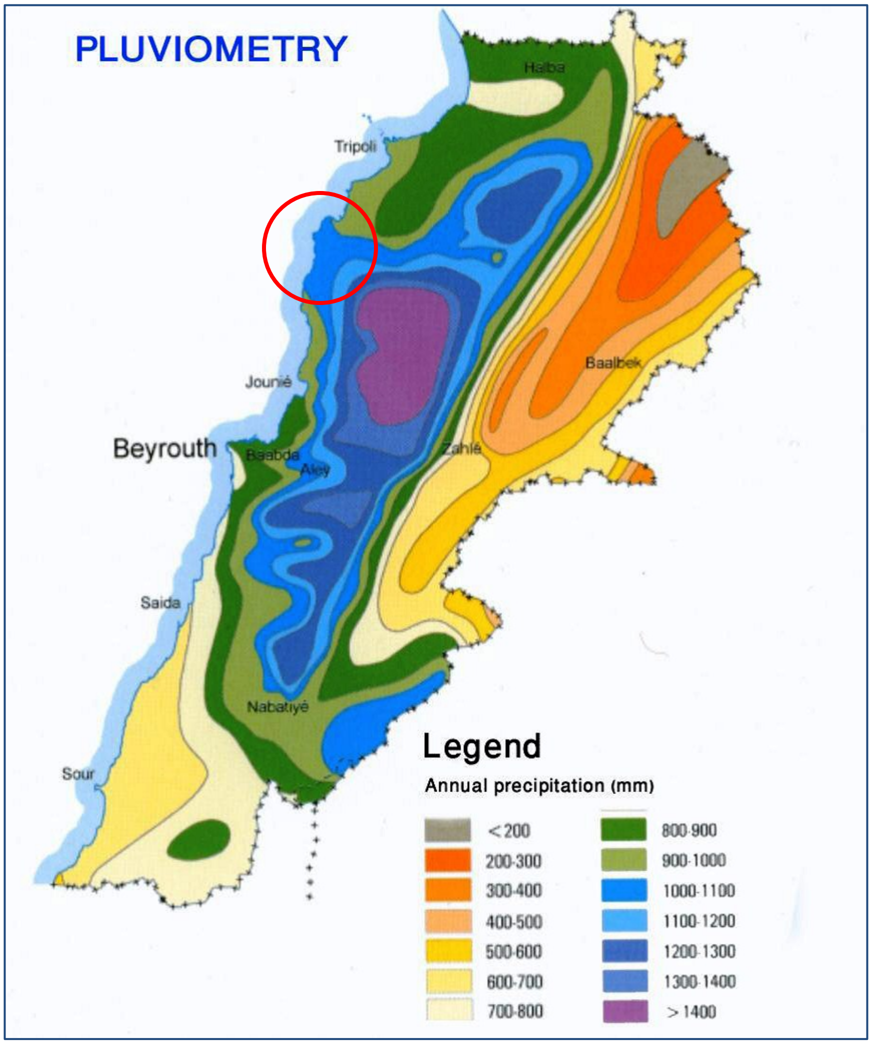


Fig.2. Annual precipitation in Lebanon (Abi Saleh & Safi, 1988).

As in most countries submitted to the Mediterranean climate, most of the rainfall falls between November and March, in the form of heavy showers. The mean annual rainfall on the coast ranges between 700 and 1000 mm (Asmar, 2009) (Fig.2).

2.6. Oak forests in Lebanon.

The kermes oak (*Quercus calliprinos*) forests cover 10% (40,000 ha) of the land area, and their dominance in the lower altitude of the western slopes of the Mount Lebanon range is an indicator of habitat degradation (ECODYT, 2009). The oak coppices found on the eastern slopes of Mount Lebanon extend in a very discontinuous manner in the low elevation zone between Yammouneh and Hermel and on the slopes of Jabal Barouk/Niha (Fig.3).

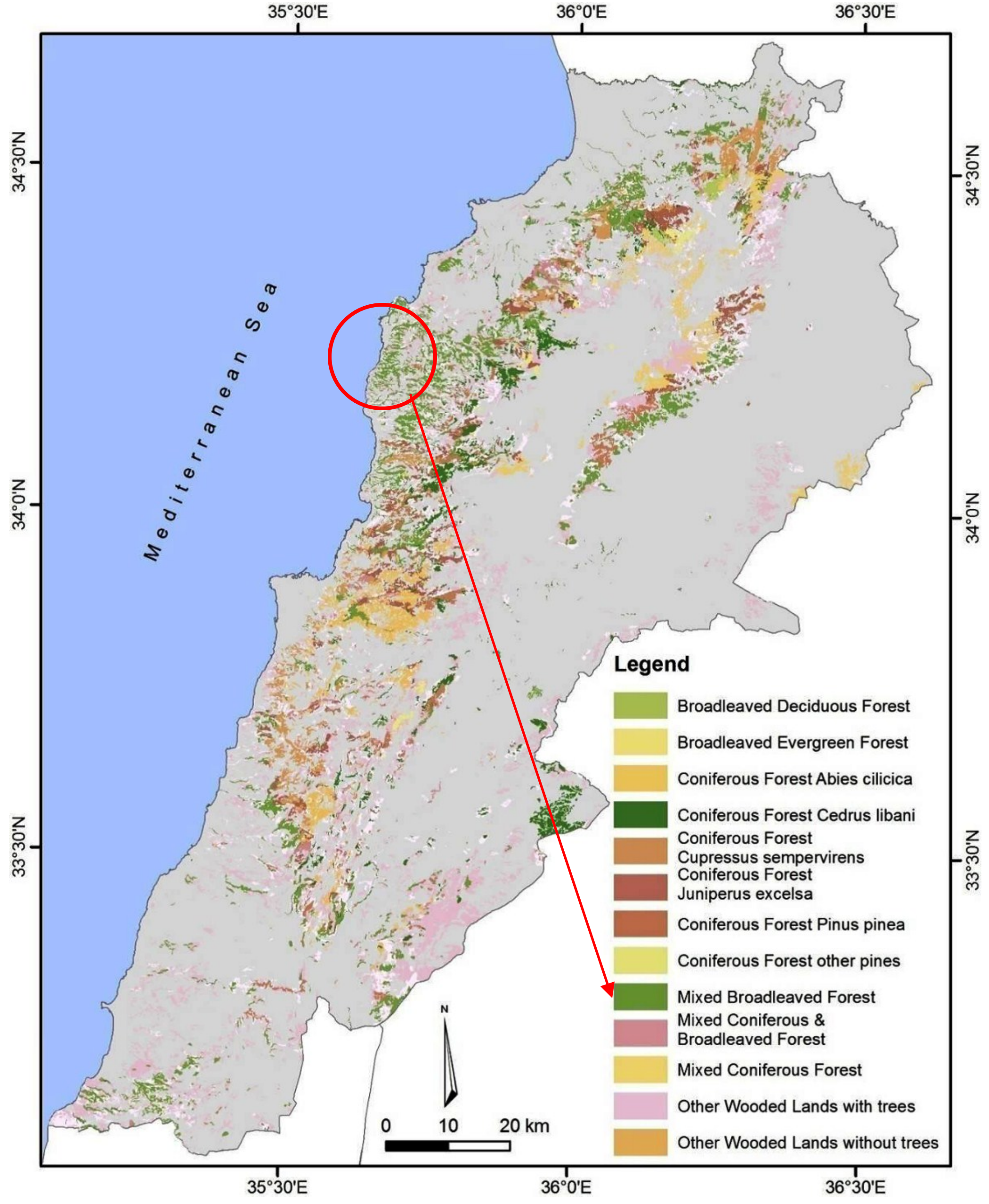


Fig.3. Lebanon's derived forest map (MoA, 2005)

On the western slopes of the Anti-Lebanon chain, only a few diminutive oak stands persist, mainly east of Baalbeck, Masnaa and around Rachaya (ECODYT, 2009). In the South, a few degraded and overgrazed oak coppices can be found on the hills of Jabal Amel. These forests have been subject to severe cutting for charcoal production and overgrazing, which has led to their deterioration and their replacement by highly degraded garrigue (ECODYT, 2009).

Additionally, sporadic trees of Turkey oak (*Q. cerris)* are found in Qamou'a and Ehden, Cedar oak (Q. *cedrorum*) and Lebanon oak (Q. *libani*) in Ehden, pennatifid oak (Q. *pinnatifida*) in Ehden, Hadeth-Tannourine and Bsharre, and brant's oak (*Q. brantii* ssp. l*ook*) in Ain Zhalta and Barouk. Cyprus oak (Q. *infectoria*) is found in cedar and fir forests (ECODYT, 2009).

2.7. Soils.

Human influence in the Mediterranean region dates back 8,000 years when the first significant deforestation began. Since that time landscapes have been as much influenced by people as by nature and today Lebanon's mosaic of overgrazed grasslands, agricultural lands, evergreen woodlands, and brush land is evidence of that (ECODYT, 2009). Land clearing, land conversion, new construction and reconstruction is occurring in every corner of the country and encroaching steadily into forested and other wooded lands (MoA, 2005).

The soils are new, friable and easily eroded, most of the country being on slope terrain. Relief, rainfall intensity and runoff contribute to the severe water erosion and soil loss, especially where the vegetation cover is reduced or lost (Asmar, 2009).

The status of the soil surface is crucial for hydrological and biogeochemical cycles in the post fire period. Reduction in the vegetation cover will lead to changes in soil thermal regime, and in general higher soil and water losses (Mataix-Solero *et al.*, 2010). The main changes in the characteristics of a soil occur more particularly in the upper layers (0-5 cm and 5-10 cm) of mineral soil (Iglesias, 2010).

Characteristics of the soil environment are altered both as sudden modifications induced by the passage of the fire and also as delayed changes derived from the simultaneous modifications of the soil physicochemical composition, of the plant covering capacity and of the biological spectra (Moreno, 2004).

The nature of the changes in soil depends on both the temperatures reached at different soil depths and the degree of heating that the different soil components can withstand before being altered (Gonzalez-Perez *et al.*, 2003).

Depending largely on burn severity (Inbar *et al.*, 1998), which is a function of the duration of burning at a particular point and its intensity (the rate at which thermal energy is produced), there are a number of physical, chemical and mineralogical, and biological changes to the soil and organic matter that can be caused by fire (Shakesby and Doerr, 2006).

2.7.1. Physical properties response

It has been accepted that the effects of wildfires on soil's physical properties depend on the inherent stability of the affected soil properties and the temperatures to which a soil is heated during a fire (Neary *et al.*, 2005). Due to the inhomogeneous spatial distribution of severity, naturally burnt soils often appear as chaotic mosaics of areas little affected by the fire alternating with others seriously impacted (Rab, 1996).

The particle-size-distribution undergoes, with the increasing temperature, a continuous increase of the sand fraction corresponding to a simultaneous decrease of the clay fraction (Moreno, 2004).

Regardless of the changes in soil characteristics, nutrient resources, hydrology and vegetation, individual plants may increase their productivity, flowering, establishment of seedlings and seed-dispersal distances after fire (Whelan, 1995).

Campo *et al.* (2008a) studied both the effect of vegetation cover and the incidence of fire on various cementing agents such as organic matter, and $CaCO_3$ (Campo *et al.*, 2008b). Their results showed that before burning, soils under a vegetation cover had higher levels of Soil Organic Matter, Aggregate Stability, greater size of aggregates (N 0.5 mm) and lower content of $CaCO_3$ than bare soils. Immediately after the fire, few changes were observed in these characteristics in all cases.

Cation exchange capacity decreases progressively with the increasing temperature. The aggregation of the clay particles into sand-sized particles with the consequent decrease of the reactive surface area and the combustion of the organic matter with the disruption of the exchange sites seem to be responsible for this (Moreno, 2004).

According to DeBano *et al*. (2005), the most sensitive textural fraction is clay. Temperatures near 400°C can affect the structure and hydration of clays, and complete destruction occurs at 700–800°C. Ulery and Graham (1993) observed that textural changes in naturally burnt soils were restricted to severely burnt areas.

In general, below ground temperatures will rise very slowly due to the fact that dry soil is a very good insulator (DeBano *et al*., 1998), and to that in moist soils the evaporation of water will not allow a moist layer to go above the water boiling point (Campbell *et al*., 1995).

The increasing heating produces different modifications of the porosity of the soils. In the clayey textured soil, the porosity increases continuously up to 460°C, after this point the porosity sharply decreases as a consequence of the loss of the OH groups from the clays and the disruption of carbonates (Moreno, 2004).

The most significant changes in chemical properties of the surface soils are likely to result from the addition of ash and partially burned material (Ulery et *al*., 1993; Murphy et *al*., 2006). When the vegetation and surface litter are burned, ash usually provides an increase in the pH of soil, as well as an increase in nutrients available to plants (Ulery et *al*., 1995; De Marco et *al*., 2004).

Some soil characteristics like organic matter content, water content and soil texture can play an important role in the heat transfer into the soil profile. Soil heating generally decreases rapidly with soil depth in a dry soil because it is a poor conductor of heat (Bradstock *et al.*, 1992; Bradstock and Auld, 1995). Depending on fire severity, the impact on the organic matter consists of slight distillation (volatilisation of minor constituents), charring, or complete oxidation (Certini, 2005).

The lipid fraction in a soil increases after fires (Almendros *et al.*, 1988). The main reason seems to be the translocation into the soil of organic substances released from burning litter or biomass (DeBano *et al.*, 1970). An increase in the abundance of the humin fraction has also been systematically observed (González-Vila and Almendros, 2003), together with the formation of black carbon. Qualitatively, SOM is also affected by the passage of fire. The pyromorphic material consists of rearranged, relatively inert macromolecular substances mostly derived from plant biomass and highly aromatic in nature (Almendros *et al.*, 1988).

2.7.2. pH response to fire

After a fire there is an increase of available nutrients in soil, mainly in the form of water-soluble components of ash that became available to living organisms. The ‘‘fertilizing’’ effect of fire is known since the beginning of agriculture and forestry and also affects soil microbial populations. Part of this effect derives from an increase in soil pH frequently observed after a fire which is associated to an increase in exchangeable cations in soil resembling the effect of liming the soil (Gonzalez-Perez *et al.*, 2004).

The causes of the initial decrease of the soils porosity could be attributed to the oxidation of certain elements, the exposure of new surfaces, the dehydration of colloids and consequent decrease of the buffer action (Moreno, 2004). Changes in soil pH immediately after burning can affect solubilisation/insolubilisation dynamics of soil nutrients (Knoepp *et al.*, 2005). Because of these implications, soil pH must be monitored during the first months after fire for restoration purposes (Gil *et al.*, 2010). Soil pH decreases with the increasing temperature up to 400°C owing to the lowering of the buffer action associated with denaturing of the colloids and the combustion of the organic matter.

The sharp increase of the pH at high temperatures, on the contrary, may be due to the loss of the OH groups from the clays and, finally may be ascribable mostly to the formation of oxides of several elements derived from the disruption of the carbonates. The Cation Exchange Capacity decreases progressively with increasing temperature (Moreno, 2004).

Especially near the surface, soil structure mainly depends on soil organic matter content. Therefore, destruction of organic matter during burning should led to a decrease in the stability of aggregates (Úbeda and Outeiro, 2009). Kutiel and Shaviv (1989) found that an increase in the temperature of the soil from 250ºC to 600ºC was followed by a reduction of most of the available nutrients. Kutiel and Shaviv (1987a) also observed that there was a significant difference in soil nutrient levels measured after a wildfire in various patches that are dominated by different species.

2.7.3. Organic Matter response to fire

From the mid-twentieth century, widespread rural depopulation has occurred in the European Mediterranean leading to large-scale abandonment of traditional land management practices (Pardini *et al*., 2003). This has led to some beneficial effects including higher organic matter content and greater aggregate stability in many cases (Lloret *et al*., 2009).

It is commonly accepted that wildfires cause a decrease in soil organic matter content after combustion in the very short-term. But, in contrast, some authors have reported no significant differences in the long-term between burnt and unburnt soils (Alexis *et al.*, 2007) or increased contents due to different causes, as incorporation of charcoal and hydrophobic organic matter and invasion of N-fixing vegetation (Johnson and Curtis, 2001), increases in black carbon (Czimczik *et al*., 2005), or even via roots (Brye, 2006).

Soil organic matter content decreases with a rapid decline in the interval 210°- 400°C. The overall trend in organic matter content agrees with the responses of the differential thermal analysis of soils and an eventual incomplete combustion of the organic matter is ascribable to the short residence time of the fire (Moreno, 2004).

The recovery of soil organic matter in the burnt areas starts with the natural or artificial reintroduction of vegetation and generally is fast, thanks to the high net primary productivity of secondary ecological successions (Certini, 2005). The effect of heating on soil Organic Matter content is well defined in all soils. There is no detectable effect until 170°C, a little decrease occurs at 220°C, whereas at 460°C the combustion is practically concluded (Moreno, 2004).
The combustion of organic matter implies the decrease of its volume fraction and an increase of the volume fraction of minerals that have a higher density and a lower porosity (Moreno, 2004).

Gonzalez-Perez *et al*. (2004) identified the following main effects of fire on soil organic matter: (i) general removal of external oxygen groups that yields materials with comparatively reduced solubility; (ii) reduction of the chain length of alkyl compounds, such as alkanes, fatty acids, and alcohols; (iii) aromatisation of sugars and lipids; (iv) formation of heterocyclic N compounds; (v) macromolecular condensation of humic substances; and (vi) production of an almost unalterable component, the socalled black carbon.

Sudden modifications are caused by both the heat wave that accompanies the fire and by the ashes deposited on soil surface as consequence of fire. The delayed changes leave their mark on the soil and determine its future evolution (Moreno, 2004).

2.7.4. Nitrogen response to fire

Moderate to high intensity fires convert most soil organic nitrogen to inorganic forms. Ammonium ($NH4^+$) and nitrate ($NO3^-$) are the inorganic forms of nitrogen that originate during the burning. Total soil nitrogen content after fire results as a compensation between the decrease due to volatilization and the increase derived from the incorporation of N-containing compounds of the deposited ashes. The ammonium nitrogen and nitrates normally are volatilized and lost

(Moreno, 2004). Ammonium is a direct product of the combustion, while nitrate forms from ammonium some weeks or months after fire as a result of biochemical reactions called nitrification (Covington and Sackett, 1992).

A little decrease occurs up to 220°C, whereas a very pronounced decrease takes place in concomitance with the combustion of the organic matter: after this combustion the content of total Nitrogen is really very low.

The NH_4^+, on the contrary, increases greatly with the heat treatment up to 220°C, then decreases above this temperature and after the 460°C is barely detectable.

The increase in NH_4^+ with heating is due to the mineralisation of organic NH_4^+ containing complexes in the soils; the decrease at higher temperatures is due to fixation or volatilization (Moreno, 2004). Also, an increased presence of N-fixing bacteria after wildfires has been observed (Gonzalez-Perez *et al.*, 2003).

2.7.5. Phosphate response to fire

The combustion of vegetation and litter causes impressive modifications on biogeochemical cycle of P. Losses of P through volatilization or leaching are small this is why forest fires have not necessarily the same impact on soil P as on N, because Burning converts the organic pool of soil P to orthophosphate (Cade-Menun *et al.*, 2000). In acid soils, orthophosphate binds to Al, Fe, and Mn oxides through chemisorption, while in neutral or alkaline soils it binds to Ca-minerals or precipitates as discrete Ca-phosphate. The heating promotes a mineralisation of the Organic Phosphorus and a continuous decrease of this form accompanied by an equivalent increase of the inorganic form is detected (Moreno, 2004).

Soil organic phosphorous decreases continuously in parallel with the combustion of the soil organic matter, whereas, the available phosphorous increases, in the same temperature interval confirming that the available phosphorous is the outcome of the mineralization processes of the organic phosphorous (Moreno, 2004).

Recovery of soil health is very low after soil fire. Also after a fire, there is an increase of available phosphorus (Pyne, 2001). Part of this effect derives from an increase in soil pH due to an increase in exchangeable cations in soil (Raison, 1979).

2.7.6. Plant response to fire

The effects of fire are complex because the response of plants varies greatly with (Moreno, 2004):

- the characteristics of fire (fire intensity, rate of spread, energy release rate, residence time, type and timing).
- the intrinsic regeneration capacities of different species (both their inherent resistance to injury and ability to recover).
- the pre-fire status of the vegetation.
- the season (being greatest during the growing season).
- the bark thickness, age, composition, chemical content (Trabaud, 1987) and rooting habit play an important part in survival.

2.8. Grazing.

As a result of unsustainable forest practices and neglect of forested lands, and as a result of the decline of controlled grazing in forest understory, oak and pine forests have become highly susceptible to fire events (MOA/FAO, 2005).

Grazing is one of the most controversial forest uses in Lebanon as it lacks organization and sustainable management. Nevertheless, the decline of grazing activities during the past decades has favored uncontrolled development of forest understory which in turn has resulted in an increased fire risk on forests (MoA, 2010).

2.9. Fire.

Fire is a very complex phenomenon in which many components act simultaneously; it, in addition, affects the whole ecosystem (Moreno, 2004).

Basically, there are two types of forest fires: prescribed (controlled) fires and wildfires. Prescribed burning of naturally accumulated forest floor or slash following tree harvest is a standard practice to reduce fuel levels, with the intention of minimizing the extent and severity of wildfires or facilitating germination and growth of desired forest species. They are primed when soil is moderately moist, and consequently they show a low severity (Walstad *et al*., 1990).

In contrast, wildfires generally occur in the presence of an abundant and dry fuel load and, thus, are very severe (Certini, 2005).

Fire is a widespread phenomenon that can cause highly damaging ecological, economic and social effects (FAO, 2001; Konstandinidis *et al*., 2005). Fire plays two major roles in ecosystems, first in shaping plant community structure and composition, and second in the effect of phytomass burning on nutrient cycling (Iglesias, 2010).

The characteristics of native Mediterranean vegetation promote high-intensity and fast-spreading wildfires because (Fig.4): (1) there are typically large accumulations of dead branches and leaves which tend to decompose relatively slowly; (2) the plant material has a high surface area to volume ratio, which allows it to dry out quickly; and (3) volatile compounds are abundant (Lloret *et al*., 2009).

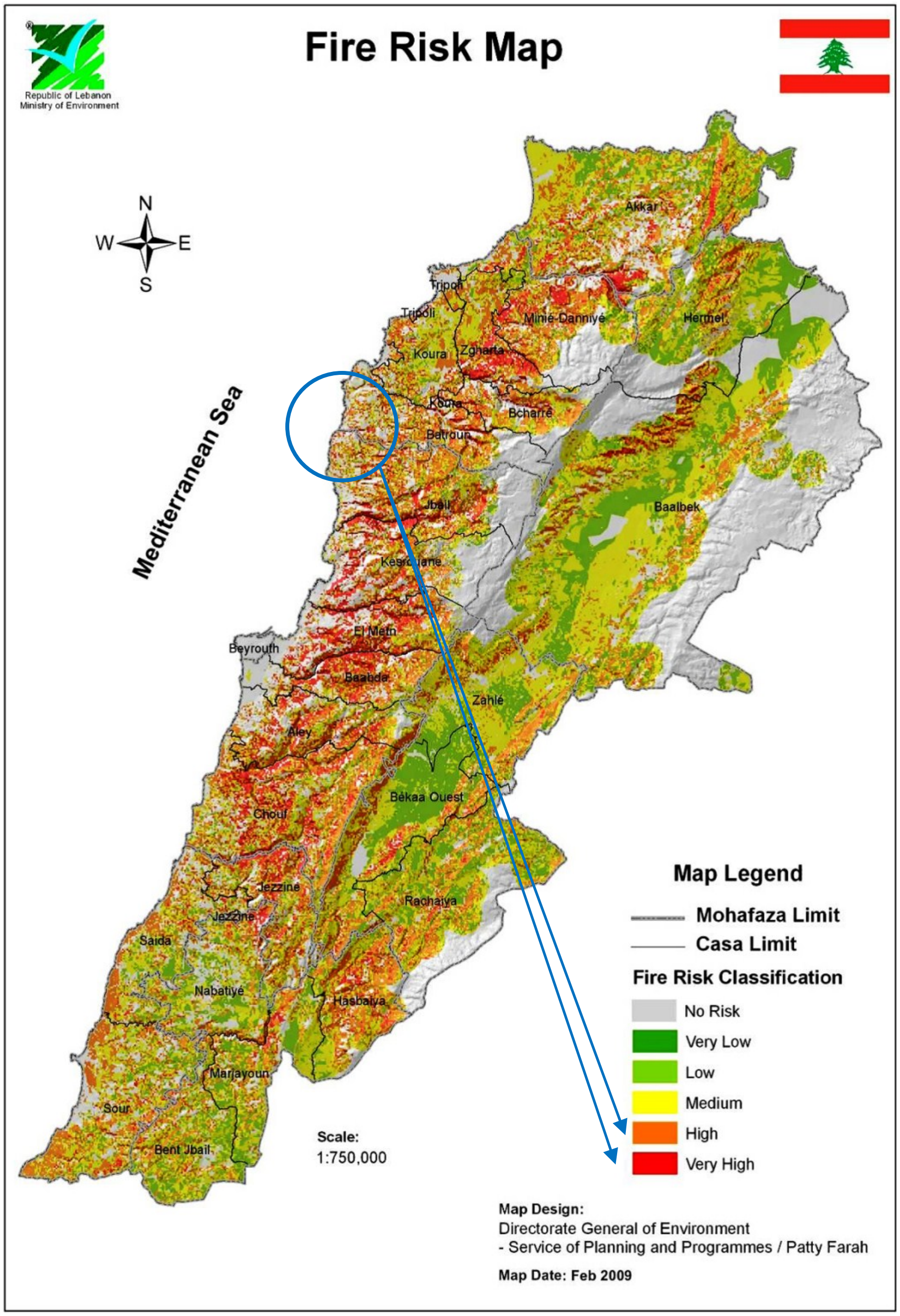


Fig.4. Fire risk map (MoA, 2005).

Forest fires constitute a serious threat on the vegetation cover and influence the decline of Lebanese forests (Fig.5). The frequency and intensity of these fires are a real threat to the sustainability of the forest ecosystems (MoA, 2010). The neglect and the lack of management of forests and other wooded lands play the main role in forest fire occurrence (MoA, 2010).

Fire can produce physical, chemical and biological alterations in soil properties (Mataix-Solero *et al.*, 2010.) Fire affects the biogeochemical properties of the soil, the hydrology and geomorphology of the area, influencing the vegetation cover and, consequently, the characteristics of subsequent fires (Whelan, 1995).

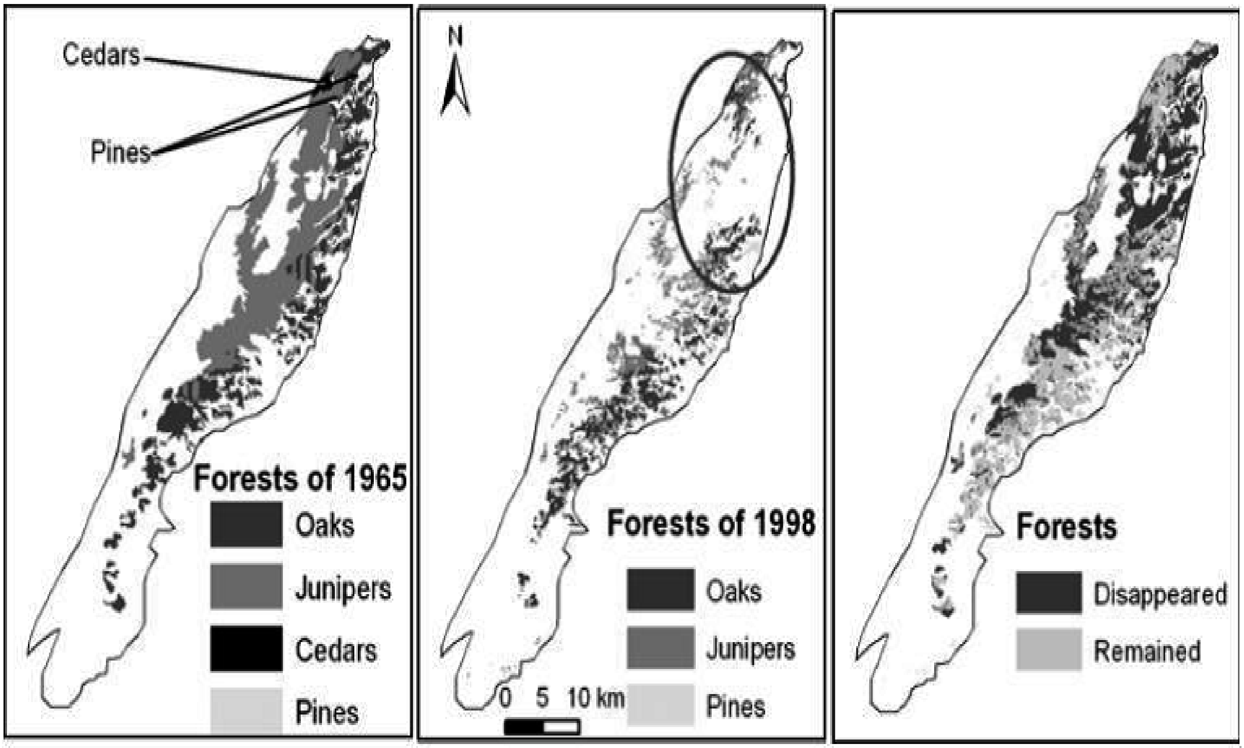


Fig.5. Spatial forest changes on the eastern flank of Mount Lebanon between 1965 and 1998 (Jomaa. *et al.*, 2007).

In Mediterranean-type ecosystems, fire is a natural and ancient occurrence that plays an important role in shaping vegetation communities and landscapes, controlling age, structure and species composition (Trabaud, 1994; Neeman *et al.*, 2004).

The Mediterranean eco-region is defined by climatic and bioclimatic similarities: the climatic conditions define a pattern of rainy and mild winters, which allow the growth of vegetation, followed by relatively long and dry summers, when the vegetation grown during winter becomes more flammable due to the dry period (Calvo *et al.*, 2003). This is why fire usually occurs at the end of summer and is followed a few weeks later by heavy showers of rain, which cause severe soil erosion (MoA, 2010).

During the last few decades, changes in land use have altered the characteristics of fire, human-caused fires are becoming more frequent and in many areas the fire regime has changed (Pausas, 2004).

The effects of fire in Mediterranean-type ecosystems vary considerably. Sever fires and slow establishment of certain plant species cause severe modifications of the environmental conditions (Pausas *et al*., 2004), which play a decisive role in the early phase of establishment of a plant after it germinates (Quintana *et al*., 2004). Furthermore, the characteristics of the soil, specifically the amount of organic matter, and the position of the hillside can affect natural regeneration (Tsitsoni, 1997).

The most typical effects of high severity fires are: 1) loss of organic matter and nutrients through volatilisation, ash entrapment in smoke columns, leaching and erosion; 2) alterations both quantitative and qualitative of microbial communities; and 3) deterioration of soil structure by affecting aggregate stability (Mataix-Solera *et al*., 2009).

Fire affects SOM both quantitatively and qualitatively. González-Pérez *et al*. (2004) reviewed of the effects of wildfires on SOM. Depending on different factors, the total SOM content can decrease or increase (Mataix-Solera *et al*., 2002a). These factors include fire type (canopy, above-ground or below-ground fires), fire intensity and severity and other factors controlling fire behavior such as slope, fuel content and moisture, and meteorological conditions (air moisture, wind velocity, etc.). SOM content changes may range from its almost total destruction to increases in the surface layers as a consequence of external inputs, mainly from dry leaves and partially burnt plant materials in fires affecting the tree canopy (Chandler *et al*., 1983).

The forest fire situation in Lebanon is significantly determined by predominating climatic conditions with prolonged summers (extending from June to October and sometimes even longer), virtually no rain and average daytime temperatures well in excess of 30°C, reducing the moisture content of forest litter to below 5 percent. Under these conditions, even a small addition of heat (lightning, a spark, a match, a cigarette butt) can be enough to start a violent conflagration. The steep slopes and the summer and eastern dry autumn winds characterized by high speed and strong desiccating power aggravate the situation (Mitri, 2008).

Forest fires, especially in the catastrophic years of 2007 and 2008 have destroyed the vegetative cover on over 4,200 ha of Lebanon's landscape (MoA, 2010). This was particularly true in October 2007, when more than 200 fires were declared in less than 24 hours, destroying thousands of hectares of forests and Other Wooded Lands (OWL) (Mitri, 2008).

The damages from those fires were big and reduced large amounts of the forest cover in a relatively short period of time (MoA, 2010). Within some hours fire destroys what has naturally grown over years and centuries (Mitri, 2008). According to the MoE‘s forest fires database, 129 fires occurred in 2004 resulting in 585 ha of burned forest areas (MoE, 2007). It has been stated that 5.6% of forests are at high risk of fires, and 25% are at medium risk (AFDC, 2007). They also raised concern at the national and international levels that they could lead to total eradication of forests if radical steps were not taken to solve the problem (Mitri, 2008).

The effects of this forest destruction have led to fragmentation and loss of the forest ecosystem services, which in turn has had a devastating impact on the livelihoods of local communities. Forests, particularly those in the 500 to 1,800 meter altitude zone are especially vulnerable to fires (Mitri, 2009). Apart from the frenzied urban building in the coastal zones, it is at this altitude where significant amounts of unmonitored construction is encroaching on forested and other wooded lands. Pine and oak ecosystems are suffering the most (MoA, 2005).

2.10. Regeneration after fire.

Fire causes by far the most important disturbances in ecosystems and seems to have acted not only as a destructive force but also as a selective and regulatory agent (Naveh, 1990). It limits the ecosystem's homeostasis because of its effects on the soil and, more particularly, on the competitive equilibrium of the grass layer species, especially for the sylvatic- characteristic species.

The effect of fires depends on their intensity, season, and frequency, and on the type of ecosystem burned (Naveh, 1990; Trabaud, 1990).

Mortality can be immediate or delayed for some time after fire occurrence, and that can vary with species, pre-fire vigor of the tree and fire severity. Because of their weakened physiological condition, fire-injured trees can also be subsequently attacked by insects or infected by diseases, increasing mortality (Catry *et al*., 2007).

Plant species regenerate after fire either by resprouting or by seed germination (Delitti *et al*., 2004) in such a way that after a short period of time, a few years, the plant species composition becomes similar to the pre-fire situation. This special case of secondary succession has been named autosuccession (Trabaud, 1994a). Resprouters tend to be more efficient in recuperating plant cover (Vallejo and Alloza, 1998) during the first post fire year, owing to their ability to rapidly mobilize underground reserves water, nutrients, carbohydrates for the new sprouts (Canadell *et al.,* 1991), with a certain independence from external conditions.

Fire initiates regeneration from buds by killing surface plant parts that inhibited their growth. The buds that become shoots are usually those nearest to the part of the plant killed by the fire. If dormant buds are destroyed, new buds may differentiate from wound tissue, called callus, and subsequently produce shoots (Blaisdell and Mueggler, 1956). The reduced understory cover and thickness of organic layers following fire can increase light near the surface, and in turn promote an increase in sprouting because light can cause rhizome tips to turn upward and develop leafy shoots once they reach the surface (Barker and Collins, 1963; Trevett 1956).

The natural regeneration of vegetation in areas affected by fire brings evident benefits, considering the intrinsic relation between the characteristics of the vegetation and the environmental conditions (Oliveira and Fernandes, 2009). To be able to sprout and support regrowth, a plant needs surviving meristems and stored carbohydrate reserves (Bond and Midgley, 2001). Older plants should have larger below-ground reserves and consequently a higher capacity to mobilize reserves in response to disturbance (Bellingham and Sparrow 2000).

Rapid resprouting and regrowth from secondary buds is the main adaptation of Mediterranean trees to major disturbances such as fire, cutting and grazing (Naveh, 1975; Bond and Midgley, 2001). If the level of damage is not so severe, partial damage to the crown buds and cambium will cause weakened apical dominance (Kozlowski, 1971) and at least some accessibility to below-ground reserves; thereby resulting in the simultaneous resprouting of the crown and base. Even though the natural regeneration of vegetation varies significantly among areas and with time of the year as a result of these factors, the capacity and speed of recovery of a burned area greatly depends on the regeneration strategy of the species present before the occurrence of fire (Calvo *et al*., 2003). Tree resistance to fire depends largely on the presence of fire adaptation traits that protect its critical tissues and on carbohydrate reserves (Whelan, 1995).

Post-fire tree survival and regeneration capacity are influenced by factors related to both fire severity and individual tree characteristics (Catry *et al*., 2007; Moreno and Oechel, 1994; Quintana *et al*., 2004)). Resprouting is an efficient mechanism through which many plants from the Mediterranean region recover above-ground biomass after they have suffered total crown consumption from a wildfire. Sprouting shoots can originate from dormant buds located above ground (axillary, branch epicormic or stem epicormic) or from the base of the plant (i.e. from the collar, roots or underground stems) (Moreira *et al*., 2008). Hereafter, these two sprouting modes will be referred as ‘crown’ and ‘basal’ sprouting.

The accumulation of different pre-fire or post-fire physiological stresses (like drought, soil erosion, branch pruning, fire, pests and diseases) can also contribute to the decay of vitality or may lead to the individual’s death (Catry *et al*., 2007). Other factors known to influence post-fire sprouting responses include site quality, disturbance frequency (Bond and Midgley, 2001), fire season (Konstantidinis *et al*., 2006).

When the level of fire damage is low (caused by low fire intensity on trees with thicker bark, and where the stem cambium is not affected), the plant is expected to resprout from crown buds that survived the fire. If the level of damage is extreme (caused by high fire intensity on trees with thinner bark or where the stem cambium is damaged), the most likely outcome is plant death. At intermediate levels of severity two response types can be identified. If the level of damage is higher, all crown buds will be killed, either directly through heat or indirectly through the destruction of the vascular cambium in the stem, as the carbohydrate reserves that support sprouting are primarily stored in belowground structures (Del Tredici, 2001).

Furthermore, apical dominance will be suppressed directly through bud destruction by heat or indirectly via damage to the cambium (Kozlowski, 1971), and the tree is therefore expected to respond through basal resprouting.

2.11. Regeneration of Quercus after fire

As obligatory root resprouters, the sclerophyllous woody plants (dominated by Quercus calliprinos) as well as the climbers regain almost one-third of their original dense cover. Their fire-stimulated vegetative regeneration is closely linked with their hydro-ecological behavior as drought-enduring and summer active plants. Since they rely on deep and well-branched root systems, they are capable of starting resprouting immediately after the fire, even in the middle of the summer by the mobilization of stored carbohydrates and possibly also of metabolized water in the roots. Due to their year-round intensive photosynthetic post fire activity, they can recover their former ground cover most approximately 10-15 years later, depending on the site, climate conditions, and prevailing post fire grazing pressures (Naveh and Carmel, 2003).

In the case of resprouters, recurrent fires may exhaust underground reserves if the intervals between fires are insufficient for recovering the reserves invested in resprouting (Canadell and Zedler 1995).

Oaks are resprouters and regenerate from shoots on the rhizome or the stem of subterranean roots (Calvo *et al*., 2003). Resprouting success is dependent on the mortality of adult plants due to fire (Eschel *et al*., 2000). In oak communities, understorey species are more abundant and species richness is high, while in pine communities herbs are practically inexistent, and therefore there is no significant competition between understorey and woody species (Franklin *et al*., 2003).

Besides the influence of the environmental post-fire conditions, Quercus species must resist to fire by protecting living tissues from which resprouting will be possible (Silva and Rego, 2007). Oaks are known for their ability to dieback and resprout (Franklin *et al*., 2003) and show very high resilience (Pausas *et al*., 2004).

Since the amount of carbohydrate, nitrogen and phosphorus resources that can be used for growth also determines the extent to which plants can resprout (Chapin *et al.*, 1990), the observed resprouting patterns will therefore also be influenced, and plants with depleted below-ground resources may suffer higher levels of damage since they are able to allocate enough energy to restore the lost biomass.

Resprouters dominate the first phase of recolonization after fire, but subsequently lose dominance in favor of obligate seeders (Montes *et al*., 2004). Quercus communities recover more rapidly than Pinus communities, but these differences are attenuated within few years after the occurrence of fire (Calvo *et al*., 2003).

Bigger trees are also less likely to resprout from the crown; resprouting ability declines with age and the below-ground carbohydrate storage in larger trees may be invested in survival rather than growth (Bond and Midgley, 2001).

The regrowth rate is commonly affected by tree age, size, aboveground biomass and stem density (Malanson and Trabaud, 1988; Bellingham and Sparrow, 2000). Tsiouvaras *et al*. (1986) showed that as response to repeated clipping of Kermes oak (Q. coccifera) canopies, growth rate of twigs had increased and the growth period was extended into the summer, a season in which Kermes oak trees do not normally grow.

2.12. Chemical composition.

Oak fodder contains relatively high levels of polyphenolic compounds and is not highly digestible but it is often available at times of the year when other fodder is in short supply. Its crude protein content is reasonable and it can be a useful supplement to poor-quality grazing or to cereal straw-based diets (Paterson, 1994).

Oak toxicity occurs sporadically when animals consume high proportion of either leaves or acorns in their diets. Symptoms of toxicity appear within a few days and death follows rapidly. The provision of alternative feed, sometimes together with supplements of calcium reduces the incidence of poisoning (Paterson, 1994). Toxicity is probably due to tannic acid, garlic acid or compounds produced by the breakdown of tannins in the gut (Basden and Dalvi, 1987).

The toxicity symptoms of oak, sporadic and reportedly low, include anorexia, constipation, rough coat, dry muzzle, abdominal pain, excessive thirst and frequent urination (Paterson, 1994).

2.13. Content of phenolic compounds.

Tannins are one of the many types of secondary compounds found in plants (Cannas, 2008). The role of plant tannins at the ecological level is almost certainly a mixed function, involving a defense mechanism against living-plant enemies and a delay in decomposition when plant tissue becomes litter, in the soil proper, as in roots, or on the soil surface, as in leaves (Rudolf *et al.*, 2007).

The high content of phenolics (including tannins) found in the foliage of all oak species influence its digestibility (Paterson, 1994).

Tannins are oligomeric compounds with multiple structure units with free phenolic groups (Fig.6). Their molecular weight ranges between 500 and 20,000. They have the ability to bind proteins and form insoluble or soluble tannin-protein complexes (Cannas, 2008). They may be classified chemically into two main groups, hydrolyzable and condensed. Condensed tannins, the larger group, form insoluble precipitates called tanner's reds, or phlobaphenes (Hagerman, 2011).

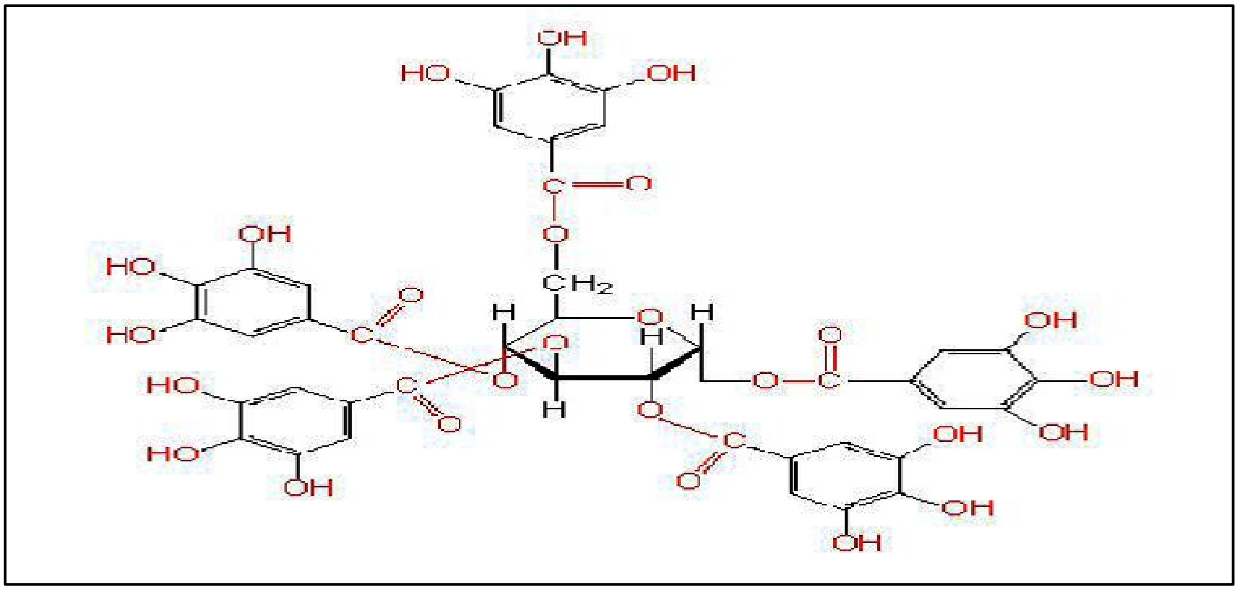


Fig.6. Structure of Tannin.

2.13.1. Hydrolysable tannins

Hydrolysable tannins (decomposable in water, with which they react to form other substances), yield various water-soluble products, such as gallic acid and protocatechuic acid and sugars. Gallotannin, or common tannic acid, is the best known of the hydrolysable tannins (Hagerman, 2011).

At the center of a hydrolysable tannin molecule, there is a carbohydrate (usually D-glucose). The hydroxyl groups of the carbohydrate are partially or totally esterified with phenolic groups such as gallic acid (in gallotannins) or ellagic acid (in ellagitannins) (Cannas, 2008). Hydrolysable tannins are hydrolyzed by weak acids or weak bases to produce carbohydrate and phenolic acids.

1. Gallotannins (Cannas, 2008)

- The phenolic groups that esterify with the core are sometimes constituted by dimers or higher oligomers of gallic acid (each single monomer is called galloyl).
- Each HT molecule is usually composed of a core of D-glucose and 6 to 9 galloyl groups.

- In nature, there is abundance of mono and di-galloyl esters of glucose (Molecular Weight about 900). They are not considered to be tannins. At least 3 hydroxyl groups of the glucose must be esterified to exhibit a sufficiently strong binding capacity to be classified as a tannin.
- The most famous source of gallotannins is tannic acid obtained ($C_{76}H_{52}O_{46}$), found in the leaves and bark of many plant species. It has a penta galloyl-D-glucose core and five more units of galloyl linked to one of the galloyl of the core.

2. Ellagitannins (Cannas, 2008)

- The phenolic groups consist of hexahydroxydiphenic acid, which spontaneously dehydrates to the lactone form, ellagic acid.
- Molecular weight range: 2000-5000.

2.13.2. Condensed tannins

Condensed Tannins are considered plant chemical defenses against pathogens and herbivores (Bernays *et al*, 1989). These tannins, as well as other phenolic compounds, are carbon based secondary compounds because they do not contain nitrogen atoms (Estiartea *et al*., 2006). Condensed tannins, also known as proanthocyanidins, are polymers of 2 to 50 (or more) flavonoid units that are joined by carbon-carbon bonds, which are not susceptible to being cleaved by hydrolysis. Proanthocyanidins polymers have complex structures because the flavonoid units can differ for some substituents and because of the variable sites for interflavan bonds (Cannas, 2008). While hydrolysable tannins and most condensed tannins are water soluble, some very large condensed tannins are insoluble. Depending on their chemical structure and degree of polymerization, they may or may not be soluble in aqueous organic solvents.

The term, proanthocyanidins, is derived from the acid catalyzed oxidation reaction that produces red anthocyanidins upon heating in acidic alcohol solutions. The most common anthocyanidins produced are cyanidin (flavan-3-ol, from procyanidin) and delphinidin (from prodelphinidin) Anthocyanidin pigments are responsible for the wide array of pink, scarlet, red, mauve, violet, and blue colors in flowers, leaves, fruits, fruit juices, and wines. They are also responsible for the astringent taste of fruit and wines.

Since the tannins serve no physiological purpose for the oak trees, there is considerable speculation as to the role of the tannins in plant defense. Several tannins have been shown to have oxidative properties and even inhibitory actions against DNA polymerases. The compounds have been implicated as anti-microbial, anti-feedants and as potential medicinal agents (Scott *et al.*, 2004).

The total phenolic content of acorns varies with both the species of oak and the stage of maturity of the fruit (Basden and Dalvi, 1987). Green acorns contained from 1.5 to 3 times the phenolic levels of ripe acorns (Paterson, 1994). Holechek *et al.* (1990) found 7.9% tannic acid equivalent of phenolic compounds in the immature leaves of Quercus grisea and 5.4% in the mature leaves. In Quercus incana, the total phenolic content and protein precipitating capacity decreases with advancing leaf maturity while condensed tannins increase (Makkar *et al*., 1991).

Paterson (1994) concluded that the heaviest insect attack during the first days of spring appeared when total tannins were in their lowest levels in the leaves of Quercus robur, thus illustrating the protective role of tannins. In contrast, Nastis and Malechek (1981) showed that the content of total phenolics fell with leaf maturity in Quercus gambelii.

2.14. Religion.

The name *Quercus* comes from the Celtic, *quer* meaning "fine," and *cuez* meaning "tree." The oak is often mentioned in the Bible as a symbol of strength, as a place of worship and as raw material for sculpting and for industry. In Genesis 18, the majestic oak tree is designated as the tree under which Abraham greeted two angels and supposedly God himself, all disguised as travelers.

The prophets used it as a metaphor for power and might: "And it will be against all the cedars of Lebanon that are lofty and lifted up, against all the oaks of Bashan" (Isaiah 2: 13) (Aloni and Livne, 2008).

The ancient Greeks believed the rustling leaves of a sacred oak to be oracles from Zeus. Historically, the Celtic religion as well as that of other cultures venerated old oak trees, using them as a focus for spiritual rituals.

2.15. Uses.

Leaves as well as the bark of the oak were internally used to treat hemorrhaging, diarrhea, tuberculosis by healers of the middle Ages as well as the Renaissance. They were used externally as a poultice to heal wounds discharging pus.

The powder of the leaves and bark were applied externally to stop bleeding nose, while talc prepared with them were used externally to end hemorrhaging or uncontrolled loss of blood. The bark is also effective for external application to treat conditions like skin infections, rashes, bruises, burns, ulcers and other problems.

Tannins have shown potential antiviral (Cheng *et al.*, 2002; Lu *et al.*, 2004), antibacterial (Funatogawa *et al.*, 2004) and antiparasitic effects (Kolodziej and Kiderlen, 2005). In the past few years tannins have also been studied for their potential effects against cancer through different mechanisms (Yang *et al.*, 2000; Tanimura *et al.*, 2005).

Tannins have also a major impact on animal nutrition because of their ability to form complexes with numerous types of molecules, including: carbohydrates, proteins, polysaccharides, bacterial cell membranes, enzymes involved in protein and carbohydrates digestion (Cannas, 2008). The anti-inflammatory effect of tannins helps control all indications of gastritis, esophagitis, enteritis, and irritating bowel disorders.

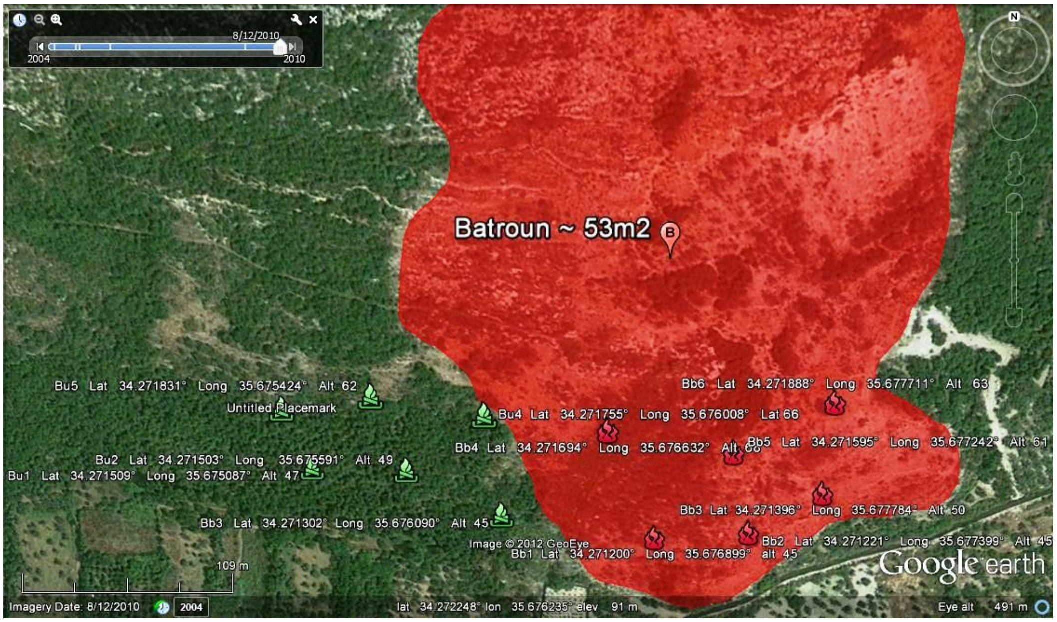
Tannins not only heal burns and stop bleeding, but they also stop infection while they continue to heal the wound internally. The ability of tannins to form a protective layer over the exposed tissue keeps the wound from being infected even more. They have also been reported to have anti-viral effects (Bajaj, 1988).

3. Materials and Methods.

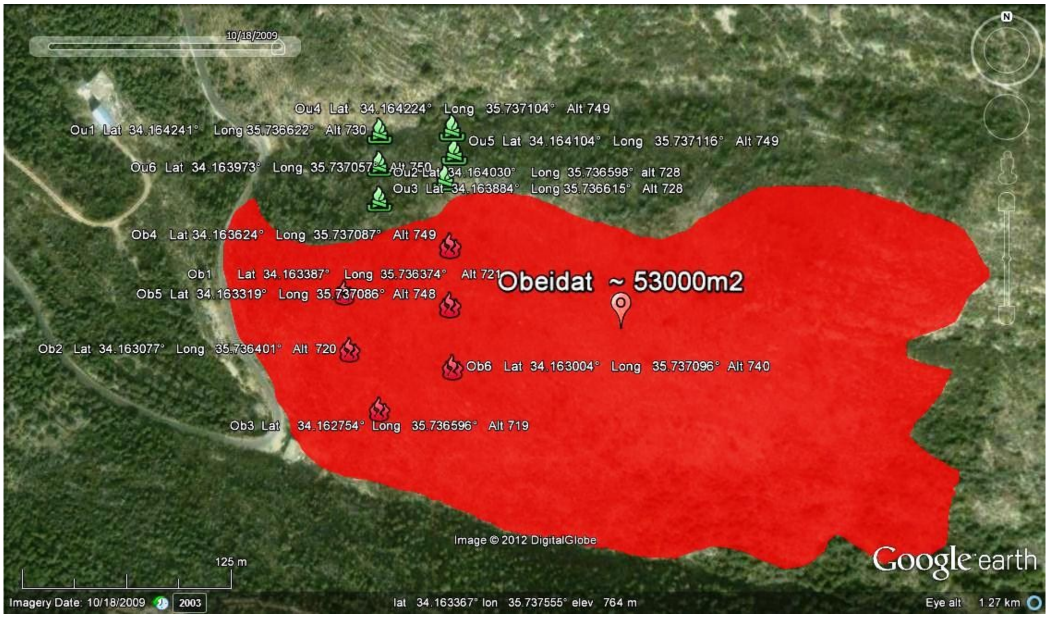
In order to study leaves components of *Quercus calliprinos* and fire effects on soil properties and the regeneration power of studied plots, samples were collected under trees in a burned and adjacent unburned forest (20-30m apart from each other). Sampling areas were dispersed at different altitudes in the North of Lebanon; Batroun (50m) (Pict.1), Kharbeh (750m) (Pict.2) and Mayfouk (950m) (Pict.3) (Fig.7).

Fig.7. Different sampling areas.

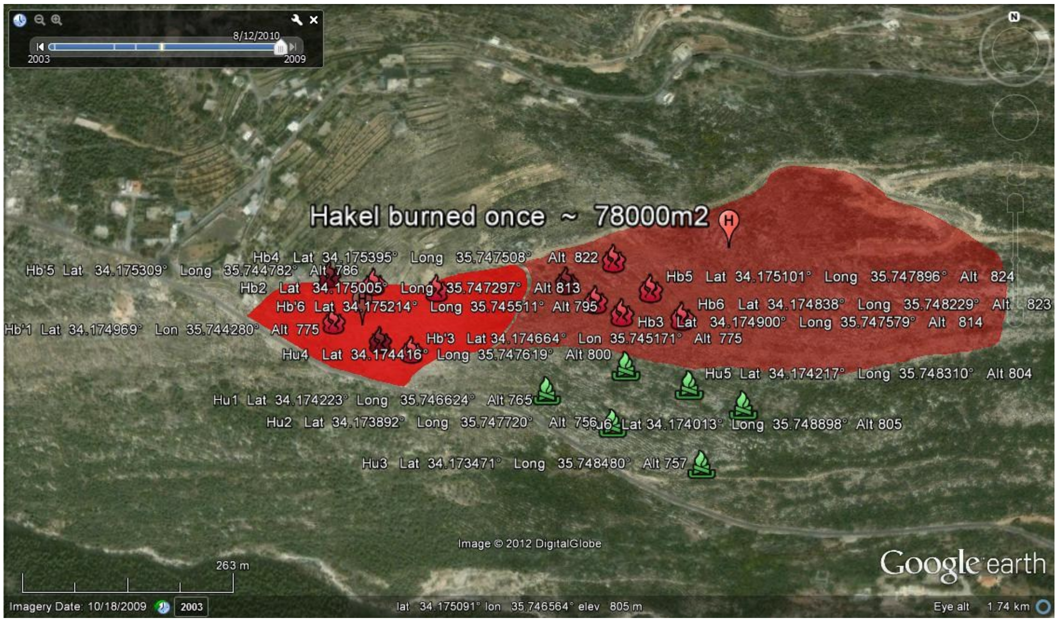
Soil was sampled using cores (5cm diameter) to an average depth of 30 cm and tested in the Lebanese Agricultural Research Institution (LARI) for the following parameters: soil texture, soil pH, $CaCO_3$, organic matter percent, electrical conductivity (EC), and nutrient content: N, P, K, Ca, Na, Mg, and Fe.



Pict.1. Burned and Unburned plots of Batroun



Pict.2. Burned and Unburned plots of Obeidat



Pict.3. Burned and Unburned plots of Hakel

According to the below design, the total number of the studied samples was 126 during the three years 2010, 2011 and 2012 (Fig.8). Within one year, 42 samples were studied, 3 from each level (upper and lower).

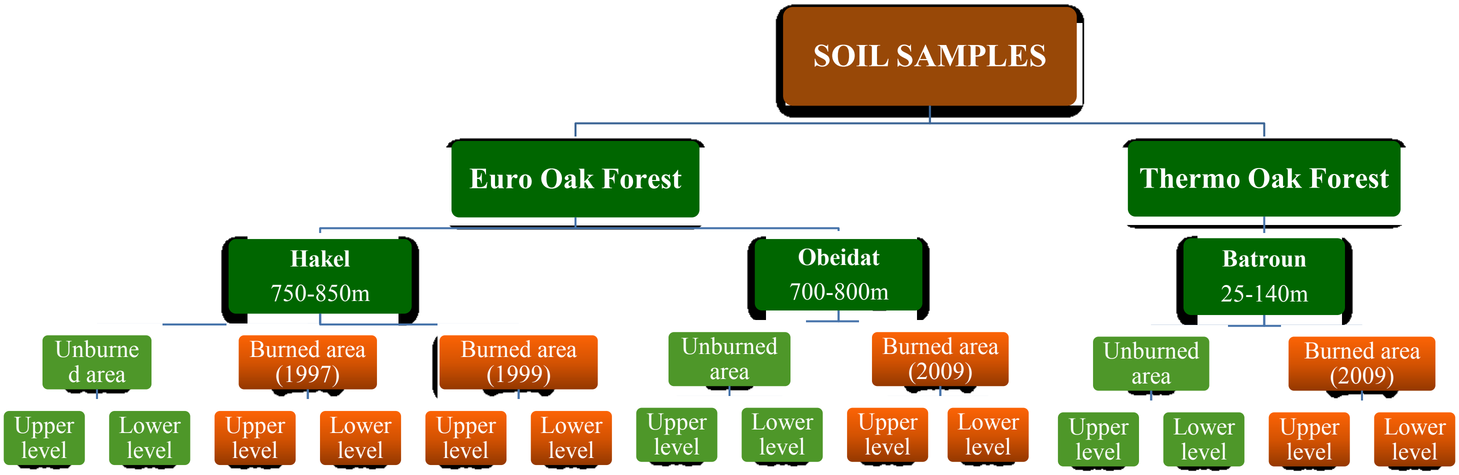


Fig.8. Soil sampling from burned and unburned areas.

3.1. Determination of soil texture.

Soil texture is a stable soil characteristic which influences the physical and chemical properties of the soil. There is a direct relation between particle size and the total surface area of particles in a given weight of soil. As particle decreases, total surface area increases. Since most of physical and chemical properties of soil are related to surface activity, determination of particle size distribution is a standard procedure for characterizing and classifying soils (Bashour and Sayegh, 2007).

Individual soil particles must be separated from each other, and kept separated during the determination in order to measure particle size distribution. Since aggregates of solid particles are usually held together by binding agent, it is necessary first to remove these substances. Once the soil aggregates are separated into individual particles, they are described by dispersed particles. Dispersion is achieved by chemical (sodium-hexametaphosphate) and mechanical means.

3.2. Soil particle analysis by Hydrometer Method (Boyoucous, 1965).

A hydrometer is a floating measurement devise that is used to determine the density of solutions. A bouyoucos hydrometer is calibrated to measure grams of soil per liter of suspension.

Apparatus

Electrical mixer with baffled stirring cup
Settling cylinder
Graduated Cylinder, 1Litre, with 1000ml mark 36±2cm from bottom
Bouyoucous Hydrometer calibrated at 200ºC
Thermometer ºC

Reagent

Sodium hexametaphosphate ($Na_6O_{18}P_6$ solution)

Procedure

50g of oven dried fine textured soil are weighed into a baffled stirring cup. The cup is then filled to its half with distilled water and 10ml of Sodium hexametaphosphate are added. The cup is placed on stirrer until soil aggregates are broken down; then, the suspension is transferred quantitatively to the settling cylinder. The hydrometer is placed in the liquid. After that, the hydrometer is removed and the suspension is shaken vigorously.

The cylinder is then placed on a table and the time is recorded; 20 seconds later, the hydrometer is inserted. Reading is made 40 seconds later. The hydrometer is calibrated to read grams of soil material in suspension.

The suspension temperature is measured. For each degree above 20ºC, 0.36 are added to the hydrometer reading, and for each degree below 20ºC, 0.36 are subtracted.

The suspension is re-shaken and the cylinder is placed on a table where it will not be disturbed. Every two hours, one reading must be taken. From the percentage of sand, silt and clay, the diagram for textural triangle is then used to determine the textural class of the soil (Fig.9).

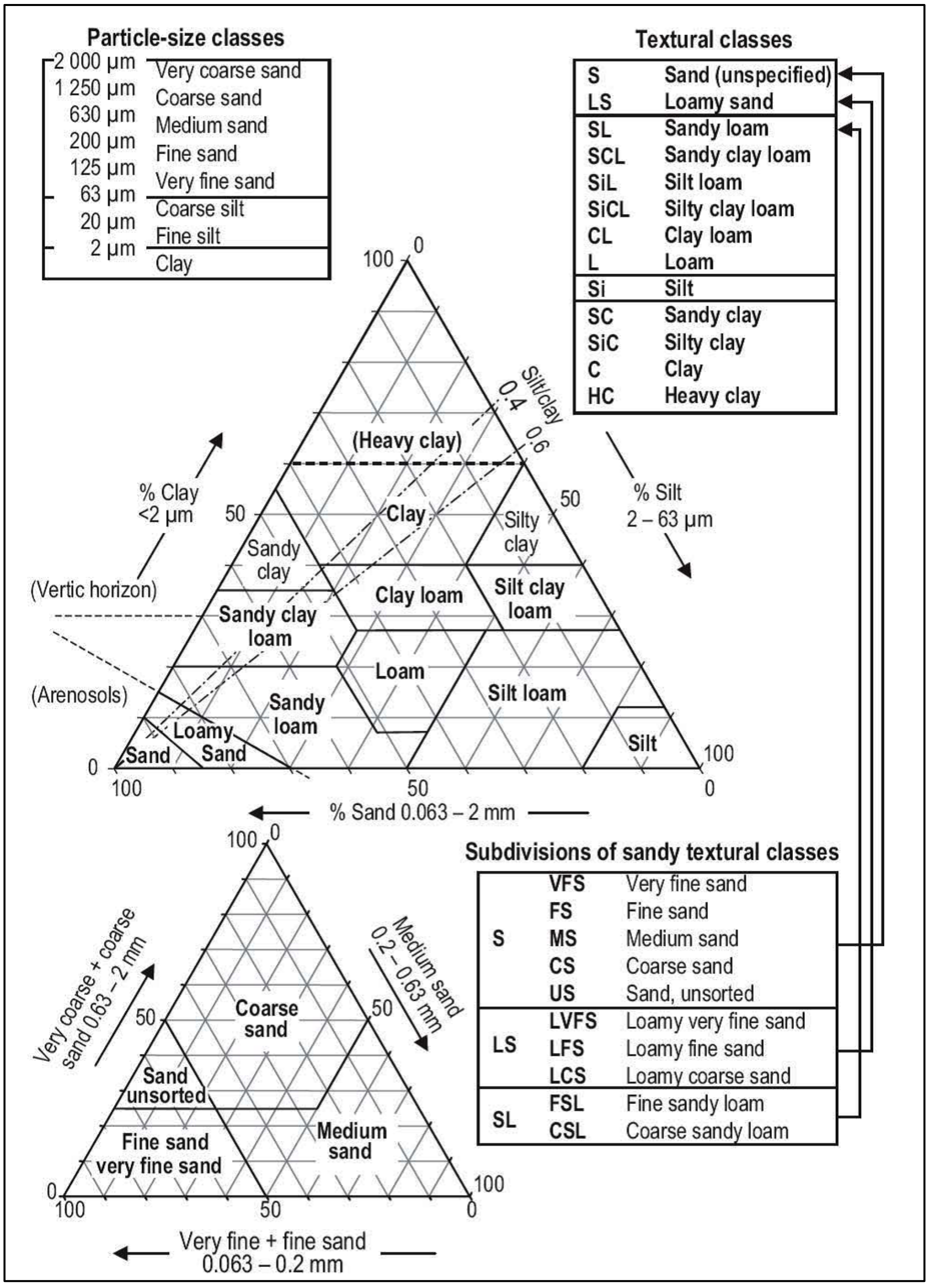


Fig.9. Textural classes based on USDA adopted and refined by FAO (FAO, 2000).

3.3. Determination of Soil Organic Matter (Walkley and Black, 1934).

Organic matter influences many of the physical, chemical and biological properties of soils. Some of the properties influenced by organic matter include soil structure, soil compressibility and shear strength. This test is performed to determine the organic content of soils. The organic content is the ratio, expressed as a percentage, of the mass of organic matter in a given mass of soil to the mass of the dry soil solids.

Apparatus

Erlenmeyer flasks (500ml)
Magnetic stirrer
Burettes (10ml)
Thermometer (200ºC)

Reagents

Potassium Dichromate solution ($K_2Cr_2O_7$; 0.1667M)
Sulphuric Acid concentrated
Ferroin indicator
Ferrous sulphate ($FeSO_4.7H_2O$; 0.5M)

Procedure

The soil is grinded in order to pass through 0.5mm screen. Contact with iron and steel must be avoided; then a weighed sample (not exceeding 5g) is transferred to a 500ml Erlenmeyer flask to which 10ml of potassium dichromate are added; the mix is swirled in order to disperse the soil and then 20ml of concentrated H_2SO_4 are added. A thermometer is inserted, then the flask is heated gently to a temperature of 150ºC; after cooling the flask to room temperature, 200ml of water and 4-5 drops of Ferroin indicator are added. Finally, the solution is titrated with ferrous sulphate 0.5N until color change from green to red.

A blank sample must be made without soil to standardize the reagents.

Calculation

Organic C % = (meq of $K_2Cr_2O_7$ – meq of $FeSO_4$) x 0.336/(Oven – dry soil)
Organic matter % = Organic C % x 1.724

3.4. Determination of Total Calcium Carbonate (Bashour and Sayegh, 2007).

Percentage of calcium carbonate, $CaCO_3$ (%), is defined as the total carbonates which is contained in 100 g of dry soil.

The determination of $CaCO_3$ (%) is based on the volumetric analysis of the carbon dioxide CO_2, which is liberated during the application of hydrochloric acid solution HCl (4N) in soil's carbonates and is described with the following reaction:

$$\mathbf{(CaCO_3 + MgCO_3) + 4\ HCl \rightarrow (CaCl_2 + MgCl_2) + 2H_2O + 2CO_2 \uparrow}$$

Apparatus

25ml and 100ml Erlenmeyer flasks

25ml Burette

Reagents

Hydrochloric acid (HCl, 1M)

Sodium hydroxide (NaOH, 0.5M)

Phenolphtalein indicator (1% in Ethanol 60%)

Procedure

5g of soil are weighed and transferred into a 250ml Erlenmeyer flask to which is added 100ml of HCl (1M).

Then the flask is covered with aluminium foil and is either kept overnight or boiled for 5 minutes and then cooled to the room temperature.

The mix is then filtered; 10ml of the filtrate are pipette into a 100ml Erlenmeyer flask. Finally, 2 or 3 drops of phenolphthalein are added to the content before titrating with NaOH (O.5M).

Calculation

% $CaCO_3$= [(mlHCl x 1M) – (mlNaOH x 0.5M)] x [Vol. HCl/ Vol. filtrate] x [100/1000x2] x 100g/ Weight of soil g.

% $CaCO_3$= [(10 x 1) – (mlNaOH x 0.5M)] x 10

3.5. Determination of Active Calcium Carbonate (Drouineau, 1942).

Active Calcium Carbonate is the active fraction of the total limestone that may dissolve easily and quickly in the soil solution. It corresponds to the fine fraction in the granulometric plan (clay soil, less than 2 microns). It helps in maintaining a high calcium saturation of the Cation Exchange Capacity (CEC) and, indirectly, a stable basic pH.

Apparatus

25ml and 100ml Erlenmeyer flasks

25ml Burette

Reagents

Ammonium Oxalate $(NH_4)_2C_2O_4$ (0.2N)

Sulphuric Acid Concentrated (NaOH, 0.5M)

Potassium Permanganate ($KMNO_4$ 0.02M)

Procedure

2.5g of soil are weighed accurately into a 500ml Erlenmeyer flask; then, 250ml of the ammonium oxalate are added. The mix is shaken for 2 hours. The suspension is filtered and the filtrate is collected; 10ml of the filtrate is pipette into an Erlenmeyer flask, to which are added 100ml of distilled water and 5ml of concentrated sulphuric acid are heated to a temperature of 60-70ºC. The mix is then titrated with $KMNO_4$ (0.02M) to a pink endpoint and the used volume is noted down. A blank is prepared in the same manner using 10ml of the ammonium oxalate solution, and the volume of the titrant used is recorded (V_{blank}).

Calculation

% Active $CaCO_3 = N_{KMNO4} (V_{blank} – V_{sample})$ x $(NH_4)C_2O_4$ (ml)/filtrate aliquote (ml) x 100g/2.5g x 5/1000

% Active $CaCO_3 = N_{KMNO4} (V_{blank} – V_{sample})$ x 250 (ml)/10(ml) x 100g/2.5g x 5/1000

% Active $CaCO_3 = N_{KMNO4} (V_{blank} – V_{sample})$ x 5

NB: The maximum concentration of active calcium carbonate that can be dissolved by this method is 20%. If active $CaCO_3$ content obtained is greater than 17%, then the analysis should be repeated with a smaller amount of soil or larger volume of oxalate extractant.

3.6. Determination of Total Nitrogen (Jackson, 1956).

Total Nitrogen analyses are divided into two types: wet digestion (Kjeldahl method) and dry combustion (Dumas method). The wet digestion technique involves the conversion of organic and inorganic N to NH_4^+ in acid and its subsequent measurement.

Apparatus

Kjeldahl digestion unit
Ammonium-N distillation unit

Reagents
Sulphuric-salicyclic acid
Sodium thiosulphate ($Na_2S_2O_3.5H_2O$)
Sulphate mixture
Sodium hydroxide (NaOH 45%)
Mossy Zinc pieces
Boric acid (4%)
Sulphuric acid (H_2SO_4 0.05M)

Bromocresol green-red methyl mixed indicator

Procedure

10g soil, which has been passed through a 20 mesh sieve, were weighed and transferred into a 800ml Kjeldhal flask; 50ml of sulphuric-salicyclic acid mixture were added to the flask and swirled to bring the sample into intimate contact and kept overnight. To this mixture, 5g of sodium thiosulphate were added and heated gently for 5 minutes; then, 10g of the sulphate mixture were added and the all are digested on the Kjeldahl apparatus gradually by raising the temperature until the digest becomes clear. After cooling, 300ml of distilled water are added followed by 100ml of concentrated NaOH to let it run down the neck and settle in the bottom of the flask. Final, a large piece of mossy zinc and 10 drops of bromocresol green-methyl red indicator were added and the mix was titrated with the sulphuric acid solution to the first faint pink.

Calculation

Kjeldahl N (%) = (T – B) x M x 2.8/S
T = ml of standard acid with sample titration
B = ml of standard acid with blank titration
M = molarity of sulphuric acid
S = weight of soil sample in g

3.7. Determination of Available Phosphorous (Olsen *et al*., 1954).

This method estimates the relative bioavailability of ortho-phosphate (PO_4-P) in soils by extraction using alkaline sodium bicarbonate (pH 8.5) solution and determining the P concentration in the extract colorimetrically. It is applicable to soils that are mildly acidic to alkaline pH and is based on the method developed by Olsen *et al*., (1954) to correlate crop response to fertilizer on calcareous soils (Molina, 2011).

Apparatus

Spectrophotometer

Funnels and filter papers

Reagents

Sodium Bicarbonate ($NaHCO_3$ 0.5M)

Ammonium Molybdate

Ammonium Molybdate - Ascorbic Acid Solution

Standard Phosphate Solution

Working Standard (dilute) Phosphate Solution

Sulphuric Acid (H_2SO_4 2.5M)

Procedure

5g of soil sample are weighed in a 250ml Erlenmeyer flask to which is added 100ml of $NaHCO_3$ solution. The mix is then shaken for 30 minutes. The suspension is then filtered through Whatman No. 40 filter paper into a clean dry 125ml Erlenmeyer flask. The suspension is shaken immediately by hand before pouring it into the funnel; 10ml of the filtrate are transferred to a 50ml volumetric flask where they were acidified to a ph of 5 by adding 1ml of 2.5M H_2SO_4. Then distilled water was added to reach 40ml of volume to which were added 8ml of ammonium molybdate-ascorbic acid solution, finally the volume is brought to 50ml. After waiting 10 minutes, the absorbance was read at 882nm on the spectrophotometer. Maximum intensity could be obtained in 10minutes.

The phosphorus concentration of the sample is determined from a calibration curve relating the readings of absorption units to concentration in μg P/ml.

Calculation

$P\ \mu g/g\ soil = P\ (\mu g/ml) \times 50ml/10ml \times (100ml/5g\ soil)$

3.8. Determination of Available Potassium (Sparks, 1996).

Potassium that is dissolved in soil water (water soluble) plus that held on the exchange sites on clay particles (exchangeable K) is considered readily available for plant growth. The exchange sites are found on the surface of clay particles. This is the form of K measured by the routine soil testing procedure (Rehm and Scmitt, 1997).

Apparatus

Centrifuge
Round bottom centrifuge tubes (50ml)
Mechanical shaker
Flame photometer

Reagents

Ammonium Acetate (NH_4OAc, 1M)
Potassium Chloride (KCl, 0.02M)
Lithium Chloride (LiCl, 0.05M)

Procedure

5g of soil are weighed accurately and transferred into a 50ml centrifuge tube; 20ml Ammonium Acetate solution (1M) are added; the mix is shaken in a reciprocal shaker for 5 minutes and centrifuged at 2000 rpm for 5minutes; then, the supernatant is decanted into a 100ml volumetric flask. This step is repeated 2 to 4 more times. The supernatant is brought to 100ml by adding ammonium acetate solution. The determination of K concentration is done in the extract by flame photometer.

Calculation

Meq of K/100g soil = Reading (meq/l) x 100ml/1000ml x 100g/Weight of soil (g)
= Rx10/Weight of soil (g)

3.9. Determination of pH (Bashour and Sayegh, 2007).

Soil acidity is determined by a measurement of the hydrogen ion concentration of a particular soil. The measurement scale used in determining soil acidity is the pH scale which ranges from 0-14.

Apparatus

pH meter with glass electrode

Glass beakers (25ml)

Reagents

Standard pH buffer solutions.

Procedure

The pH meter must be standardized using the standard pH buffers. A portion of the already prepared saturated paste is transferred to fill about the ¾ of a 25ml tall beaker. The electrode is rinsed carefully with distilled water and immersed into the paste. The beaker must be raised and lowered repeatedly to have better contact between the electrode and the paste, then the pH recording is recorded.

3.10. Determination of Soil Salinity (Bashour and Sayegh, 2007).

Total soluble salts refer to the total amount of salt dissolved in the soil extract expressed in parts per million (ppm). The salts include substances that form common table salt (sodium and chloride) as well as calcium, magnesium, potassium, nitrate, sulfate and carbonates. The reading in mS/cm of electrical conductivity is a measure of the soluble salts content in the extract, and an indication of the salinity status in the soil.

Apparatus

Electrical conductivity meter

Reagents

Standard Potassium Chloride (KCl; 0.01 and 0.1M)

Procedure

The conductivity electrode is washed with distilled water and rinsed with KCl solution (0.01M). Some of this solution is poured into a 25ml beaker and the electrode is dipped in the solution. The conductivity meter must be adjusted to read 1.412Ms/cm. The electrode is then washed and dipped into the saturated paste extract. The digital display is then recorded.

3.11. Determination of Soluble Sodium (Bashour and Sayegh, 2007).

Soil extracts can be analyzed for sodium, potassium and calcium by flame emission methods involving use of filter photometers without preliminary concentrations of the solutions (David, 1960).

Apparatus

Flame photometer

Procedure

The flame photometer is warm-up for 15minutes. The instrument is calibrated with blank and standard solutions. The capsules are filled with the soil extracts. The suction tubing is then inserted in the capsule and the reading is recorded. The tubing is dipped in distilled water in order to wash the system and the sample is read. Readings express the concentration of Sodium as meq/l of the saturation extract.

Calculation

meq of soluble Na/100g soil = meq/litre x SP/1000

3.12. Determination of Soluble Calcium and Magnesium (Bashour and Sayegh, 2007).

Water-soluble calcium and magnesium are measured in the soil saturation extract. Exchangeable Ca and Mg are determined in ammonium acetate extraction solution.

Apparatus

Microburette (10ml)

Reagents

Ammonium Chloride-Ammonium Hydroxide buffer solution
Sodium Hydrixide (NaOH 4M)
Calcium Chloride ($CaCl_2$ 0.01N)
Eriochrome black T indicator
Calred indicator
Ethyldiaminetetraacetic acid (EDTA 0.01N)

Procedure

1. Calcium determination

An aliquot of soil extract (2-5ml) is pipette in 50ml white porcelain dish and diluted with distilled water to 25ml; then, 2ml of NaOH (4M) and 2-3mg of calred indicator are added. The contents are titrated slowly with EDTA (0.01N) until a sky-blue end point is obtained.

A blank must be prepared using 2-5ml of distilled water.

<u>Calculation</u>

Meq of Ca/litre = 1000 x (ml EDTA used for soil extract – ml EDTA used for blank) x N of EDTA/ml of sample taken (aliquot)

2. Calcium and Magnesium determination

An aliquot of soil extract (2-5ml) is pipette in 50ml evaporating porcelain dish and diluted with distilled water to 25ml; then, 5ml of Ammonium Chloride-Ammonium Hydroxide buffer solution and 3-4 drops of Erichrome black T indicator are added. The contents are titrated slowly with EDTA (0.01N) until a sky-blue end point is obtained.

A blank must be prepared using 2-5ml of distilled water.

Calculation

Meq of (Ca+Mg)/litre = 1000 x (ml EDTA used for soil extract – ml EDTA used for blank) x N of EDTA/ml of sample taken (aliquot).

3. Magnesium determination

Concentration of Magnesium, as meq/l, is calculated by subtracting meq/l of Ca from meq/l (Ca+Mg). The difference is the concentration of Mg as meq/l.

3.13. Elongation and regeneration.

To follow seasonal variations within this specie, number of newly developed leaves and the elongation of new sprouts were measured at different times of the year, so that plants were at different stages of development. Sampling took place at three different seasons during 2012, namely: (i) Mars (winter) (ii) May-June (spring); and (iii) July-August (summer); so that plants were at different maturity stages.

3.14. Gas chromatography.

The browse plants were clipped with scissors collecting a mixture of leaves and thin stems. In the laboratory, leaves were manually separated from the original samples.

Samples were naturally dried in plastic bags for two weeks at room temperature and then grounded in a hammer mill using a 1mm sieve to fine powder by electric blender, and stored in plastic containers at 4ºC; 4g of the dried powder were mixed with ethanol (12ml) in a 25ml flask and submerged for 15minutes in the ultrasonic machine (0ºC); then, 6ml of ethanol are added in the ultrasonic machine for 10 minutes. Finally, 4ml of ethanol are added. The solution, decantated for 10 minutes, is double filtered using Merck filter paper (125mm); the volume is finally bought to 10ml by adding azote.

After ethanol extraction, all the extracts obtained were analyzed by gas chromatography coupled with mass spectrometry GC/MS « Agilent Technologies 6890, USA » (Fig.10). The following operating conditions were adopted:

- The temperature of the injector is 250˚C.

- The capillary column of the type DB-5MS (J.&W. scientific, USA) possesses a length of 30 m, a diameter of 0.25 mm and a film thickness of 0.1 µm.

- The flow of the carrier gas, helium, was 0.7 ml/min.

- The temperature of the oven is set as: initial temperature is 35˚C, followed by a rise in the temperature up to 85˚C with an increase of 5˚C/min., it remains constant at this temperature for 20 min., then increases up to 300˚C with an increase of 10˚C/min. where it’s kept at this temperature for 5 minutes.

- The mode of ionization and electron impact ionization energy is of 70 eV.

- The temperature of the detector MSD is 310˚C, for the mass spectra between 50 and 545, at a rate of 2.91 scans/second.

- In the qualitative analysis, the peaks are identified by referring to Wiley 275 library.

Fig.10. GC/MS « Agilent Technologies 6890, USA.

3.15. Statistical Analysis.

An analysis of ANOVA variance and correlation of all the mentioned parameters were performed using SPSS version 14.0 to examine the effects of different factors; season, number of days after fire, burned and unburned plots on all the soil parameters (physical and chemical), regeneration power of the trees and leaves composition.

4. Results and Discussion.

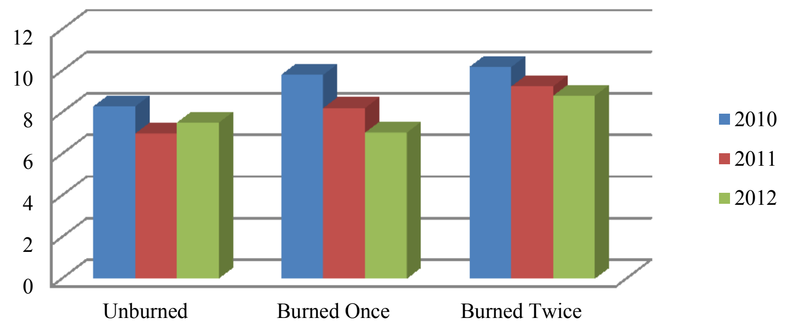
4.1. Organic matter.

Soil organic matter is created when the primary productivity exceeds decomposition. Organic matter accumulations can vary from thick surface duff layers located mainly on the soil surface to deep deposits of peat that have been accumulating for thousands of years. The organic matter in a soil profile is concentrated at, or near, the soil surface where it is directly exposed to heating by radiation produced during the combustion of aboveground fuels (DAFS, 2005).

On average, the soil organic matter in the burned studied plots decreased gradually with years and varied between 9.8% (2010) and 7% (2012); while, there wasn't a significant difference within the unburned plots and the rate varied respectively between 6.9 (2011) and 8.2% (2012) (Fig.11;Tab.1).

The high content of the organic matter in the burned plots of Obeidat, Hakel and Batroun (with respectively 9.8%; 8.2%; 7.1%) (Fig.11) acted similarly to the soil studied by Neary *et al.* who mentioned the total destruction of the soil OM after a high-intensity fire, but when it comes to a medium-intensity or low-intensity fire, organic matters increased only in the lower layer but decreased in superficial layer (Shaoqing *et al*., 2010). This will lead us to classify the fire within low and medium intensity fire.

Fig.11. Influence of the status on the OM between 2010 and 2012



In the burned plots and after the fire, the sharpest decrease in OM content was observed and reached 38.2% in case of Obeidat plot and varied between 12.7% and 7.85% followed by the burned plot of Hakel with a decrease from 9.33 to 7.33% (21.4%). The lowest decrease was recorded on Batroun plot with 21.3%; this could be due to the acceleration of the soil physico-chemical properties and the temporal removal of the herbaceous layer, with effective erosion-controlling belowground root structures (Andreu *et al.*, 1996) (Pict.4).

Pict.4. Removal of Herbaceous layer after fire

Iglesias (2010) recorded significant differences between the upper two layers of burned soils: soils with the highest organic matter content were the most recently burned and twice burned; and the other group comprises the control and the oldest burned soils; a part of these nutrients has most likely been transferred down to the second layer, probably by translocation in the soil profile (Iglesias *et al.*, 1996, 1997).

Concerning the twice burned plot of Hakel, it showed the same trend of the burned once plots and the organic matter decreased when passing from one year to another from 10.2% in 2010 to reach 8.8 in 2012 (Fig.12)

Anova test showed a significant difference between years ($p < 0.01$) and the only increase in the organic matter content was recorded in the unburned plot of Obeidat during 2012 with an increase of 8.14% between 2010 (8.8%) and 2012 (9.5%) (Tab.1; Fig.12).

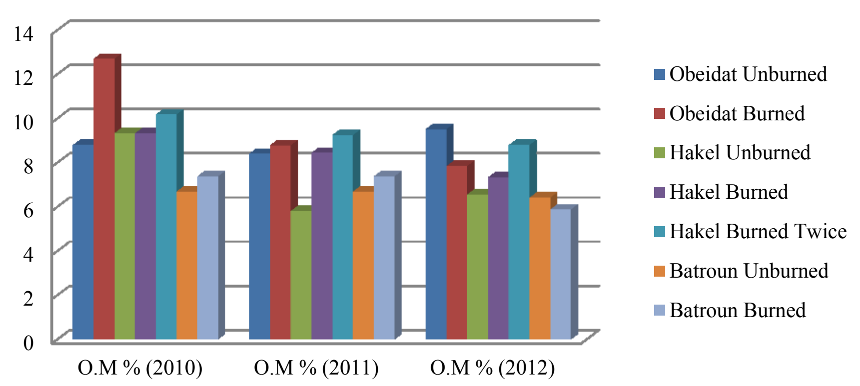


Fig.12. Influence of time after fire on OM

The site highly influenced the content of OM with a maximum of 9.78% in Obeidat and a minimum of 6.61% in Batroun; this is mainly due to the difference of altitude i.e the pluviometry and temperature that consequently influence the type of shrubs and ground cover in each plot and therefore the necromass accumulation varies a lot (Tab.1).

Tab.1. Influence of the year, site and status on the organic matter, ph and electrical conductivity.

	Year		Site		Status	
	F	p	F	p	F	p
Organic Matter	5.226	0.007**	11.500	0.000***	4.244	0.017*
pH	12.655	0.000***	20.137	0.000***	0.734	0.482
CE	7.423	0.001**	18.641	0.000***	1.177	0.312

*** indicates significant difference from initial value at $p<0.05$; ** indicates significant difference from initial value at $p<0.01$; *** indicates significant difference from initial value at $p<0.001$.**

The significant influence of the organic matter content within the burned plots showed an increase that varied between 4.2% in Batroun (6.6-6.9%) and 15.6% in Hakel (7.2-9.4%) (Tab.1 Fig.13). This increase is similar to the one observed in the work of Chandler and its colleagues who showed that this increase may reach 30% in the surface layers as a consequence of external inputs, mainly from dry leaves and partially burnt plant materials in fires affecting the tree canopy (Chandler *et al.*, 1983). The effect of fire on the total soil OM content is highly variable, suggesting a substantial incorporation of forest necromass (Mataix-Solera *et al*., 2011) and depends on several factors including fire type (canopy or aboveground, underground fires), intensity (Gonzalez Perez *et al*., 2004), severity and other factors controlling fire behavior such as slope, fuel content and moisture, and meteorological conditions (air moisture, wind velocity, etc.) (Mataix-Solera *et al*., 2011).

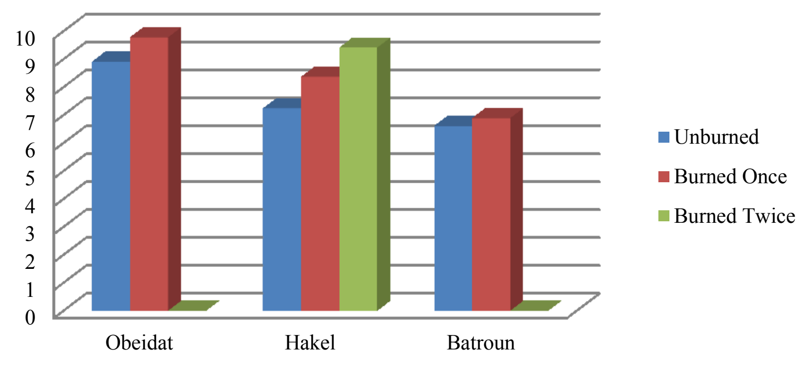


Fig.13. Influence of the site on OM

These results are similar to the one observed by Iglesias (2010) who recorded a significant increase in organic matter content after fire. Litter and necromass accumulation during the post-fire phase increased soil organic matter in the surface horizon of the fire-affected soil (Knicker *et al*., 2005), and the values are below pre-fire levels in soils burned in 1981, probably because we observed different vegetation in this site (Iglesias, 2010); in contrast, some authors have reported no significant differences in the long-term between burnt and unburnt soils (Alexis *et al*., 2007; Roscoe *et al*., 2000) or increased contents due to different causes, as incorporation of charcoal and hydrophobic organic matter and invasion of N-fixing vegetation (Johnson and Curtis, 2001), increases in black carbon (Czimczik *et al*., 2005; Dai *et al*., 2005; Knicker *et al*., 2005), or even via roots (Brye, 2006).

4.2. pH.

The combustion of organic matter during a fire and the subsequent release of soluble cations tend to increase pH slightly because basic cations are released during combustion and deposited on the soil surface *(DAFS, 2005)*. Changes in pH with burning are very dependent on the amount and nature of the ash, the depth of sampling, time after fire and the time the ash has been in contact (liming effect of ash) with the mineral soil (Ulery *et al*., 1995; Úbeda *et al*., 2004).

The pH value was 7.5±0.33 and varied between 7.7±0.36 at control plots and 7.6±0.33 at plots burned once. Concerning the plot burned twice, it didn't show any difference from the plots burned once with 7.7±0.22. This is why, no significant differences were observed between average pH from burned and unburned plots (Tab.1; Fig.14). The highest increase was recorded on the plots burned once with 4.8% followed respectively by Hakel burned twice (3.7%) and Obeidat (2.6%). Our results are in accordance to the ones of Ekinci (2006) who didn't find any significant difference between the un-burnt soil and burned soil. The highest difference didn't exceed (0.47 units). Many researches on fire disturbance have been reported, among which, Shaoqing *et al.* (2010) discovered that soil pH rise significantly after burning, while Sha *et al.* discovered that soil pH significantly rise in 0–10 cm soil layer, but no significant change was discerned in 10–30 cm soil layer.

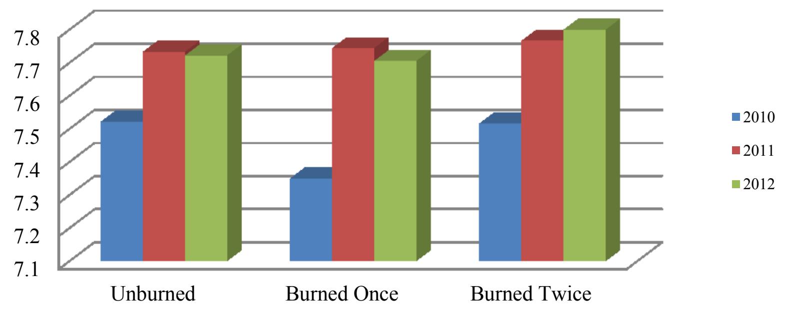


Fig.14. Influence of the status on pH between 2010 and 2012

The year parameter highly influenced the pH (Tab.1). Yearly pH values from Obeidat control plots varied between 6.98 (2010) and 7.58 (2012). Soil acidity varied approximately during the first two years of the experiment more than one pH unit, ranging from 6.55 to 7.7 (1.15 unit) during 2010 and between 6.55 and 7.87 (1.32 unit) during 2011; while, this difference didn't exceed 0.3 during 2012 with respectively 7.57 in the burned plot of Obeidat and 7.87 in the unburned plot of Hakel (Fig.15).

The pH low difference between plots could be due to the low or medium intensity of the fire; because Granged *et al.* (2011) showed that the pH increase between different plots may be favored by the complete oxidation of soil organic matter under high fire intensity, and the release of substantial amounts of cations. Significant increases occur only at high temperatures (>450–500ºC), in coincidence of the complete combustion of fuel and the consequent release of bases (Arocena and Opio, 2003) that also leads to an enhancement of base saturation (Macadam, 1987).

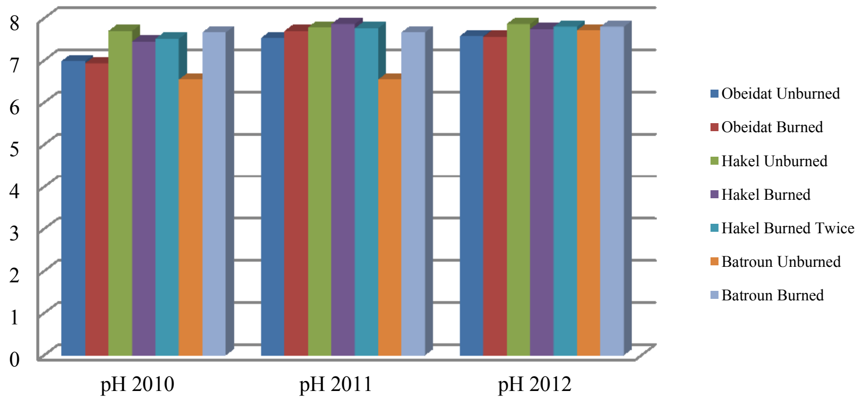
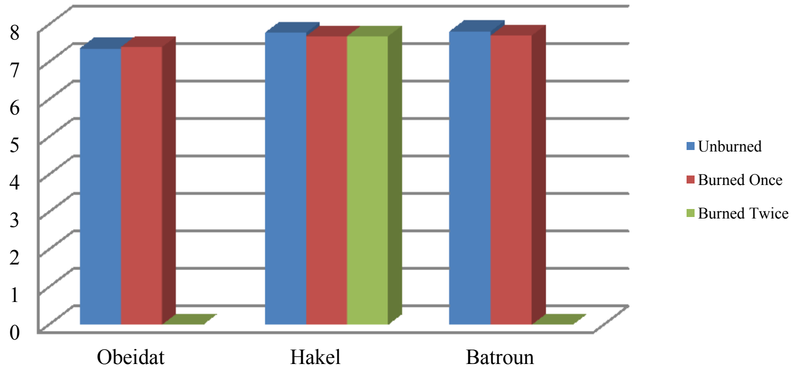


Fig.15. Influence of time ater fire on pH

The site highly influenced the soil pH which increased slightly from 7.36 (unburned) and 7.4 (burned) in Obeidat plots; while, the pH decreased progressively from 7.78 (unburned) to 7.69 (burned) in Hakel plots (Tab.1; Fig.16). Concerning the Hakel plot which was burned twice, the pH was similar to the plot burned once (7.69). Batroun sites showed the same trend of Hakel and decreased from 7.8 to 7.7.

This small difference could be due to the low fire intensity that lead to absence/poor understory vegetation; Shaoqing *et al* (2010) discovered that the understory vegetation was relatively abundant, thus large amount of ash wound be produced when the forest was burned, leading to the rise of soil pH. Badía and Martí (2003) have shown that heating soil at 250-500 °C causes a decrease in pH.

Fig.16. Influence of the site on pH



Granged *et al*. (2011) recorded an increase of the soil pH approaching to 7, and decreased progressively, returning to pre-burn values during October–November (6 months after the fire). This behavior is in agreement with observations by several authors, who have reported the re-establishment of pre-burn pH values after periods varying in length. At Lapseki site soil changes persisted for 2 weeks following fire (Ekinci, 2006).

The pH recovery time in the burnt plots (Obeidat, Hakel and Batroun) has been relatively short (less than one year) and this is in agreement with Mataix-Solera (1999), Jordán *et al*. (2010a), and Pereira *et al*. (2010) who showed that there were rapid removal of ashes by wind or rainfall after less than six months. It must be noted that the first samples collection was done one year after the fires in all sites even with the Hakel plot burned twice.

Ubeda *et al.* (2005) found that pH from calcareous soils returned to pre-fire values in shorter periods, just one year after the fire. In general, the increase in pH is temporary, since it is related to the pH before the fire, the amount of ash produced, the chemical composition of ash and moisture (Wells *et al*., 1979).

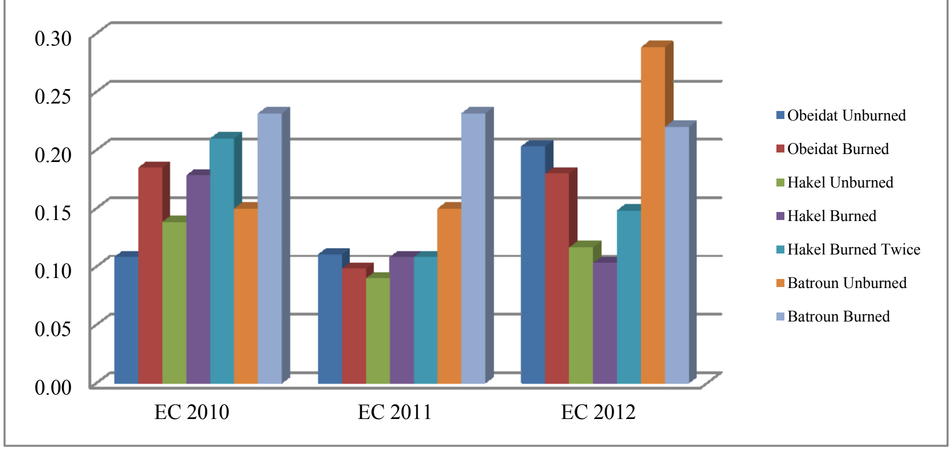
Our results are in accordance with Ulery (1993) who recorded a 5 unit increase in the pH after high intensity fires. This high increase may be related to the loss of \OH groups from clay minerals and oxide formation (Giovannini *et al*., 1990), as well as the release of soluble cations after combustion of organic matter; due to the recorded increase in the OM between unburned and burned plots of Obeidat, Hakel and Batroun and the low severity of the fire, there wasn't a significant difference in the pH.

4.3. Electrical Conductivity.

Concerning the samples collected from the burnt and unburned studied plots, the EC values varied between 0.09 during 2011 in the unburned site of Hakel 0.23 during the same year in the Burnt site of Batroun. The year parameter highly influenced the electrical conductivity. All the burned sites had a mean of electrical conductivity higher than the unburned sites with respectively 0.23 (Batroun), 0.16 (Obeidat) and 0.13 (Hakel). While the EC of the unburned sites were as follows: 0.2 (Batroun), 0.14 (Obeidat) and 0.12 (Hakel) (Fig.17). These results are in accordance to those of Certini (2005) who reported an ephemerally increase in electrical conductivity (Naidu and Srivasuki, 1994; Hernandez *et al*., 1997) as a result of the release of inorganic ions from the combusted organic matter.

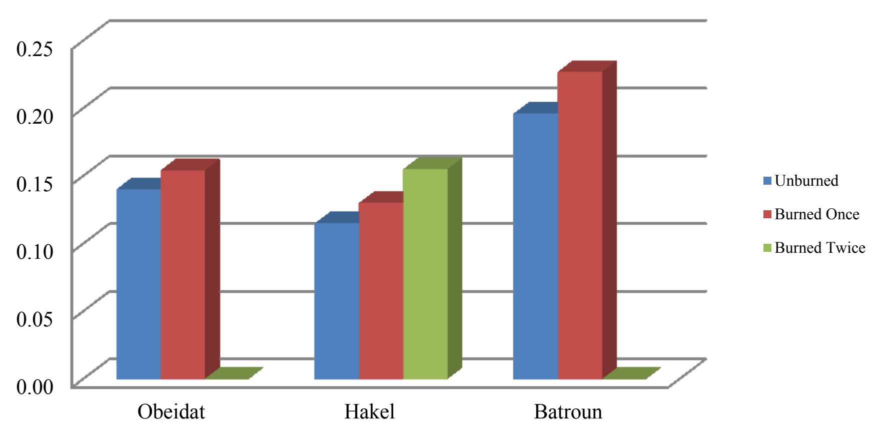
In Hakel site, the highest EC mean was recorded on the site that was burned twice with 0.15 followed by the site burned once with 0.13 and the unburned with 0.12.

Fig.17. Influence of time after fire on EC



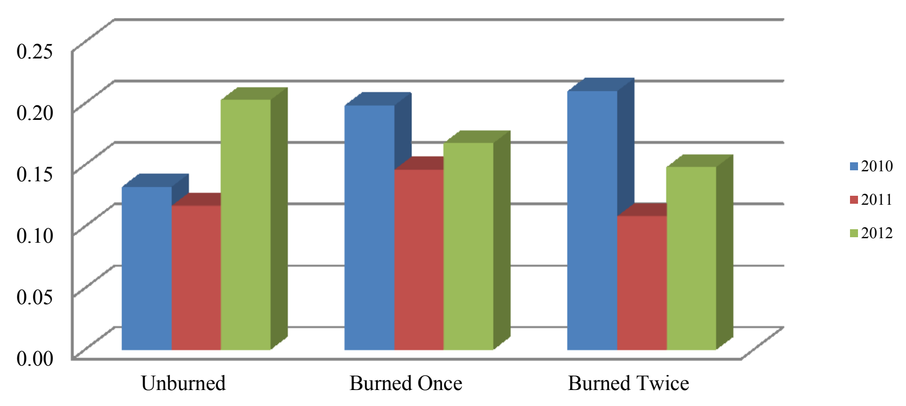
The site parameter highly influenced the EC (Tab.1). The highest recorded data was in Batroun sites, with 0.23 in the burned plot, while the EC didn't exceed 0.15 on the unburned plot while the lowest EC (0.12) was detected in the unburned plot of Hakel (Fig.18). Soil samples from burned sites had higher EC and pH values than un-burned control (Ekinci, 2006); this could be due to the release of ash and charcoal on the ground after the organic matter burning (Hernández *et al*., 1998). Ash contains the inorganic elements and base cations such as Ca^{2+}, Mg^{2+} and K^{+} in the ash leads to increased pH and EC (Ekinci, 2006).

Fig.18. Influence of the site on the EC



Electrical conductivity wasn't influenced by the status of plots and it varied between 0.12 and 0.21. All plots showed a decrease during the second year and were followed by an increase during the third year (Fig.19). Iglesias (2010) reported a non significant decrease of the EC for the first two layers and the reached values were below the unburned soil values. This could be due to precipitation reactions and leaching.

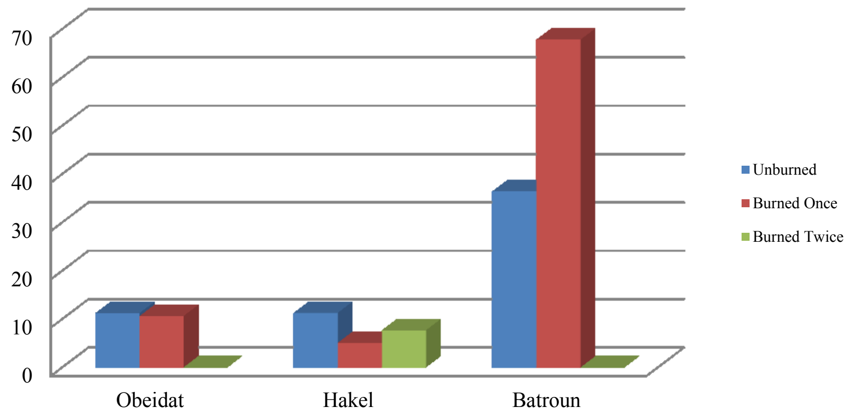
Fig.19. Influence of the status on EC between 2010 and 2012



4.4. Total $CaCO_3$.

The site highly influenced the total $CaCO_3$, and significant differences were recorded between plots. The amount ranged in the case of burned plots between 5.1% (Hakel) and 67.8% (Batroun) while in the unburned plot, $CaCO_3$ varied between 11.2% (Obeidat) and 36.4% (Batroun) (Tab.2; Fig.20). The increase in the $CaCO_3$ of Batroun plots (36.4-67.8%) results are in accordance with Campo *et al.* (2008) who showed that the $CaCO_3$ content increased significantly (45-50%) after two different fire intensities in Mediterranean soil; while Iglesias (2010) reported that there was no significant difference between the soil sites with regard to the content of $CaCO_3$.

Fig.20. Influence of the site on the total $CaCO_3$



Differences between the carbonates values within the same status were statistically significant at $p<0.05$ and it ranged between 17.4 and 22.1% in case of the unburned plots and between 6 and 10.1% in the plots burned twice. The lowest recorded difference was on the plots burned once and varied between 26.8 and 28.3% (Fig.21).

Tab.2. Influence of the year, site and status on the $CaCO_3$ and active Ca.

	Year		Site		Status	
	F	P	F	p	F	p
$CaCO_3$	0.209	0.812	221.989	0.000***	6.416	0.002*
Active Ca	0.793	0.455	325.779	0.000***	4.806	0.010*

*** indicates significant difference from initial value at $p<0.05$; *** indicates significant difference from initial value at $p<0.001$.**

Our results are in accordance of Parlak (2011) who reported a constant decrease of $CaCO_3$ as the temperature inclined; this variation was due to the loss of carbonates as CO_2. It is to note that carbonate is the main constituent of calcareous soils, and could resist temperatures up to 1,000ºC (Rabenhorst, 1988) and, thus, rarely undergo fire induced changes (Certini, 2005).

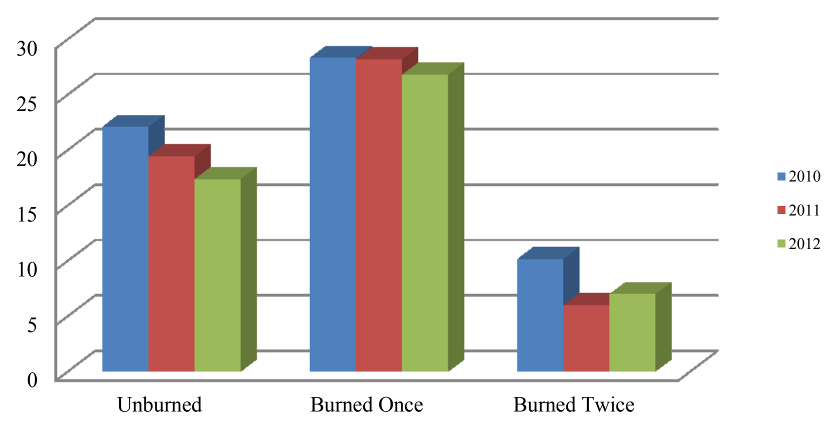


Fig.21. Influence of the status on the total $CaCO_3$

4.5. Active $CaCO_3$.

Concerning the active $CaCO_3$, it was highly influenced by the site and decreased from 3.1% to 2.8% in Obeidat, and from 11.3% to 5.1% in Hakel; only Batroun sites showed an increase in the active carbonate amount (11.2-16.1%); while the year parameter didn't have any influence (Tab.2; Fig.22).

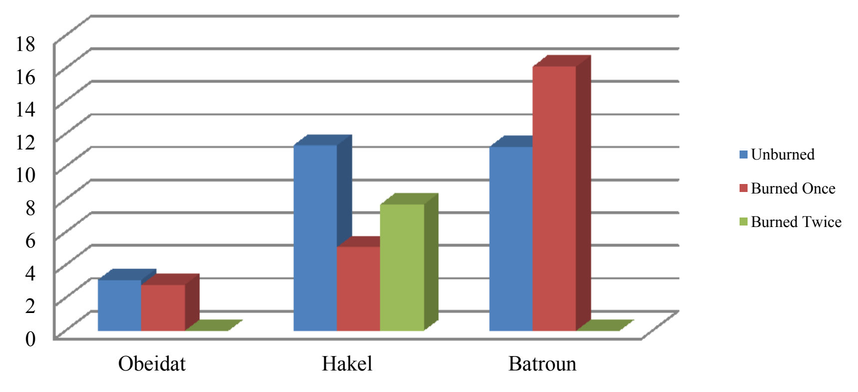


Fig.22. Influence of the site on active carbonate

The status of plots were statistically significant at $p<0.01$ and varied between 1.83 (Hakel burned twice) and 6.56 (unburned plots); during the second year of the experiment, all the plots showed a decrease in the active carbonate and this was for all studied status (unburned, burned and burned twice) (Tab.2; Fig.23).

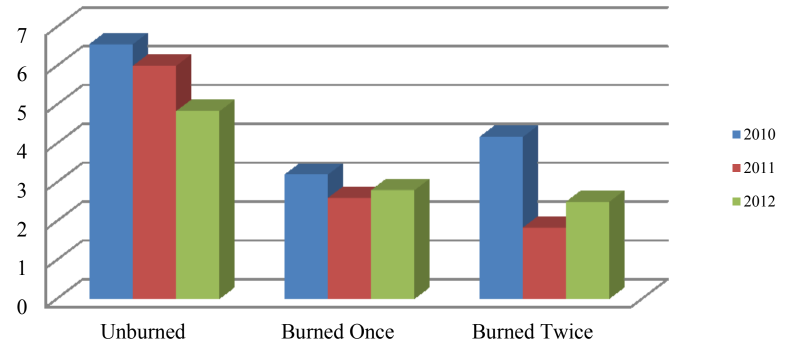


Fig.23. Influence of status on active carbonate between 2010 and 2012

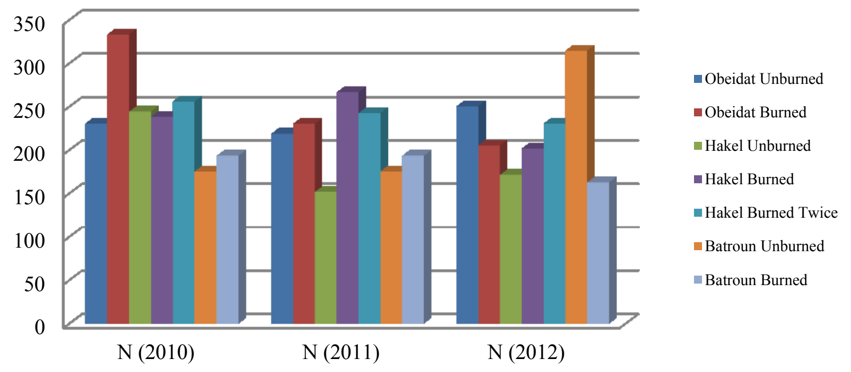
4.6. Nitrogen.

The effect of forest fires on N availability is important because N availability is one of the most common limiting factors to forest productivity worldwide (Ekinci, 2006). Nitrogen is unique because it is the only soil nutrient that is not supplied to the soil by chemical weathering of parent rock material. Almost all N found in the vegetation, water, and soil of wildland systems has to be added to the system from the atmosphere *(DAFS, 2005)*. Concerning the availability of nitrogen in the studied plots, neither the number of years nor the status influenced it. The highest content of N was detected in the burned plot of Obeidat with 333.5 Kg/ha (Pict.5) while the lowest (152 Kg/ha) was recorded in the unburned plot of Hakel.

Pict.5. Highest vegetative growth in Obeidat

All the burned sites showed a decrease in the N content after the fire when passing from year to another; the highest consumption of N was in the Obeidat plot with 38.4% and passed from 333.5 Kg/ha to 205.7 Kg/ha. The lowest decrease was observed on the plot of Hakel (burned twice) with 10% (Tab.3; Fig.24).

Fig.24. Influence of time after fire on Nitrogen



Our results are in accordance with Shaoqing *et al*. (2010) who discovered that no significant changes were found in 10–40 cm soil layer concerning the total soil nitrogen, phosphorus, potassium while, all these parameters increased notably in 0–10 cm soil layer. Covington and Sackett (1986) observed that higher mineral N was due to a decreased uptake caused by root mortality at the surface.

Tab.3. Influence of the year, site and status on nitrogen and phosphorus content.

	Year		Site		Status	
	F	P	F	p	F	p
N	1.562	0.214	3.084	0.049*	1.034	0.359
P	3.41	0.036*	9.989	0.000***	1.135	0.325

*** indicates significant difference from initial value at p<0.05; *** indicates significant difference from initial value at p<0.001.**

As mentioned before, the status didn’t influence the availability of N, however it increased gradually when passing from unburned to burned (once and twice) plots. The detected concentrations varied between 182.2 Kg/ha (unburned 2011) and 284.6 (burned once 2011).

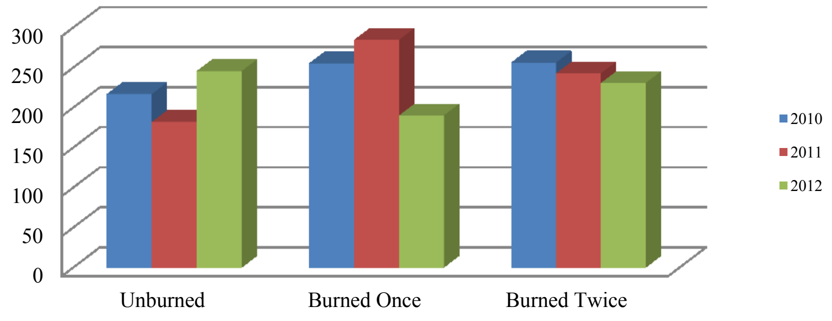
Several studies have found either total N decreases or increases with interval burning in different forest types. These results are in accordance with Alban (1977) who found no difference in total N among plots burned annually, biennially, and controls in red pine (*Pinus resinosa* Ait.) (Covington and Sackett, 1986).

The N concentrations decreased in the unburned (217-182%) and burned twice plots (256-231%); while in plots that was burned once; an increase was recorded during the second year of the project (2011) and passed from 255 to 285% (Fig.25). The latter was also observed by Certini (2005) who found that nitrate concentrations weren't affected immediately but 1 year after burning they had become dramatically higher than the pre-fire level. After fire, the increased mineralization rate in the soil could lead to an increase in biological N fixation (Ekinci, 2006).

Our results are in accordance with Moehring *et al.* (1966) who compared plots of mixed shortleaf pine (*Pinus echin*ata Mill.) and loblolly pine (*Pinus taeda* L.), that had been burned annually and biennially, with unburned plots and found that there was no significant difference in total N among any of the plots.

The increase in the burned plots was followed by a decrease during the third year of the experiment. Certini (2005) also found that five years after burning, the increase of nitrogen had disappeared. Grogan *et al.* (2000) assessed that the $NH4^+$ pulse generated by a severe wildfire in a mature forest of P. muricata was dissipated by the end of the second growing season (Certini, 2005). Iglesias (2010) found significant differences in the first layer (10-15cm) for N content between burned and unburned soils, whereas N content in another burned soil has returned to pre-fire levels.

Fig.25. Influence of the status on the availability of Nitrogen



While, the observed results contradicts Covington *et al*. (1991) who found that fire caused an immediate strong increase in soil ammonium in a Pinus edulis and Juniperus spp. Stand.

Different site influenced significantly the availability of N (statistically significant at $p<0.01$). Obeidat and Hakel acted similarly and the amount of N in burned plots was higher than the unburned plots. It increased from 233.5 to 256.6Kg/ha (9.9%) in Obeidat and from 189.4 to 236Kg/ha (24.5%) in Hakel (Tab.3; Fig.26). Several mechanisms may be involved in causing increased soluble N following burning. Both $NH4^+$ and $NO3^-$ can be produced directly by burning; $NH4^+$and $NO3^-$ may be leached into the mineral soil from the residual ash and forest floor (Covington and Sackett, 1986). This increased N availability enhances post fire plant growth, and gives the impression that more total N is present after fire. Any temporary increase in available N following fire is usually quickly utilized by plants within the first few years after burning (DAFS, 2005).

The nitrogen increase in burned plots could be attributed to increases in the bacteria species fixing nitrogen as a result of an increase in mineralization in a short period after forest fire. So this resulted in more nitrogen in the soil (Ekinci, 2006) which will enhance the under storey propagation that was observed in burned plot of Obeidat (Pict.6).

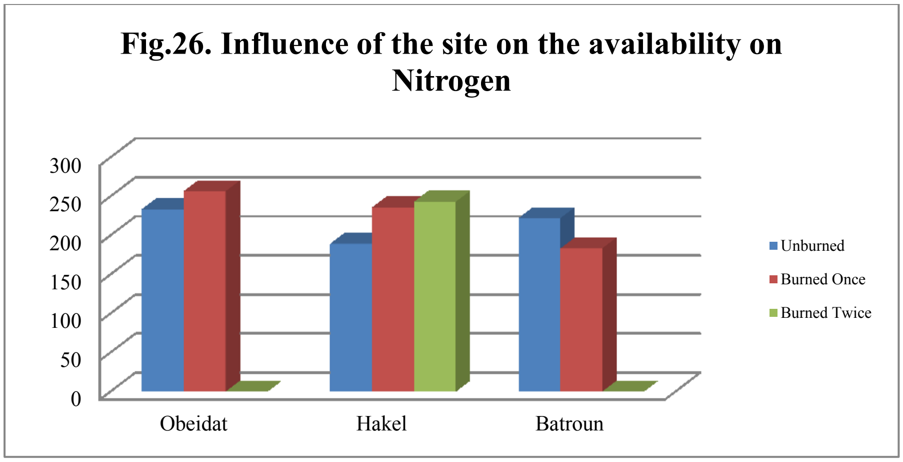


Fig.26. Influence of the site on the availability on Nitrogen

Pict.6. Under storey vegetation

The exception was the burned plot of Batroun, where the amount of N decreased from 222.1 to 183.4 Kg/ha (17.4%) (Fig.26). This result is similar to the one observed by Knight who figured that soil nitrogen decreases after burning, and the decrement varies with different heated level of soil (Shaoqing *et al*., 2010).

Depending on the ecosystem, the frequency and severity of fire; increase, decrease or non-variation in total soil N content have been reported; on the other hand, most authors found an increase in the ammoniacal N content immediately after burning, which is maintained for several months or, in some cases, is followed by an increase in the nitrate content (Ekinci, 2006).

4.7. Phosphorus.

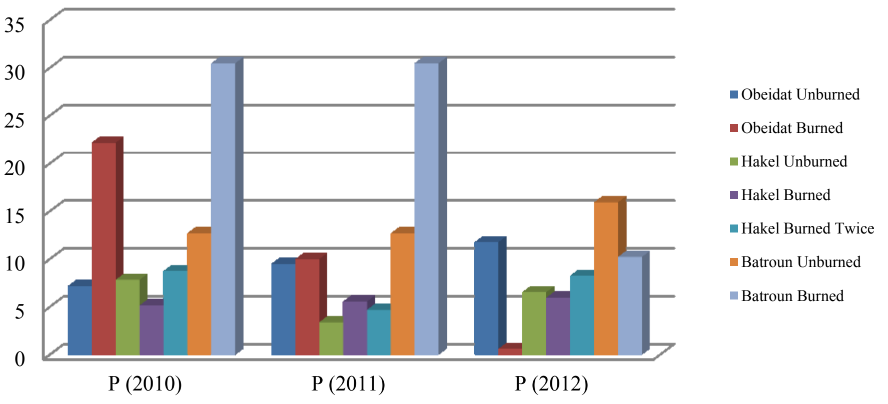
Phosphorus is the second most limited nutrient found in natural ecosystems. The combustion of organic matter leaves a relatively large amount of highly available P in the surface ash found on the soil surface immediately following fire (DAFS, 2005).

The year parameter influenced significantly the phosphorus amount in the different studied plots (Tab.3). In the unburned Obeidat and Batroun plots, the phosphorus content increased between 7.2 and 11.8ppm for the first and between 12.7 and 15.9ppm for the second; while in the same regions, but in the burned plots the phosphorus content decreased and varied 22.2 and 0.63 in Obeidat plot and between 30.5 and 10.2 in Batroun plot (Fig.27).

The plot that was burned twice had the same trend of the other burned plots and decreased from 8.7 to 8.2ppm. Shaoqing *et al*. (2010) showed that possible mechanism for the decrease of soil phosphorus might be soil phosphorus loss in the form of fine ash particles. Spatial and temporal differences exist to these changes in soil due to the complicated influences of soil type, soil moisture, fire intensity and fire duration.

Concerning the Hakel plot that was burned once, the phosphorus content increased from 5.2 during 2010 and reached 5.9 in 2012 (Fig.27). This increase is in accordance with DeBano (1991) who reported that plants and plant residues turn back to the soil as ash following fire. If it is not carried out from soil by wind or run off, it will stand in the soil and increase soil P contents (Ekinci, 2006).

Fig.27. Influence of time after fire on Phosphorus



The change of soil P content generally depends on soil temperature during the fire and tends to increase in burned soils (Kutiel and Shaviv, 1993). The high amount of phosphorus in the burned plot of Obeidat during 2010 (22.2ppm) is positively correlated with the pH (6.97). Sharpley (2000) showed that the peak of P bioavailability being around pH 6.5, any fire-induced change in soil pH toward neutrality has a positive effect in this regard.

The soil P values of burned soil were higher than unburned control, but no significant difference was recorded. This result contradict the results of Ekinci (2006) who detected a significant difference between the unburned and burned sites at p<0.01 after 2 week following fire. The phosphorus content varied between 8.5 and 11.4ppm in the unburned plots while this content increased to reach 19.3ppm in the burned plots during the first year after fire (Tab.3; Fig.28).

Our results are in accordance with Iglesias (2010) who showed that the available P content didn’t show a significant increase in layer 2 after fire; while a significant difference was recorded in the first layer of the unburned and burned plots and also in twice burned soil.

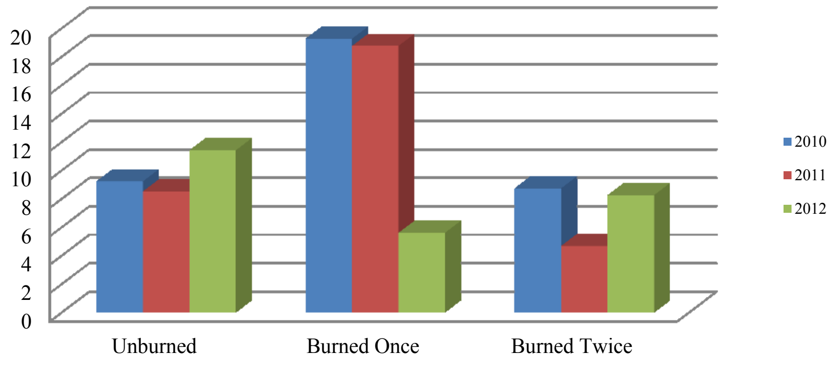


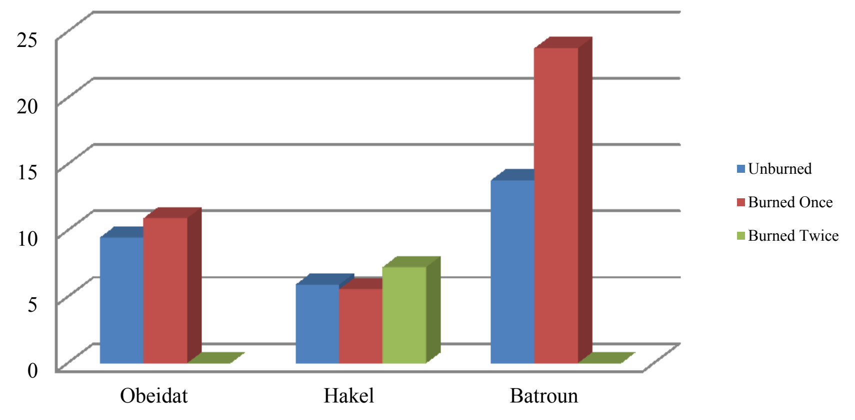
Fig.28. Influence of the status on the availability of Phosphorus

Fires result in an enrichment of available P, but this enrichment is destined to decline soon. The decline of phosphorus in the burned plots during 2011 could be due to its binding to Ca-minerals or precipitates as discrete Ca-phosphate in neutral or alkaline soils while in acid soils orthophosphate binds to Al, Fe, and Mn oxides through chemisorptions (Certini, 2005).

Concerning the site, it highly influenced the phosphorus with the highest recorded content (23.7ppm) and increases (72%) in the burned plot of Batroun region; followed by Obeidat region with respectively 10.9ppm and 15% (Fig.29). An increase in available P may be due to the combustion of organic P and to mineralization occurring as a result of the high temperature reached during the fire (Iglesias, 2010).

In a Picea dominated forest, Macadam (1987) even found that 9 months after slash burning, available P in the upper 30cm mineral soil had increased by up to 50% and this increase persisted, although somewhat diminished, 21 months after the fire event.

Fig.29. Influence of the site on the availability of Phosphorus

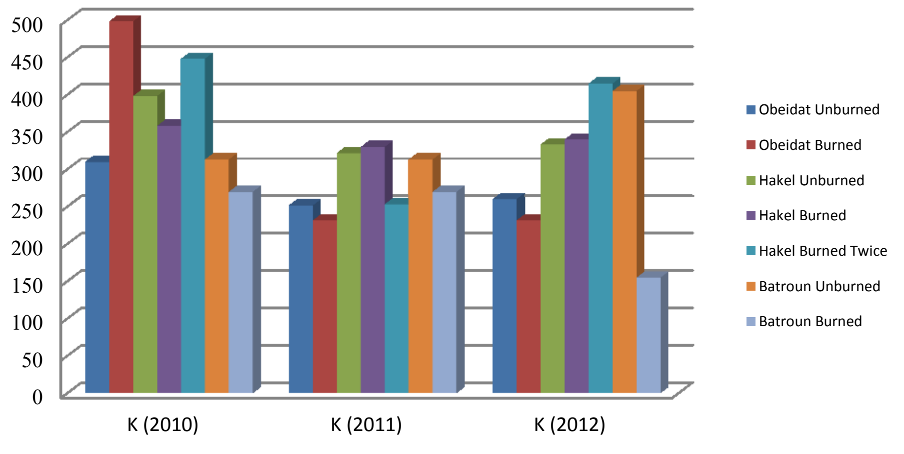


Forest fires have not necessarily the same impact on soil N as on P, because losses of P through volatilization or leaching are small (Certini, 2005). Nevertheless, the combustion of vegetation and litter cause's impressive modifications on biogeochemical cycle of P. Phosphorus is lost at a higher temperature during soil heating, and only about 60% of the total P is lost by when organic matter is totally combusted (DAFS, 2005); due to the low and medium intensity fire that took place in the studied plots of Obeidat, Hakel and Batroun, the temperature didn't reach the amount where the phosphorus could be lost at high quantities.

4.8. Potassium.

Potassium content was influenced significantly (at $p<0.001$) by the year and varied between 498 and 155mg/kg in the burned plots while the difference between the unburned plots was less and varied between 251 and 155mg/kg. In all burned region, the potassium had a decrease trend and the loss reached 53.5% in Obeidat region, followed by Batroun region 42.6%. The lowest recorded loss was in Hakel region with 5.1% (Tab.4; Fig.30). The fire directly affects K and P availability of soil by chemically altering of these elements and indirectly by altering soil temperature, pH, and water flow (Ekinci, 2006).

Fig.30. Influence of time after fire on Potassium



No significant influence was recorded concerning the status of the site and the burned and unburned plots acted similarly. Potassium content of burned plots was higher than that of unburned soils. The lowest recorded difference was on the burned plots with 12.4%. The highest amount of potassium was observed 448 mg/kg during 2010 while the lowest was 242.2mg/kg in the once burned plots during 2012 (Fig.31). Our results contradict De Ronde (1990) who reported that K content was significantly higher in burned forests 21 months after fire.

The increase between the unburned and burned plots (Fig.31) was also observed by Yao *et al.* (2008) who found that soil total and available nitrogen, phosphorus, potassium increased in Juglans mandshurica plantation after burning.

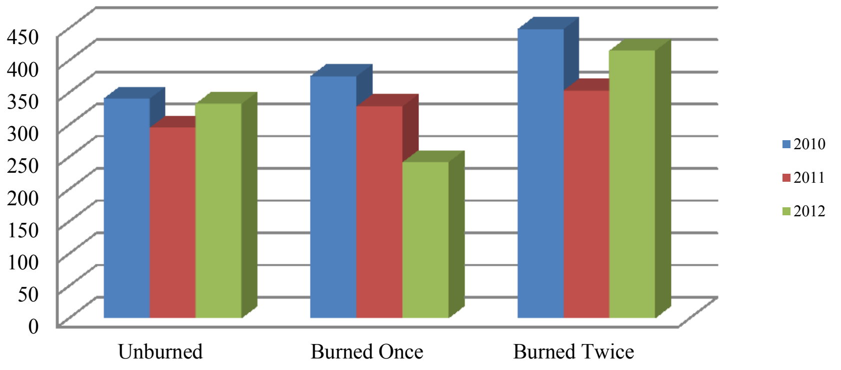


Fig.31. Influence of the status on the availability of Potassium

The site influenced significantly the availability of potassium and the highest detected contents in the burned and unburned sites were in Obeidat plots with respectively 256 and 233mg/kg. The plot that was burned twice recorded the highest amount of potassium in Hakel region with 243mg/kg. For the Batroun region, potassium was higher in the unburned plot with 222mg/kg while the burned plot recorded 183mg/kg (Tab.4; Fig.32).

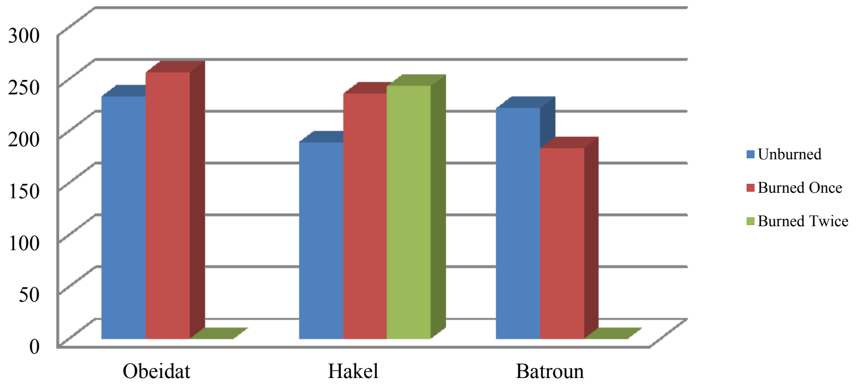
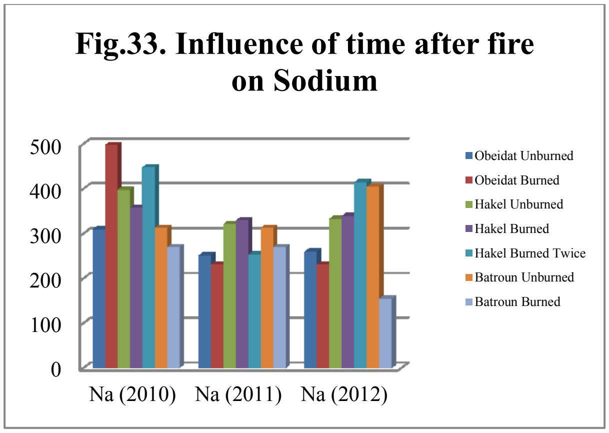


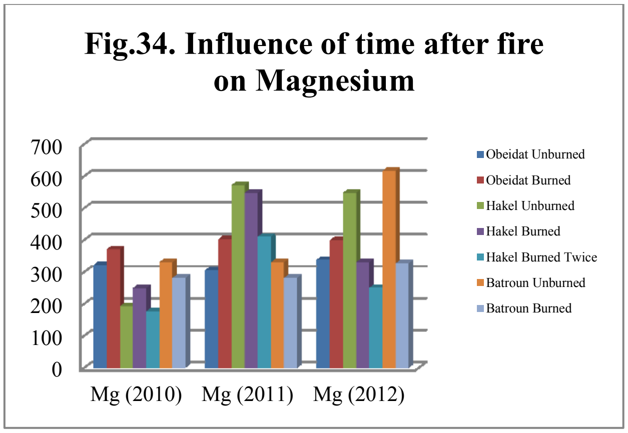
Fig.32. Influence of the site on the availability of Potassium

4.9. Cations.

Cations found in the soil that are affected by fire include Na, Mg, Ca, and ammonia (NH4) although these cations are not usually deficient in most wild land soils (DeBano, 1991). The availability of these nutrients generally is increased by the combustion of soil organic matter and the increase is strictly dependent upon type of nutrient, burnt tree species, soil properties, and pathway of leaching processes (Kutiel and Shaviv, 1993).

The year parameter highly influenced all the studied cations (Na, Mg, Ca and Fe) who responded differently from each others. For the Sodium, all the burned plots showed a decrease and varied between 498.3 and 231.7 (53.5%) for Obeidat, followed by Batroun with 42.6% and Hakel 5.1%; the loss in Hakel burned twice was higher with 7.4%. One year after the fire, all the studied plots showed an increase in the Magnesium content and was respectively 32.5%, 16.1% and 7.6% in Hakel, Batroun and Obeidat. The plot of Hakel that was burned twice recorded the highest increase with 41.8% (Fig.33 and 34).





Calcium acted similarly to the magnesium content after fire. The increase reached 41.5% in case of Batroun that varied between 3266 and 4624ppm, while the lowest recorded content was in Hakel with 5.7% increase. Concerning the Iron, all the content decreased ephemerally in all the studied plots but the biggest loss was recorded on the Hakel site (burned once and twice) with respectively 99.3 and 99.4% (Tab.4; Fig.35 and 36).

Fig.35. Influence of time after fire on Calcium

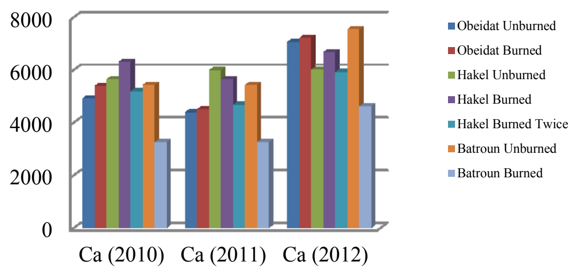
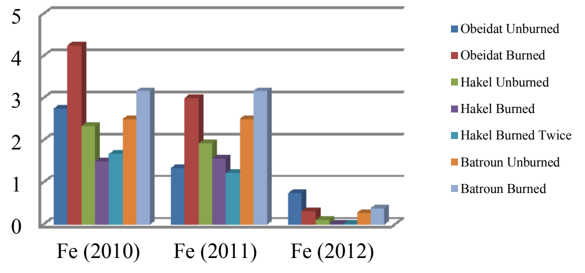


Fig.36. Influence of time after fire on Iron



Although these readily available monovalent and divalent cations probably do not materially affect plant growth directly, their amount and composition determines base saturation, which plays an important role in controlling the pH regimes in soils (DeBano *et al*., 1998).

Tab.4. Influence of the year, site and status on potassium, sodium, magnesium and calcium content.

	Year		Site		Status	
	F	P	F	p	F	p
K	5.809	0.004**	3.890	0.023*	2.299	0.105
Na	68.998	0.000***	9.199	0.000***	0.594	0.553
Mg	7.164	0.001**	0.018	0.982	2.630	0.076
Ca	25.842	0.000***	5.539	0.005**	3.638	0.029*
Fe	75.417	0.000***	7.222	0.001**	3.605	0.030*

*** indicates significant difference from initial value at $p<0.05$; ** indicates significant difference from initial value at $p<0.01$; *** indicates significant difference from initial value at $p<0.001$.**

The status only influenced significantly the calcium and iron ($p<0.05$), while the magnesium and sodium acted similarly. During the first two years of the experiment, the sodium decreased in the studied plots (burned and unburned). The biggest recorded decrease (50.4%) was in the burned twice plot of Hakel and the content passed from 205 to 81.7ppm which is lower than the recommended quantity in normal soil that should be 100ppm. All the sodium amounts at the end of the experiment were lower with respectively 98.3ppm in the unburned plots and 82.8ppm in the burned plots (Fig.37).

The magnesium content increased during the three years of the experiment in the unburned plots, while in the burned plots, the content increased during the first (2010) and second year (2011) and then decreased in 2012. The highest content in the magnesium was recorded during 2011 on the burned plot with 520.5ppm while the highest increase was detected on the plot of Hakel that was burned twice with 232% (from 177 to 411.5ppm) (Fig.38). The lowest increase was in the unburned sites with 42.8%. This is in accordance with Soto and Diaz-Fierros (1993) who detected a significant increase in soil cation concentration following either prescribed burning or a wildfire (DAFS, 2005).

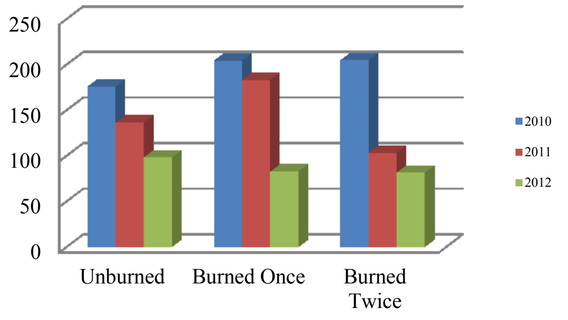


Fig.37. Influence of the status on the availability of Sodium

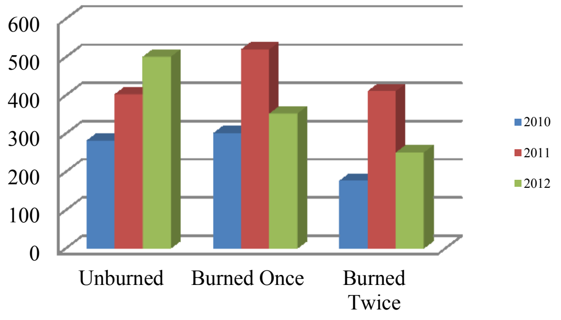


Fig.38. Influence of the status on the availability on Magnesium

For the calcium content, a significant difference was detected and the highest observed raise was on the burned plots with 20.6% while in the two others status, the amount decreased respectively by 1.2% in the unburned plots and 10% in the burned plots of Hakel. The content varied between 4680 and 6879ppm (Tab.4; Fig.39).

Concerning the iron which was also influenced by the status, the content ranged between 0.01 and 2.97ppm in different burned plots. These amounts are lower than the recommended quantity which is 10ppm. Iron in all studied sites decreased when passing from one year to another and reached their lowest contents during the third year of the experiment with respectively 0.37, 0.24 and 0.01ppm (Fig.40).

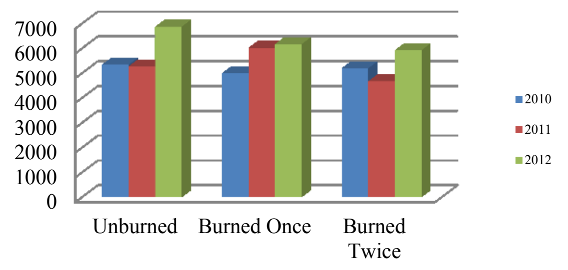


Fig.39. Influence of the status on the availability of Calcium

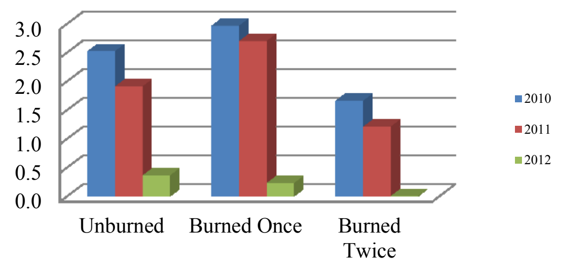


Fig.40. Influence of the status on the availability of Iron

Magnesium is the only cation that wasn't influenced by the site parameter. It ranged between 280 and 438.4ppm one year after fire (Fig.42). This result contradicts the ones of Iglesias (2010) who observed significant differences in the first two layers regarding the Mg, between burned and unburned soils, which was probably due to deposit from ash.

Sodium was highly influenced by site and varied between 99.4 (Hakel) and 143.3ppm (Batroun) (Tab.4; Fig.41).

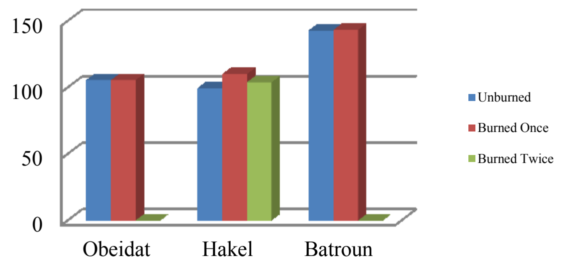


Fig.41. Influence of the site on the availability of Sodium

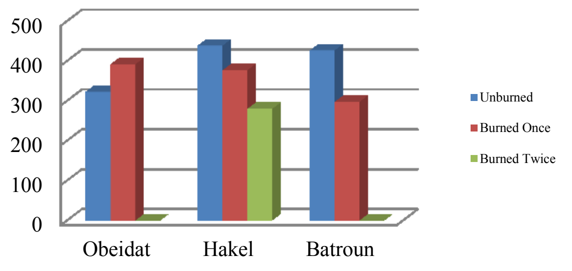


Fig.42. Influence of the site on the availability on Magnesium

Calcium and iron was highly influenced by the site parameter. The best recorded amount of the first was in Hakel with 6223.5ppm while the lowest was in Batroun with 3719ppm. The slight increase in the calcium content (4.5-5.6%) was also observed by Iglesias *et al.* (1997) who concluded that an increase was more obvious shortly after the fires and that was due to the release of Ca from plant material (Fig.43 and 44).

For the iron content, the maximum amount was reached during the first year after the fire in Batroun. The lowest content 0.96 was detected in the plot of Hakel that was burned twice.

Cations have high temperature thresholds and, as a result, are not easily volatilized and lost from burned areas. The ash deposited on the soil surface during a fire contains high concentrations of cations, and their availability is increased (DeBano *et al.*, 1998).

Fig.43. Influence of the site on the availability of Calcium

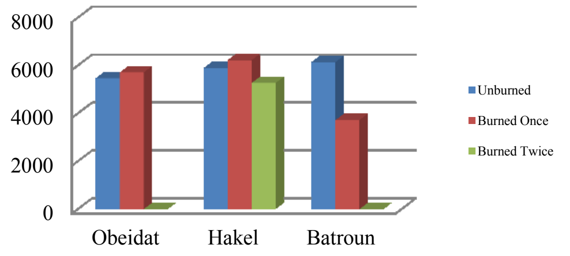
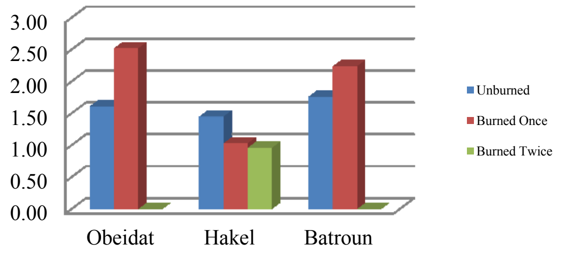


Fig.44. Influence of the site on the availability of Iron



Our results are in accordance with Certini (2005) who showed that concentrations of cations, such as Ca^{2+}, Mg^{2+}, and K^+ increase considerably in the soil solution immediately following burning (Khanna and Raison, 1986). On Aleppo pine forests, increases in exchangeable Ca^{2+} were also observed in the first layer Ulery *et al*. (1993).

4.10. Soil Texture.

Soil texture is based on the relative proportion of different-sized inorganic constituents that are found in less than 2mm mineral fraction of the mineral soil (DeBano *et al.*, 1998). The components of soil texture (sand, silt, and clay) have high temperature thresholds and are not usually affected by fire unless they are subjected to high temperatures at the mineral soil surface (DAFS, 2005).

Number of years didn't influence the soil texture and different components of Lime, Clay and Sand acted similarly. The silt content varied in the burned plots between 25 and 34%; while in the unburned plots, the difference was lower and varied between 26.7 and 32.7%. The highest increase in the silt content was recorded on the plot of Hakel that was burned twice with 15.4% (30.33 and 35%). The silt decreased in the burned plots of Batroun and Obeidat; the detected losses were respectively 17.65 and 8% (Tab.5; Fig.45).

For the clay, the highest detected content (57.7%) and increase (17.3%) was observed during 2012 in the burned plot of Obeidat; while the lowest (33.3%) was observed on the Burned plot of Batroun (Fig.47). According to DeBano *et al*. (2005), the most sensitive textural fraction is clay. Temperatures near 400°C can affect the structure and hydration of clays, and complete destruction occurs at 700–800°C (Granged *et al*., 2011).

Concerning the sand, it varied between 18.9 and 19.2% while the highest increase (13.2%) was detected on the burned plot of Batroun. The Obeidat and Hakel sand content decreased in the burned plot and the loss was 15 and 22.5% of its total content (Fig.46).

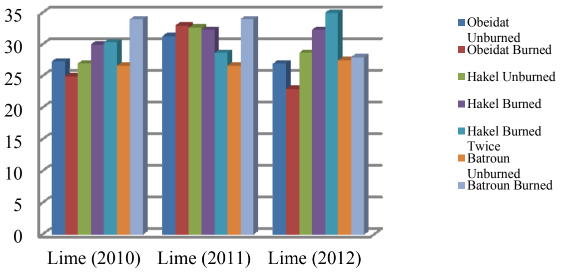


Fig.45. Influence of time after fire on Silt content

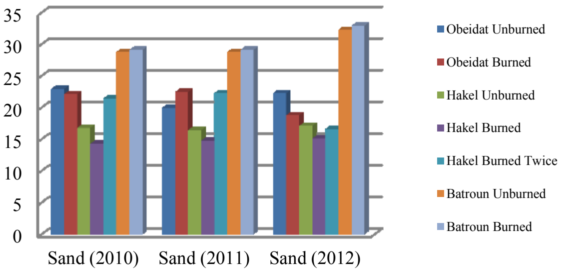


Fig.46. Influence of time after fire on Sand content

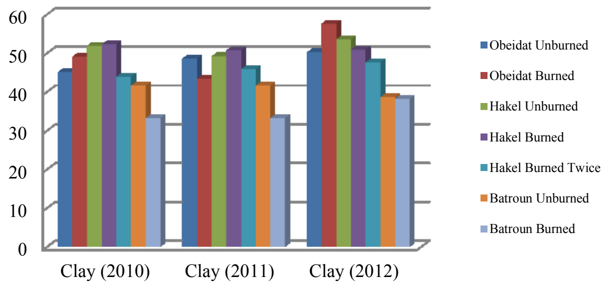


Fig.47. Influence of time after fire on Clay content

Concerning the site influence, highly significant differences were observed in sand and clay content from control plots (Tab.5). Sand ranged between 14.8 to 20.2% within the Hakel sites (unburned, burned once and twice); while between sites, the sand content varied between 14.8 and 30.4% (Fig.49); for the clay content the lowest (35%) was recorded in the burned plot of Batroun while the highest (51.7%) was detected in the burned plot of Hakel (Fig.48); this difference could be attributed to spatial variations. This difference was also observed by Granged *et al*. (2001).

Texture variations were too small at different studied plots, where the sand content decreased slightly from 21.7 to 21.2% in Obeidat, 16.8 and 14.8% in Hakel; the increase in sand content in Batroun from 30 to 30.4% could be attributed to the post-fire erosion processes (Pict.7), favoring the detachment and transport of fine particles (clay and silt) from burnt less-stable aggregates.

Pict.7. Post-fire erosion

The mean clay content decreased from 40.6 to 35% (14%) in Batroun plots while no detected difference was observed on Hakel plots; a small increase was recorded in Obeidat region and varied between 48.1 and 50.1%. When decreased, Clay content from Batroun plots showed a behavior similar to the one observed by Granged *et al*. (2011) who detected a non significant decrease (17%) between unburned and burned plots and ranged between 12.3 and 14.8%.

Concerning the silt, its content increased slightly after fire, from 29.4 and 31.5% at Hakel plots and 26.9 and 32% at Batroun sites. No significant differences were detected (Tab.5; Fig.50).

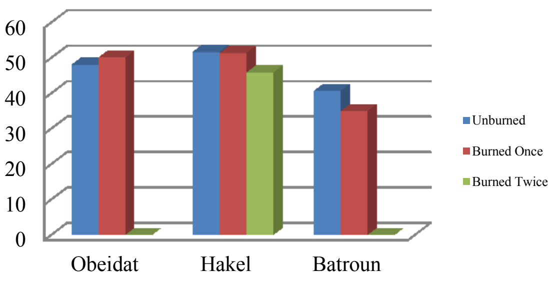


Fig.48. Influence of the site on Clay content

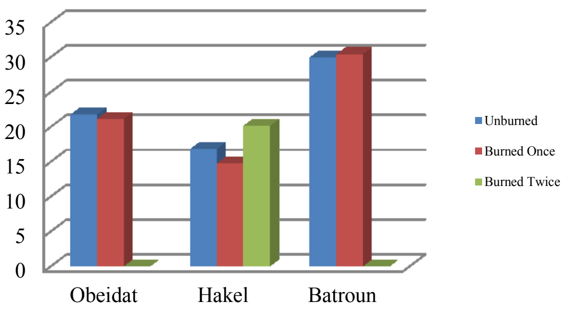


Fig.49. Influence of the site on the Sand content

In general, after the passage of fire, a trend to coarser soil textures is observed. It is due to some extent to a heat induced formation of stable aggregates from clay and silt fractions (Ulery and Graham, 1993; Ketterings *et al*., 2000). Particle-size distribution is not directly affected by fires (Oswald *et al*., 1999) but, on steep surfaces, selective removal of the fine fraction through erosion can lead to soil coarsening (Mermut *et al*., 1997).

Fusion of quartz materials (sand, silt and clay) occurs only at extreme temperatures (above 2500°C), leading to coarser texture and more erodible soils (DeBano *et al*., 2005), but this process is not common after low and medium intensity burning.

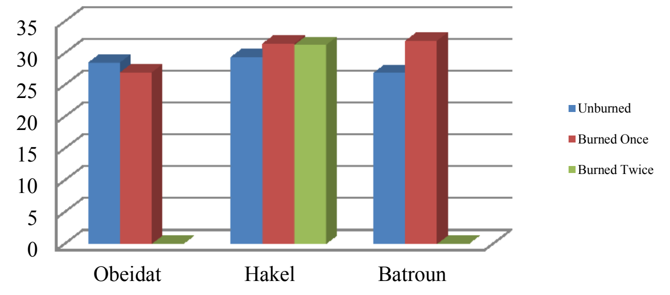


Fig.50. Influence of the site on the Silt content

Tab.5. Influence of the year, site and status on clay, silt and sand content.

	Year		Site		Status	
	F	p	F	p	F	p
Clay	8.259	0.081	84.816	0.000***	5.641	0.023*
Lime	4.594	0.083	1.888	0.202	2.647	0.120
Sand	0.078	0.926	31.266	0.000***	2.283	0.152

*** indicates significant difference from initial value at p<0.05; ** indicates significant difference from initial value at p<0.01; *** indicates significant difference from initial value at p<0.001.**

Concerning the studied parameters, all soil components acted similarly. Soil texture from different plots did not vary significantly during the three years of the experiment, but at the end of the study, texture became coarser (Tab.5). This result is similar to the one observed by Granged *et al*. (2011). On average, clay and sand contents decreased during 2010 in burned plots (clay: 46 to 44%; sand: 22.9 to 21.5%) while silt increased from 27 to 30.3% (Fig.51, 52 and 53). A decrease in clay content, from 13.2±3.3 to 10.8±4.5%, was also observed by Granged *et al*. (2011).

Fig.51. Influence of the status on Clay content

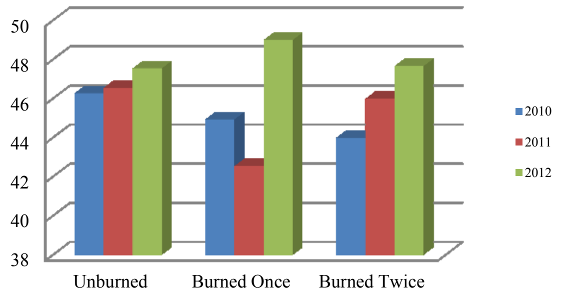


Fig.52. Influence of the status on Sand content

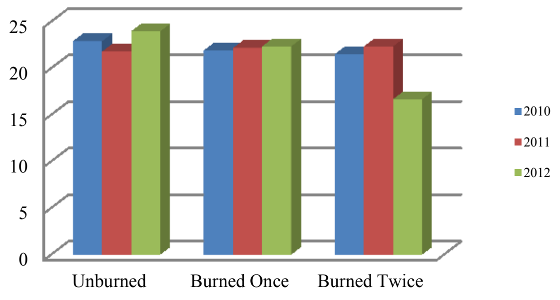
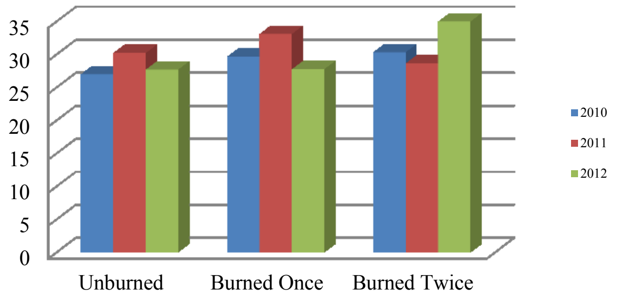


Fig.53. Influence of the status on the Silt content



4.11. Vegetative growth after fire.

Plant species have evolved contrasting strategies for persisting in fire-prone environments, which can be by seedling establishment, resprouting (Pict.8) or a combination of both (Barton, 1999). Plants may sprout soon after a fire or not until the following spring if the fire occurs after the plants have become dormant (Miller, 1978). The response of vegetation to fire depends on its characteristics before fire, the season when fire occurs, the intensity of fire and the concentration of ash, weather parameters, the physical-chemical alterations of soil due to fire and the animal populations associated with the habitat (Oliveira and Fernandes, 2009); when basal cambial tissue is seriously damaged by fire, injuries often permit the entry of insects or decay that may ultimately kill the tree.

Pict.8. Resprouting after fire

All the studied parameters influenced significantly the elongation of the twigs. Concerning the collection date, it increased from one collect to another and reached its longest measure during July with respectively 7.05cm and 5.85cm in the burned and unburned plots. The difference between the burned and unburned plots could be due to the higher concentration of the fixing bacterial nitrogen after the fire that enhances the vegetative propagation (Tab.6; Fig.54; Pict.9).

Tab.6. Influence of the date, site and status on the twigs elongation during the growing seasons of 2012.

	Date		Site		Status		Repetition	
	F	P	F	p	F	P	F	p
Elongation of the twigs	10.834	0.000***	9.392	0.001**	36.574	0.000***	1.086	0.451

**** indicates significant difference from initial value at p<0.01; *** indicates significant difference from initial value at p<0.001.**

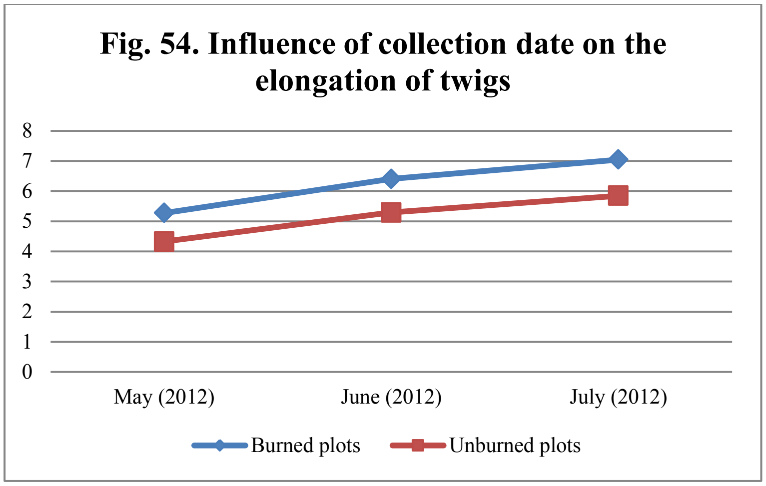
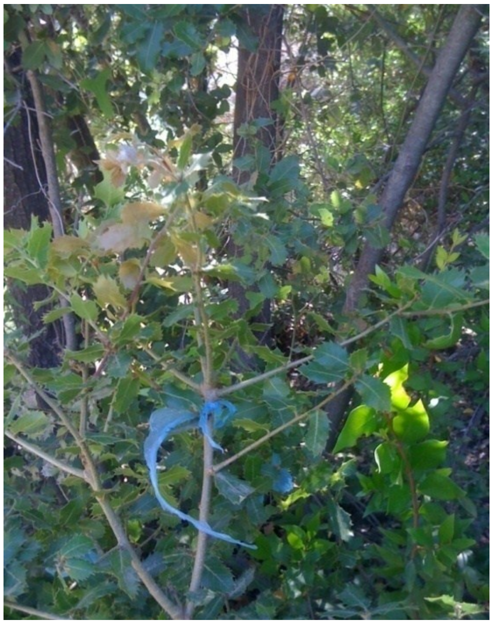


Fig. 54. Influence of collection date on the elongation of twigs

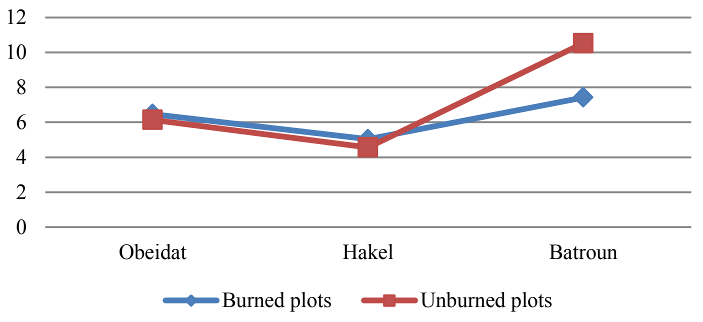
Similar to the collection date, the site influenced the length of the twigs and varied between 4.57 and 10.53cm in the unburned plots while the length varied between 5.03 and 7.43cm in the burned plots.



Pict.9. Longest twig in the burned plot of Obeidat

The longest twigs were recorded in the burned plots was the one of Batroun (7.43cm) followed respectively by Obeidat (6.47cm) and Hakel (5.03cm) (Fig.55; Tab.6; Pict.). Even though the natural regeneration of vegetation varies significantly among areas and with time of the year as a result of these factors, the capacity and speed of recovery of a burned area greatly depends on the regeneration strategy of the species present before the occurrence of fire (Calvo *et al.*, 2003).

Fig.55. Influence of the site on the elongation of twigs



A significant difference was also observed between the burned and unburned plots (Tab.7). The longest twig (19cm) was detected during the third measure of 2012 (July) in the burned plot of Batroun while the lowest (1cm) was observed on the burned plot of Hakel on the sixth studied sample.

Similar to the length of twigs, the number of newly developed leaves was also influenced by all the studied parameters (Tab.7).

Tab.7. Influence of the date, site and status on the newly developed leaves during the growing seasons of 2012.

	Date		Site		Status		Repetition	
	F	p	F	p	F	P	F	p
Newly developed leaves	32.735	0.000***	14.183	0.000***	8.804	0.01*	0.821	0.642

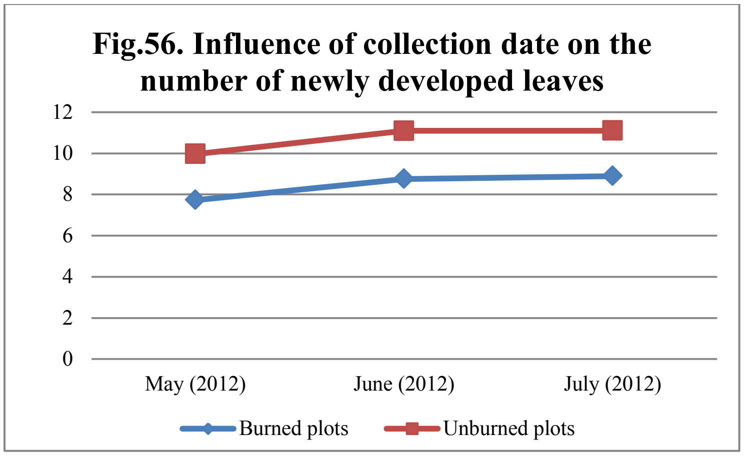
*** indicates significant difference from initial value at $p<0.05$; *** indicates significant difference from initial value at $p<0.001$.**

Season highly influenced the vegetative propagation. The unburned plots recorded the highest number of leaves (11.1) during July 2012, while the number of leaves didn’t exceed 8.9 in the burned plots (Fig.56; Tab.7; Pict.10). This lower number of newly developed leaves in the burned plots could be due to the sprouting promoted by fire and that lead to high stem density where competition for the existing nutrients in the soil influenced the number of leaves.

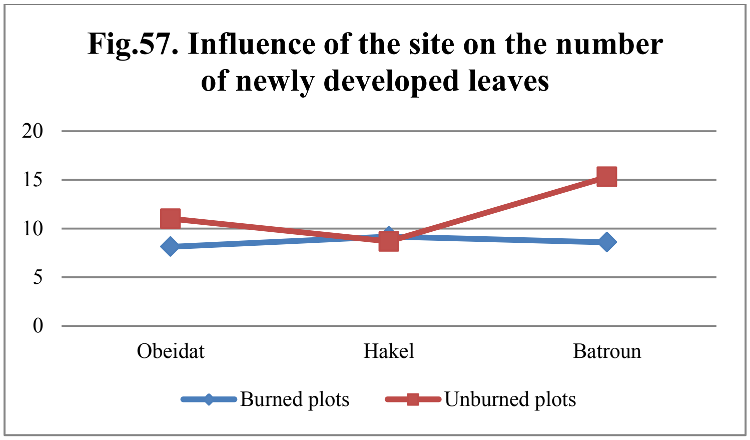
Pict.10. Sprouting in a high stem density

The number of leaves varied between 7.73 and 8.9cm in the burned plots, while this number varied between 9.97 and 11.1cm in the unburned plots (Fig.56).

Fig.56. Influence of collection date on the number of newly developed leaves



The number of newly developed leaves was highly influenced by the site. In Obeidat and Batroun, this number was higher in the unburned plots than the burned plots with respectively 11 and 8.13leaves in Obeidat and 15.3 and 8.6leaves in Batroun. The exception was observed in Hakel where the burned plot recorded a higher number of new leaves (9.19) than the unburned plot 8.68 (Fig.57).



Status also influenced the newly developed leaves and the highest recorded number was 24 in the burned plots of Batroun.

One year after the fire, herbaceous perennials became clearly dominant in the studied plots of oaks communities. There were abundance and specific richness of the herbaceous species appearing after the fire. These observations are in accordance with Calvo *et al*. (2003) who detected a greater quantity of herbs in the areas affected by the fires (Pict.11).

Pict.11. Herbaceous perennials

These perennials were no longer in competition with the main woody specie, the oaks, for the light and their shallow root systems allow them a fast absorption of nutrients ensured by the ash that increased after fire.

4.12. Gas Chromatography.

The compounds that were detected in the leaf extracts of *Q. calliprinos* from resprouts after fire and from controls were studied. Neither the site nor the status influenced the studied components (18) which acted similarly in burned and unburned plots (Tab.8). The only compound that figured in all plots was the Cyclotrisiloxane (Fig.60) while the highest was the inositol with a mean of 11.86 (Fig.58). Batroun 1 recorded the highest content with 24.34% while Obeidat 1 gave the lowest (7.99%).

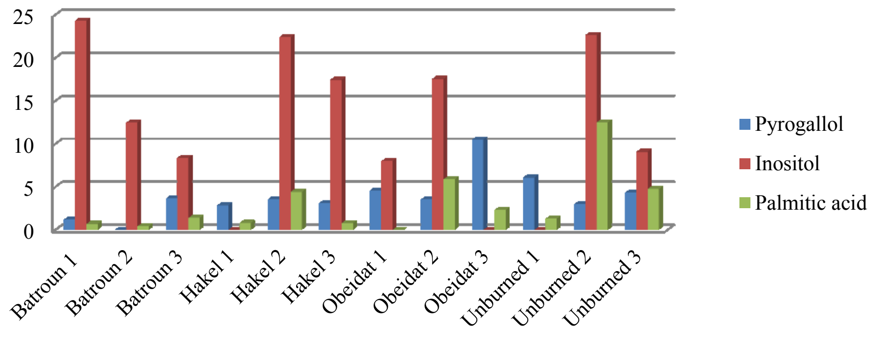


Fig.58. Pyrogallol, Inositol and Palmitic acid contents in different studied plots

Pyrogallol and gallic acid are natural components of some hardwood species such as oak trees (e.g. Quercus robur, Q. alba, Q. rubra) and eucalyptus wood (e.g. E. microcrys f. muell., E. triantha link., E. regnans f. muell.) (Fig.59), and they are known to display fungicidal/fungistatic properties as well as strong affinity to form complexes (Ziegler and Billes, 1993). The pyrogallol appeared in the leaf extracts of Q. calliprinos with a mean of 3.87. The highest recorded content was in Obeidat 3 (10.51%) while the lowest (1.2%) was in Batroun 1 (Fig.58).

Similar to inositol and cyclotrisiloxane, neither the status nor the site influenced the pyrogallol content (Tab.8).

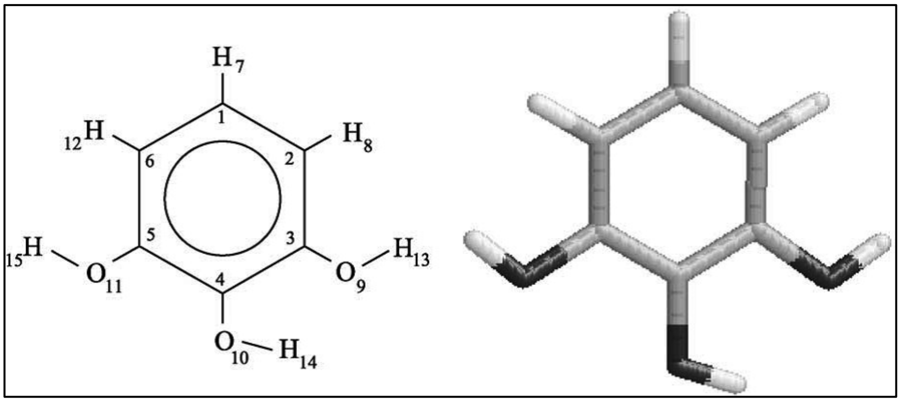
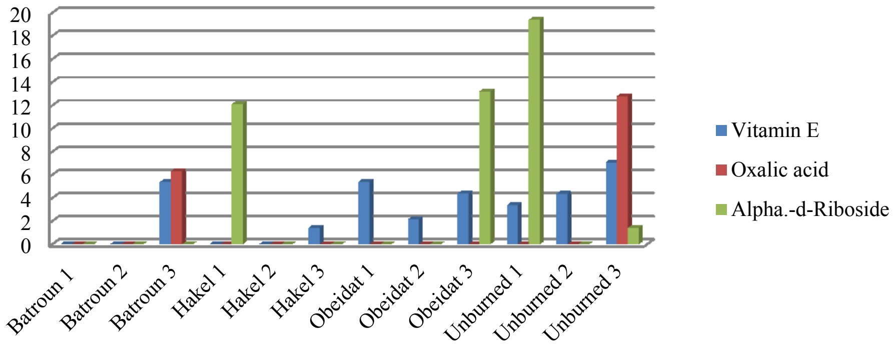


Fig.59. Structure of pyrogallol and the numbering of its' atoms

Palmitic acid or hexadecanoic acid is the most common fatty acid found in plants, animals and microorganisms (Gunstone *et al*., 2007) and mainly used to produce soaps and cosmetics. Its contents varied between 0.71% in Batroun 1 and 12.49% in the unburned plot number 2. Four over the eighteen studied components showed the highest contents in the burned plots and are the following: oxalic acid (12.78%), palmitic acid (12.49%), trimethylphenoxysilane (9.87%) and vitamin E (7.09%).

Concerning the α-Tocopherol (Vitamin E), the content ranged between 1.44 in Hakel 3 and 7.08% in the unburned plot number 2 with a mean of 4.19% (Fig.60). Our results are in accordance with Chevolleat *et al*. (1993) who identified the α-Tocopherol as the main antioxidant in hexane extracts of leaves of sixteen Mediterranean plant species. The tocopherol content of the extracts was in the range of 0.0–4.7%, and that of the dry leaves was 0–846 ppm. The highest α-tocopherol content was found in the leaves of a Mediterranean oak, *Quercus ilex* (Chevolleau *et al.*, 1993).

Fig.60.Vitamin E, Oxalic acid and Alpha-d-riboside contents in different studied plots



Oxalic acid is produced by a variety of plants and animals and can exist in the cell, either as soluble Na and K salts or as calcium oxalate, an insoluble crystal. Calcium oxalate crystals are formed as a result of the bonding of calcium ions with metabolically formed oxalate ions. The calcium oxalate crystals in plants ensure calcium storage and as a defense mechanism against animals (Çolgecen *et al*., 2009). In the studied plots, burned and unburned, Oxalic acid was detected and ranged between 6.31% in Batroun 3 and 12.78% in the unburned plot number 3 with a mean of 1.59% (Fig.60). No significant difference was recorded.

Similar to the above compounds, Alpha-d-riboside wasn't influenced by the status and the site; it was mainly detected in the unburned plots and recorded respectively the highest (19.38% in the unburned plot number 1) and the lowest contents (1.41% in the unburned plot number 3) with a mean of 3.84% (Fig.60).

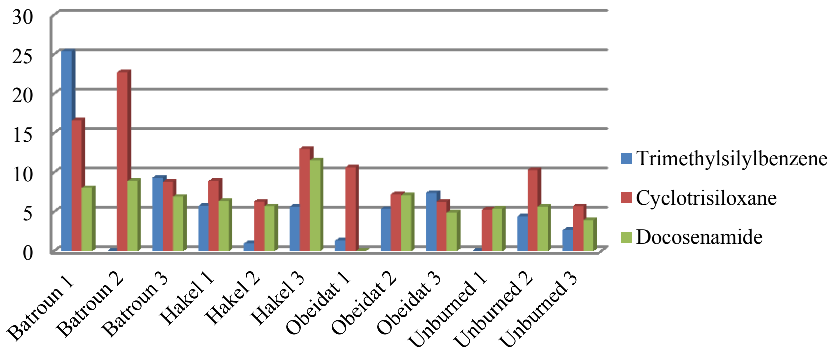
cis-13-docosenoic acid which is also known as Erucic acid, varied between 3.93% in the unburned plot number 3 and 11.56% in Hakel 3 with a mean of 6.21% (Fig.61). It is a monounsaturated omega-9 fatty acid and can be converted into surfactants, lubricant and is a precursor to bio-diesel. This acid is not soluble in water and dissolves in methanol and could be used to produce a wide range of chemicals including nylon, polyester, lubricants and cosmetics. It can also be used as a component of the bio-diesel.

As mentioned above, Cyclotrisiloxane hexamethyl is the only compound that was detected in all the studied plots (burned and unburned) with a mean of 10.15% (Fig.61). The highest amount (22.72%) was recorded in Batroun 2 while the lowest (5.28%) was in unburned plot 1. An aqueous extract from West Anatolian Olive leaves that had an antimicrobial activity was mainly constituted of Cyclotrisiloxane hexamethyl (Keskin *et al.*, 2012). It inhibited the growth of a large number of tested Gram-positive and Gram-negative bacteria.

Tab.8. Influence of the site and status on different components of Quercus calliprinos leaves.

	Site		**Status**	
	F	**p**	**F**	**p**
Pyrogallol	3.265	0.092	0.931	0.363
Inositol	0.332	0.727	0.061	0.811
Palmitic Acid	0.235	0.796	1.546	0.249
Trimethylsilylbenzene	1.106	0.377	0.176	0.686
Cyclotrisiloxane	2.995	0.107	0.075	0.792
13-Docosenamide	2.434	0.149	0.239	0.638
Cycloheptatrien	2.044	0.192	0.350	0.570
Benzoquinoline	2.114	0.183	0.140	0.718
Tetrasiloxane	0.659	0.543	0.056	0.819
Silane	0.944	0.428	0.643	0.446
Methyltrimethylsiloxyacetophenone	1.123	0.372	0.105	0.754
Silicic acid	3.871	0.067	2.646	0.142
Trimethylphenoxysilane	0.114	0.893	4.428	0.068
Vitamine E	2.227	0.170	0.330	0.582
Oxalic acid	1.231	0.342	0.873	0.377
Eicosane	2.872	0.115	1.335	0.281
Alpha-d-riboside	0.320	0.735	0.172	0.689
Propoxypentane	0.525	0.610	3.799	0.087

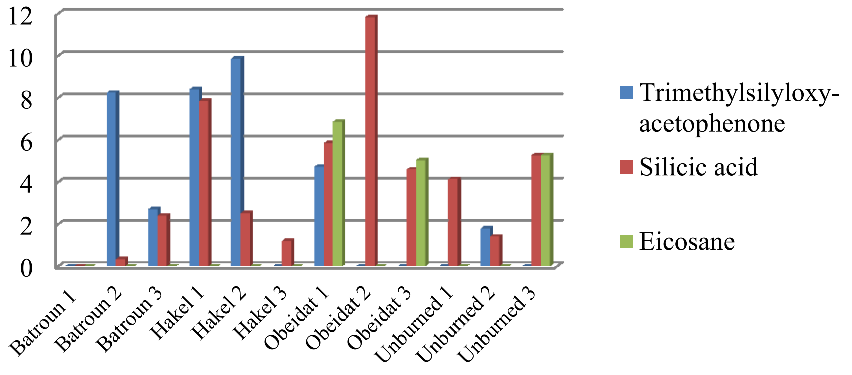
Fig.61. Trimethylsilylbenzene, cyclotrisiloxane and Docosenamide contents in different studied plots



Concerning the Trimethylsilylbenzene, it constituted the main compound with 25.28% in Batroun 1, while this content decreased to less than 1% in the case of Hakel 2 (Fig.61). It is to note, that no significant differences were detected in the two studied parameters (site and status).

Trimethylphenoxysilane was highly detected in the unburned plot number 2 with 9.55%, while this content didn't exceed 1% (0.72%) in the case of Obeidat 3 (Fig.62). The mean of this compound was 2.41%. For the Silicic acid, the mean is 3.96 ± 3.44, with highest amount (11.84%) in Obeidat 2; the lowest recorded content was in Hakel 3 with 1.21% (Fig.62). For the Eicosane, the mean was 1.43% and ranged between 5.04% in Obeidat 3 and 6.87% in Obeidat 1 (Fig.62).

Fig.62. Trimethylsilyloxy-acetophenone, Silicic Acid and Eicosane contents in different studied plots



5. Conclusion.

The chemical changes in the soil are mainly due to the combustion of SOM and alteration of nutrient availability. Concerning the soil organic matter, it decreased with years with the exception of the unburned plot of Obeidat that increased during 2012. This decrease is mainly due to the difference of altitude between the studied plots that consequently influence the type of shrubs and ground cover. For the pH, only the year parameter highly influenced its content while no significant difference between the un-burnt soil and burned soil was recorded. This behavior is due to the re-establishment of pre-burn pH values after short periods of fire. The EC increased with years as a result of the release of inorganic ions from the combusted OM. The site and year parameters highly influenced the EC.

Total and active $CaCO_3$ was highly influenced by the site and status which decreased with years between the burned and unburned plots.

Concerning the nutrient availability, neither the number of years nor the status influenced the nitrogen content in Obeidat, Hakel and Batroun who recorded a decrease due to the highest consumption of N in the burned sites. The phosphorus content decreased only in the plot that was burned twice while it increased with year in plots that was burned once and was highly influenced by the site and year parameter. For the potassium content, it fell in all studied plots; this is mainly due to the fire which directly affected K and P availability of soil by chemically altering of these elements and indirectly by altering soil temperature and pH. All studied Cations were highly influenced by year, Iron and Sodium decreased while Calcium and Magnesium increased. It is to note that only Mg is the only cation that wasn’t influenced by the site parameter.

Concerning soil texture, only clay showed a slight decrease that was mainly due to the low intensity of the fire in Batroun region. Lime and Sand acted similarly and weren't influence by the status.

The biggest vegetative growths after fire was observed during the third collect (July) in the burned and unburned plots. Similar to the length of the twigs, the highest number of leaves (11.1) was recorded during July 2012 in the unburned plots. The low number of newly developed leaves in the burned plots could be due to the high stem density after fire where competition for the existing nutrients in the soil influenced the number of leaves.

Concerning the GCMS, all the detected components which constituted 82.3% of the aqueous extract of the Quercus calliprinos leaves wasn't influenced either by the site or by the status and acted similarly. The content showed components that have fungicidal properties such as Pyrogallol (3.87%), others could be used in the production of soap such as palmitic acid (2.9%), and α-Tocopherol (4.2%) which is an important antioxidant; cis-13-docosenamide could be used for the production of nylon and cosmetics while the Cyclotrisiloxane hexamethyl (10.15%) has as anti-microbial activity that inhibits the growth of a large number of tested Gram-positive and Gram-negative bacteria.

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ANNEXE 1:
SOIL SAMPLES ANALYSIS
REPORT 1/2010

SYM	NUM	S.G %	S.F %	L.G %	L.F %	A %	M.O %	PH (2:5)	CE (2:5)	CaCO3 %		N kg/ha	P ppm	K ppm	Na ppm	Mg ppm	Ca ppm	Fe ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
OBEIDAT																		
Ou1	378	20	5	12	14	44	11.7	7.4	0.15	15	4	305	10	330	180	387	5040	2
Ou2	379	18	6	12	16	44	7.9	7.7	0.09	15	4	207	6	250	180	242	5040	1.5
Ou3	380	20	3	10	12	50	11.2	6.2	0.16	15	4	294	8	380	180	484	4800	4
Ou4	381	18	6	16	12	44	6.8	7	0.08	13	3	179	8	310	180	194	5120	2
Ou5	382	23	3	16	12	41	7.6	6.9	0.09	14	3	200	4	220	180	339	4560	5
Ou6	383	14	2	22	10	48	7.6	6.7	0.08	14	3	200	7	370	180	290	5040	2
Ob1	384	13	5	18	10	50	10	6.6	0.11	13	3	270	20	280	180	436	5280	2
Ob2	385	20	5	14	12	44	12.3	7.2	0.25	16	4	322	30	460	190	290	5360	6
Ob3	386	14	4	10	12	55	10	6.8	0.11	13	3	263	19	410	180	339	5760	5
Ob4	387	19	7	16	8	48	20.4	6.7	0.25	14	3	533	23	530	230	339	4960	3.5
Ob5	388	20	4	14	10	48	10.5	7.2	0.18	16	4	273	27	750	200	339	4880	4
Ob6	389	18	4	14	12	50	13	7.1	0.21	14	4	340	14	560	190	488	6160	5

ANNEXE 2:
SOIL SAMPLES ANALYSIS
REPORT 1/2010

SYM	**NUM**	**S.G %**	**S.F** %	**L.G** %	**L.F** %	**A** %	**M.O** %	**PH** (2:5)	**CE** (2:5)	**CaCO3** %		**N** kg/ha	**P** ppm	**K** ppm	Na ppm	**Mg** ppm	**Ca** ppm	**Fe** ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
HAKEL																		
Hb1	459	12	9	14	14	46	7.5	7	0.18	4	4	197	4	190	250	145	7200	2
Hb2	460	9	3	16	12	56	9.1	7.2	0.19	4	4	239	6	520	200	194	5840	2
Hb3	461	10	5	20	10	50	9.9	7.7	0.18	4	4	260	8	470	180	194	6080	1
Hb4	462	8	2	24	10	54	9.9	7.7	0.17	3	3	260	6	400	180	145	6240	1
Hb5	463	16	2	14	12	54	9.8	7.5	0.19	4	4	256	5	310	180	387	6560	2
Hb6	464	8	2	24	10	54	9.8	7.6	0.16	3	3	221	2	260	210	436	6000	1
Hb'1	465	18	10	14	12	42	10.7	7.5	0.26	5	5	281	17	600	250	48	5360	1
Hb'2	466	11	4	16	20	44	9.5	7.6	0.22	4	4	190	5	520	150	290	5520	1
Hb'3	467	20	6	16	12	42	10.9	7.5	0.17	20	6	284	9	360	200	242	4800	2
Hb'4	468	15	5	20	16	40	8.9	7.7	0.17	15	4	232	5	200	230	97	5120	1
Hb'5	469	14	4	16	10	52	8.2	7.7	0.15	8	3	214	8	340	150	145	5200	2
Hb'6	470	18	4	16	14	44	12.9	7.1	0.29	9	3	337	85	670	250	242	5200	3
Hu1	471	18	4	14	12	48	9.8	7.8	0.13	25	6	256	3,5	440	90	48	4880	2
Hu2	472	12	4	14	12	54	10.1	7.2	0.14	14	4	263	0	400	210	97	6560	3
Hu3	473	16	2	16	10	52	9.5	7.9	0.16	14	4	249	1	470	130	290	5920	4
Hu4	474	8	3	18	10	56	8	7.9	0.1	10	3	211	3	360	170	97	5840	1
Hu5	475	10	4	14	12	56	9.8	7.7	0.11	9	3	256	10	390	200	194	5200	2
Hu6	476	15	5	16	14	46	8.8	7.7	0.19	11	3	232	33	330	180	436	5520	2

ANNEXE 3:
SOIL SAMPLES ANALYSIS
REPORT 1/2010

SYM	NUM	S.G %	S.F %	L.G %	L.F %	A %	M.O %	PH (2:5)	CE (2:5)	CaCO3 %		N kg/ha	P ppm	K ppm	Na ppm	Mg ppm	Ca ppm	Fe ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
BATROUN																		
Bb1	477	19	8	18	16	34	7.5	7.8	0.15	67	18	197	11	360	200	242	3200	3
Bb2	478	20	8	22	14	34	5.5	7.8	0.15	72	19	144	15	220	130	145	3040	3
Bb3	479	25	10	12	20	28	7.1	7.8	0.25	65	18	186	50	460	240	532	3520	3
Bb4	480	18	21	14	16	30	6.4	7.5	0.24	76	16	168	62	230	170	242	3200	3
Bb5	481	13	13	18	16	36	7.2	7.3	0.32	66	14	190	14	170	300	242	3040	3
Bb6	482	12	8	18	20	38	10.6	7.8	0.28	56	12	277	31	180	270	290	3600	4
Bu1	483	26	7	14	18	30	7.5	8	0.22	46	15	197	19	360	180	339	5040	2
Bu2	484	20	6	20	12	42	3.5	7.9	0.11	44	14	91	7.8	240	230	290	5200	2
Bu3	485	28	6	16	8	38	5.8	7.9	0.12	45	14	151	6.5	160	180	194	4960	2
Bu4	486	24	5	12	12	42	8.8	8,0	0.13	33	11	232	18	210	200	339	5600	3
Bu5	487	19	7	14	10	50	7.4	7.6	0.16	30	10	193	12	430	160	436	5680	3
Bu6	488	20	5	14	10	48	7.2	7.9	0.16	31	10	190	13	480	160	387	6160	3

ANNEXE 4:
SOIL SAMPLES ANALYSIS
REPORT 2/2011

SYM	**NUM**	**S.G %**	**S.F** %	**L.G** %	**L.F** %	**A** %	**M.O** %	**PH** (2:5)	**CE** (2:5)	**CaCO3** %		**N** kg/ha	**P** ppm	**K** ppm	Na ppm	**Mg** ppm	**Ca** ppm	**Fe** ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
OBEI DAT																		
Ou1	526	10	4	26	14	46	5.6	7.6	0.09	12	3	148	12	230	110	629	1960	1
Ou2	527	15	5	16	10	54	9.4	7.3	0.123	12	3	245	9	300	120	242	5040	1
Ou3	528	23	7	16	12	42	14	7.4	0.14	14	3	351	12	260	140	97	4800	1
Ou4	529	22	6	16	12	44	9.04	7.5	0.12	15	4	245	7	280	110	629	4400	1
Ou5	530	14	4	22	10	50	6.3	7.7	0.09	13	4	165	9	230	100	145	5360	1
Ou6	531	7	3	22	12	56	6.1	7.7	0.1	15	4	160	8	210	110	97	4800	3
Ob1	520	23	5	20	10	41	10	7.9	0.12	12	3	266	14	330	130	97	5280	3
Ob2	521	14	4	20	12	50	6	7.4	0.08	12	3	158	6	180	100	194	4880	3
Ob3	522	16	4	20	12	48	6.7	7.7	0.09	12	3	175	12	170	110	339	4960	3
Ob4	523	16	5	26	10	42	10.2	7.6	0.11	12	3	266	11	250	120	581	1960	3
Ob5	524	22	4	16	16	38	10	7.6	0.1	12	3	263	8	260	110	581	4960	3
Ob6	525	17	5	20	16	42	9.8	8	0.09	12	3	256	9	200	110	629	5040	3

ANNEXE 5:
SOIL SAMPLES ANALYSIS
REPORT 2/2011

SYM	NUM	S.G %	S.F %	L.G %	L.F %	A %	M.O %	PH (2:5)	CE (2:5)	CaCO3 %		N kg/ha	P ppm	K ppm	Na ppm	Mg ppm	Ca ppm	Fe ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
HAKEL																		
Hu1	682	24	8	16	10	48	6.3	7.7	0.09	5	2	165	3.8	390	120	678	6000	2.8
Hu2	683	21	5	20	12	40	9.9	7.3	0.12	6	2	260	5.6	300	120	726	4800	1.3
Hu3	684	6	2	24	14	52	3.2	8	0.06	7	2	84	2.7	220	110	387	5760	1.6
Hu4	685	6	3	24	12	50	5.9	7.8	0.08	6	2	154	2.8	320	100	339	6480	1.3
Hu5	686	6	4	22	12	52	5	8	0.1	7	2	130	2.8	360	110	871	6560	2
Hu6	687	11	3	20	10	54	4.6	7.9	0.09	9	3	119	2.7	340	100	436	6400	2.5
Hb1	670	18	2	12	12	54	8.6	7.8	0.09	5	2	224	4.7	390	110	484	6240	1.6
Hb2	671	12	4	18	12	52	11.2	7.8	0.12	7	2	295	5.4	400	130	484	5600	1.8
Hb3	672	10	2	22	12	52	9.4	8.1	0.1	6	2	245	6	350	110	387	5600	1.3
Hb4	673	14	2	22	10	51	11.5	7.8	0.13	6	2	301	7	460	100	968	5680	1.8
Hb5	674	6	2	30	12	48	10..9	7.8	0.11	5	2	284	5.1	310	160	532	5600	1.2
Hb6	675	12	5	18	14	48	10	7.9	0.1	5	2	252	5.3	70	100	436	5280	1.7
Hb'1	676	12	4	22	10	48	8.8	7.8	0.11	7	2	232	3.7	320	100	242	4880	0.9
Hb'2	677	12	4	24	10	46	7.5	8	0.09	7	2	197	3.5	250	100	678	4880	1
Hb'3	678	28	4	20	12	36	12.3	7.8	0.14	6	2	323	6.3	160	80	436	4560	2
Hb'4	679	14	4	12	14	54	12.3	7.9	0.13	7	2	323	6.6	400	110	629	5360	1.4
Hb'5	680	20	6	14	10	46	7.4	7.5	0.08	4	1	193	4.4	190	110	97	4000	1
Hb'6	681	22	4	14	10	46	7.2	7.6	0.1	5	2	189	3.7	200	120	387	4400	1

ANNEXE 6:
SOIL SAMPLES ANALYSIS
REPORT 2/2011

SYM	NUM	S.G %	S.F %	L.G %	L.F %	A %	M.O %	PH (2:5)	CE (2:5)	CaCO3 %		N kg/ha	P ppm	K ppm	Na ppm	Mg ppm	Ca ppm	Fe ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
BATROUN																		
Bb1	477	19	8	18	16	34	7.5	7.8	0.15	67	18	197	11	360	200	242	3200	3
Bb2	478	20	8	22	14	34	5.5	7.8	0.15	72	19	144	15	220	130	145	3040	3
Bb3	479	25	10	12	20	28	7.1	7.8	0.25	65	18	186	50	460	240	532	3520	3
Bb4	480	18	21	14	16	30	6.4	7.5	0.24	76	16	168	62	230	170	242	3200	3
Bb5	481	13	13	18	16	36	7.2	7.3	0.32	66	14	190	14	170	300	242	3040	3
Bb6	482	12	8	18	20	38	10.6	7.8	0.28	56	12	277	31	180	270	290	3600	4
Bu1	483	26	7	14	18	30	7.5	8	0.22	46	15	197	19	360	180	339	5040	2
Bu2	484	20	6	20	12	42	3.5	7.9	0.11	44	14	91	7.8	240	230	290	5200	2
Bu3	485	28	6	16	8	38	5.8	7.9	0.12	45	14	151	6.5	160	180	194	4960	2
Bu4	486	24	5	12	12	42	8.8	8,0	0.13	33	11	232	18	210	200	339	5600	3
Bu5	487	19	7	14	10	50	7.4	7.6	0.16	30	10	193	12	430	160	436	5680	3
Bu6	488	20	5	14	10	48	7.2	7.9	0.16	31	10	190	13	480	160	387	6160	3

ANNEXE 7:
SOIL SAMPLES ANALYSIS
REPORT 3/2012

SYM	**NUM**	**S.G %**	**S.F** %	**L.G** %	**L.F** %	**A** %	**M. O** %	**PH** (2:5)	**CE** (2:5)	**CaCO3** %		**N** kg/ha	**P** ppm	**K** ppm	Na ppm	**Mg** ppm	**Ca** ppm	**Fe** ppm
Desired value							2.5	8	0.4	To tal	Ac tif	70	15	400	100	250	3500	10
OBEI DAT																		
Ou1	189	20	6	18	14	42	10	7.3	0.29	6	2	270	5.9	340	100	345	6912	1.5
Ou2	190	20	4	18	8	50	10	7.5	0.24	5	2	263	14.34	320	100	365	7494	0.69
Ou3	191	18	4	12	14	50	9	7.9	0.15	8	3	235	12.55	180	70	279	7154	0.72
Ou4	192	16	4	12	16	52	8.4	7.7	0.14	5	2	221	12.19	250	80	273	6814	0.19
Ou5	193	21	5	14	8	52	10.6	7.3	0.23	5	2	277	13.03	290	70	446	6282	1.33
Ou6	194	11	5	16	12	56	9.1	7.8	0.17	5	2	238	12.67	180	70	326	7762	0
Ob1	183	16	5	18	6	54	7.2	7.6	0.19	5	2	189	0	170	70	484	7007	0.3
Ob2	184	16	6	14	8	56	9.5	7.4	0.2	6	2	249	1.2	240	60	358	7276	0.6
Ob3	185	14	4	14	10	56	8.4	7.6	0.2	5	2	221	2.6	220	60	323	7573	0.3
Ob4	186	13	3	14	8	62	6.3	7.6	0.15	5	2	165	0	220	70	376	7272	0.2
Ob5	187	15	5	14	8	58	7.8	7.7	0.19	6	2	203	0	330	90	300	7096	0.4
Ob6	188	13	3	10	14	60	7.9	7.5	0.15	5	2	207	0	210	60	560	7110	0.1

ANNEXE 8:
SOIL SAMPLES ANALYSIS
REPORT 3/2012

SYM	NUM	S.G %	S.F %	L.G %	L.F %	A %	M.O %	PH (2:5)	CE (2:5)	CaCO3 %		N kg/ha	P ppm	K ppm	Na ppm	Mg ppm	Ca ppm	Fe ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
HA KEL																		
Hu1	284	26	7	10	16	40	7.1	8	0.16	38	8	186	11	330	80	251	5538	0.01
Hu2	285	15	9	20	10	46	6.2	8.1	0.11	17	4	161	4.2	320	80	262	6606	0.01
Hu3	286	7	3	14	10	66	4.4	7.9	0.1	6	2	116	6	310	90	468	6792	0.5
Hu4	287	9	3	20	10	58	6.4	7.9	0.11	6	2	168	7.7	330	100	363	6499	0.01
Hu5	288	8	4	16	14	58	8.3	7.6	0.12	6	2	217	5	350	80	817	5711	0.06
Hu6	289	9	3	18	14	54	7	7.7	0.1	8	3	182	5.4	360	70	1132	4961	0.01
Hb1	291	7	2	16	16	58	5.8	7.9	0.08	6	2	150	5	220	60	396	7119	0.01
Hb2	295	14	4	18	12	50	6.4	7.8	0.09	7	2	168	6.3	320	60	304	6477	0.01
Hb3	297	12	4	18	14	50	6.8	7.8	0.11	5	2	179	8	370	80	251	6615	0.01
Hb4	298	13	5	18	14	48	8	7.7	0.13	6	2	210	4.5	410	90	370	6550	0.01
Hb5	299	11	4	22	12	50	8.4	7.8	0.11	6	2	281	5.6	330	90	239	6908	0.01
Hb6	300	11	4	22	12	50	8.6	7.5	0.1	5	2	225	6.5	390	100	429	6434	0.01
Hb'1	290	17	3	18	14	48	9.9	7.7	0.28	9	3	260	4.4	740	70	281	6159	0.01
Hb'2	296	12	4	20	18	46	8.6	7.7	0.12	5	2	225	8.6	360	80	236	5749	0.01
Hb'3	292	10	4	24	12	50	8.6	7.9	0.11	8	3	225	15	350	80	288	5711	0.01
Hb'4	293	12	4	22	16	46	8.6	7.9	0.13	9	3	225	4.2	330	90	228	6047	0.01
Hb'5	294	11	5	14	20	46	8.8	7.9	0.11	5	2	232	11.7	340	70	238	5848	0.01
Hb'6	301	12	6	20	12	50	8.3	7.7	0.14	6	2	218	5.7	370	100	237	6059	0.01

ANNEXE 9:
SOIL SAMPLES ANALYSIS
REPORT 3/2012

SYM	**NUM**	**S.G %**	**S.F** %	**L.G** %	**L.F** %	**A** %	**M.O** %	**PH** (2:5)	**CE** (2:5)	**CaCO3 %**		**N** kg/ha	**P** ppm	**K** ppm	Na ppm	**Mg** ppm	**Ca** ppm	**Fe** ppm
Desired value							2.5	8	0.4	Total	Actif	70	15	400	100	250	3500	10
BATROUN																		
Bb1	216	14	13	18	14	40	3	8	0.13	69	18	133	7.7	160	120	368	4564	0
Bb2	217	16	10	18	16	38	8.4	7.9	0.15	63	16	219	8.7	100	110	319	4940	0
Bb3	218	16	7	24	10	42	7	7.9	0.26	69	17	184	11.9	250	100	327	4735	0
Bb4	219	16	14	18	10	42	3	7.7	0.25	77	17	79	8.4	100	90	247	4304	0
Bb5	220	37	15	12	4	32	4.2	8	0.2	77	15	108	6.5	100	80	243	3736	0.3
Bb6	221	30	10	14	10	36	9.7	7.3	0.33	61	13	254	18.2	220	100	461	5466	2
Bu1	210	23	7	13	14	38	3.3	7.7	0.32	32	10	307	14	420	80	745	7911	0.6
Bu2	211	25	5	18	10	42	2.3	7.8	0.15	35	8	105	8.7	140	90	401	5943	0
Bu3	212	28	4	18	10	38	12.7	7.8	0.39	15	4	570	29.8	670	220	774	9227	0.2
Bu4	213	27	7	14	14	36	8.8	7.8	0.22	37	8	395	15.6	580	110	781	7802	0
Bu5	214	24	6	16	10	44	8.2	7.6	0.37	32	10	368	14.5	310	170	517	8420	0.8
Bu6	215	30	8	18	10	34	3.2	7.6	0.28	47	13	144	13.1	310	110	485	5997	0.03

ANNEXE 10:
STEMS ELONGATION

	March 25, 2012		May 19, 2012	June 17, 2012	July 16, 2012
OBEIDAT	SAMPLES				
TOu1 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	10L, 5cm	10L, 5.5cm	11 L, 6cm
		S2	13L, 8cm	13L, 10cm	13l, 11cm
		S3	1) 7L, 11cm	7L, 11cm	7L, 11cm
			2) 7L, 11cm	7L, 12.5cm	7L, 13cm
		S4	1) 7L, 10cm	9L, 10cm	10L, 10cm
			2) 7L, 10cm	9L, 10cm	10L,10cm
TOu2 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	1) 10L, 6cm	10L, 7cm	10L, 8cm
			2) 10L, 6cm	10L, 7cm	10L, 8cm
			3) 10L, 6cm	10L, 7cm	10L, 8cm
			4) 10L, 6cm	10L, 7cm	10L, 8cm
			5) 10L, 6cm	10L, 7cm	10L, 8cm
		S2	1) 10L, 6cm	12L, cm	13L, 7cm
			2) 7L, 2cm	7L, 2cm	7L, 2cm
		S3	1) 1L, 1cm	3L, 3cm	5L, 4cm
			2) 1L, 1cm	3L,3cm	5L, 4cm
		S4	1) 7L, 5cm	9L, 6cm	9L, 7cm
			2) 7L, 5cm	9L, 6cm	9L, 7cm
TOu3 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	4L, 1cm	7L, 3cm	8L, 4cm
		S2	4L, 1cm	4L, 1cm	4L, 1,5cm
		S3	4L, 1cm	7L, 2cm	8L, 3cm
		S4	Cut	Cut	Cut
TOb1	4L, 1cm each	S1	1) 9L, 6cm	15L, 9cm	17L, 11cm
			2) 5L, 2cm	12L, 9cm	15L, 11cm
			3) 6L, 2cm	13L, 10cm	16L, 11cm
		S2	1) 11L, 3cm	13L, 6cm	14L, 8cm
			2) 10L, 3cm	cut	cut
		S3	1) 10L, 8cm	12L, 8cm	12L, 9cm
			2) 10L, 4cm	10L, 5cm	10L, 5cm
			3) 5L, 2cm	6L, 2.5cm	6L, 3cm
		S4	1) 13L, 5cm	13L, 6cm	13L, 6cm
			2) 13L, 6cm	13L, 7cm	13L, 7cm
			3) 10L,2cm	10L, 3cm	10L, 3cm
			4) 10L, 2cm	10L, 3cm	10L, 3cm
TOb2	4L, 1cm	S1	1) 17L, 7cm	17L, 7cm	17L, 7cm
			2) 18L, 10cm	20L, 10cm	20 L, 10cm
			3) 20L, 10cm	20L, 10cm	20L,10cm
			4) 14L, 16cm	28L, 25cm	32L, 30cm
		S2	1) 7L, 3cm	8L, 4cm	8L, 4cm
			2) 8L, 3cm	8L, 4cm	8L, 4cm
			3) 7L, 3cm	8L, 4cm	8L, 4cm

			4) 7L, 3cm	8L, 4cm	8L, 4cm
			5) 8L, 3cm	8L, 4cm	8L, 4cm
		S3	12L, 6cm	13L, 10cm	13L, 12cm
		S4	1) 4L, 3cm	9L, 6cm	11L, 7cm
			2) 4L, 3cm	4L, 3cm	4L, 3cm
			3) 4L, 3cm	4L, 3cm	4L,3cm
TOb3	4L, 1cm	S1	5L, 2cm	8L, 5cm	10L, 6cm
		S2	4L, 2cm	9L, 3cm	9L, 3cm
		S3	7L, 3cm	9L, 6cm	9L, 8cm
		S4	Cut	cut	cut

ANNEXE 11:

STEMS ELONGATION

SYM	March 25, 2012		May 19, 2012	June 17, 2012	July 16, 2012
BATROUN	SAMPLES				
TBu1 **3 SAMPLES S1,S2,S3**	4L, 1cm each	S1	1) 11L, 16cm	13L, 16cm	13L, 16cm
			2) 6L, 6cm	7, 6,5cm	8L, 6.5cm
			3) 9L, 8cm	10L, 8cm	10L, 8cm
			4) 8L, 6cm	8L, 6cm	8L, 6cm
		S2	1) 10L, 10cm	12L, 10cm	12L, 10cm
			2) 11L, 10cm	12L, 11cm	13L, 12cm
			3) 7L, 6cm	9L, 8cm	9L, 9cm
		S3	1) 10L, 5cm	10L, 5cm	10L, 5cm
			2) 8L, 4cm	10L, 5cm	11L, 5,5cm
TBu2 **3 SAMPLES S1,S2,S3**	4L, 1cm each	S1	1) 7L, 7cm	8L, 8cm	8L, 9cm
			2) 6L, 5cm	6L, 5cm	4L, 5cm
		S2	1) 10L, 5cm	10L, 5cm	10L, 5cm
			2) 7L, 5cm	7L, 5cm	cut
		S3	1) 9L, 10cm	12L, 11cm	12L, 11cm
			2) 7L, 7cm	7L, 8cm	7L, 8cm
			3) 5L, 5cm	6L, 5cm	6L, 5cm
			4) 5L, 3cm	5L, 4cm	5L, 4cm
TBu3 **3 SAMPLES S1,S2,S3**	4L, 1cm each	S1	1) 6L, 12cm	14L, 17cm	16L, 18cm
			2) 8L, 7cm	10L, 9,5cm	10L, 10cm
			3) 4L, 5cm	7L, 7cm	7L, 7,5cm
		S2	1) 8L, 8cm	9L, 9cm	9L, 10cm
			2) 8L, 6cm	6L, 7cm	6L, 7cm
			3) 7L,6cm	9L, 6,5cm	9L, 6,5cm
			4) 4L, 4cm	5L, 4,5cm	5L, 5cm
		S3	1) 6L, 5cm	13L, 16cm	15L, 19cm
			2) 6L, 5cm	8L, 8cm	9L, 9cm
			3) 6L, 5cm	12L, 10cm	14L, 11cm
			4) 6L, 2cm	6L, 3cm	4L, 3cm
			5) 6L, 2cm	6L, 3cm	4L, 3cm
TBb1 **3 SAMPLES S1,S2,S3**	4L, 1cm each	S1	1) 15L, 10cm	20L, 20cm	
			2) 15L, 12cm	20L, 13cm	cut
		S2	1) 16L, 12cm	16L, 14cm	16L, 15cm
		S3	1) 11L, 7cm	11L, 7cm	11L, 7cm
			2) 2L, 1cm	3L, 2cm	3L, 2cm
			3) 9L, 4cm	9L, 4cm	8L, 4cm
		S1	1) 20L, 10cm	18L, 12cm	16L, 13cm
			2) 12L, 4cm	10L, 5cm	10L, 6cm
			3) 10L, 2cm	10L, 3cm	8L, 3cm
		S2	1) 20L, 15cm	24L, 15cm	24L, 15cm

TBb2 **3 SAMPLES S1,S2,S3**	4L, 1cm each		2) 17L, 12cm	15L, 13cm	10L, 14cm
			3) 18L, 15cm	19L, 15cm	19L, 15cm
			4) 21L, 14cm	22L, 16cm	22L, 17cm
		S3	1) 17L, 12cm	25L, 17cm	29L, 19cm
			2) 11L, 12cm	16L, 15cm	18L, 16cm
			3) 12L, 10cm	20L, 18cm	22L, 20cm
			4) 15L, 12cm	21L, 17cm	24L, 20cm
			5) 11L, 6cm	12L, 7cm	12L, 7cm
TBb3 **3 SAMPLES S1,S2,S3**	4L, 1cm each	S1	1) 14L, 12cm	16L, 13cm	17L, 14cm
			2) 6L, 3cm	8L, 4cm	8L, 4cm
		S2	20L, 10cm	22L, 11cm	23L, 12cm
		S3	16L, 8cm	21L, 9,5cm	22L, 10cm

ANNEXE 12:
STEMS ELONGATION

SYM	March 25, 2012		May 19, 2012	June 17, 2012	July 16, 2012
HAKEL		SAMPLES			
THu1 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	3L, 1cm	4L, 3cm	5L, 4cm
		S2	1) 14L, 6cm	14L, 7cm	14L, 7cm
			2) 8L, 2cm	8L, 3cm	8L, 4cm
		S3	8L, 4cm	14L, 4cm	14L, 4cm
		S4	1) 10L, 6cm	10L, 7cm	10L, 8cm
			2) 3L, 1cm	3L, 3cm	3L, 3cm
			3) 5L, 2cm	5L, 3cm	5l, 3cm
		S1	9L, 3cm	10L, 4cm	11L, 5cm
THu2 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S2	1) 14L, 9cm	14L, 10cm	14L, 10cm
			2) 8L, 5cm	8L, 5cm	7L, 5cm
		S3	1) 8L, 4cm	10l, 4.5cm	10L, 5cm
			2) 4L, 1cm	5L, 2cm	5L, 2.5cm
		S4	1) 14L, 9cm	14L, 10cm	14L, 11cm
			2) 8L, 3cm	8L, 4cm	8L, 4cm
			3) 3L, 1cm	4L, 2cm	4l, 3cm
THu3 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	1) 11L, 5cm	12L, 6cm	13L, 7cm
			2) 12L, 5cm	10L, 5cm	10L, 5cm
			3) 7L, 3cm	7L, 5cm	7L, 6cm
			4) 9L, 3cm	9L, 6cm	9L, 7cm
		S2	1) 7L, 3cm	7L, 4cm	8L, 4cm
			2) 7L, 1cm	7L, 1cm	7L, 1cm
		S3	1) 11L, 6cm	11L, 6.5cm	11L, 7cm
			2) 8L, 3cm	10L, 4cm	11L, 5cm
			3) 5L, 1cm	7L, 3cm	8L,4cm
		S4	1) 17L, 10cm	15L, 11cm	14L, 12cm
			2) 10L, 8cm	10L, 8cm	10l, 8cm
			3) 8L, 6cm	9L, 6cm	9L, 6cm
			4) 7L, 2cm	6L, 3cm	6L, 4cm
THb1 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	1) 12L, 6cm	11L, 6.5cm	11L, 7cm
			2) 13L, 7cm	13L, 8cm	11L, 8cm
			3) 13L, 7cm	11L, 8cm	11L, 8cm
			4) 12L, 6cm	12L, 7cm	11L, 7cm
		S2	1) 5L, 2cm	6L, 3cm	6L, 4cm
			2) 5L, 2cm	6L, 3cm	6L, 4cm
			3) 5L, 2cm	6L, 3cm	6L, 4cm
		S3	1) 10L, 3cm	10L, 6cm	10L, 7cm
			2) 10L, 4cm	10 L, 7cm	10L, 7cm
			3) 10L, 4cm	10L, 7cm	10L, 7cm
			4) 10L, 3cm	10L, 7cm	10L, 7cm
			5) 10L, 3cm	10L, 7cm	10L, 7cm
		S4	1) 10L, 7cm	10L, 8cm	9L, 8cm
			2) 8L, 4cm	8L, 5cm	5L, 5cm
			3) 8L, 2cm	7L, 3cm	6L, 3cm
THb2 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	1) 11L, 5cm	11L, 5cm	11L, 5cm
			2) 8L, 3cm	9L, 5cm	9L, 6cm
			3) 7L, 3cm	7L, 4cm	7L, 4cm
			4) 9L, 4cm	7l, 4cm	6L, 4cm
			5) 7L, 2cm	7L, 3cm	7L, 3cm
		S2	1) 8L, 2cm	8L, 3cm	8L, 3cm
			2) 8L, 2cm	8L, 3cm	8L, 3cm
			3) 8L, 2cm	8l, 3cm	8L, 3cm
		S3	1) 6L, 1,5cm	8L, 2.5cm	9L, 3cm
			2) 8L, 1.5cm	9L, 3cm	9L, 3cm
			3) 7L, 1.5cm	9L, 3cm	9L, 3cm
		S4	1) 7L, 2cm	8L, 3cm	8L, 3cm

			2) 7L, 2cm	6L, 3cm	6L, 3cm
			3) 7L, 2cm	6L, 3cm	6L, 3cm
THb3 **4 SAMPLES S1,S2,S3,S4**	4L, 1cm each	S1	11L, 5cm	11L, 10cm	Broken
		S2	1) 9L, 4cm	9L, 5cm	9L, 6cm
			2) 5L, 5cm	9L, 4.5cm	9L, 5cm
			3) 5L, 3cm	5L, 3cm	5L, 3cm
		S3	1) 15L, 8cm	15L, 9cm	15L, 10cm
			2) 7L, 3cm	9L, 4cm	9L, 4cm
			3) 5L, 1cm	5L, 4cm	5L, 4cm
		S4	1) 9L, 6cm	10L, 7cm	10L, 7cm
			2) 9L, 6cm	9L, 6cm	8L, 6cm
			3) 7L, 3cm	6L, 3cm	6L, 3cm