Fig. 1. View of the oasis of Laghouat.

Fig. 2. Wood market at Laghouat. Juniper, oak, pine, and other kinds of wood, each bunch a camel load, exposed for sale.

Fig. 3. Wood market at Laghouat. Roots of Zizyphus, branches of juniper and pine, and pine bark. The latter is said to be used for staining.

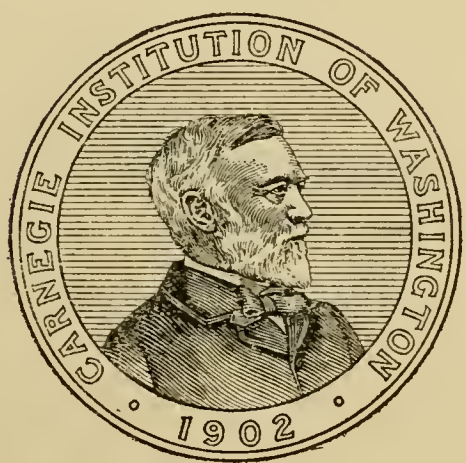
BOTANICAL FEATURES

OF THE

ALGERIAN SAHARA

BY

WILLIAM AUSTIN CANNON



WASHINGTON, D. C.

PUBLISHED BY THE CARNEGIE INSTITUTION OF WASHINGTON

1913

CARNEGIE INSTITUTION OF WASHINGTON
PUBLICATION NO. 178

PRESS OF J. B. LIPPINCOTT COMPANY
PHILADELPHIA

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OUTLINE MAP OF ALGERIA

SHOWING MAIN FEATURES OF SURFACE DRAINAGE

Compiled by G. Sykes, Esq. F. R. G. S.

Scale

0 50 100 Miles

0 50 100 Kilometers

Note. — The position of many oueds and chotts are approximate only as surveys and other sources of information are very incomplete

BOTANICAL FEATURES OF THE ALGERIAN SAHARA.

INTRODUCTION.

The present paper is designed to give the results of some field-work in southern Algeria in the autumn of 1910 and the spring of 1911. The chief purpose of the tour was to examine the more obvious features of the physiological conditions prevalent in the region in question and, in connection with these observations, to make some detailed studies of the root-habits of the most striking species of the native flora. The route lay through the Atlas Mountains, over the High Plateau, and for some distance into the Sahara itself, returning by a somewhat similar way farther to the east. The country traversed was extremely varied in topography and in plant life, and probably the most southern regions seen may be taken as typical of much of the western Sahara. The distance covered in the more arid portions of the colony was about 1,000 miles.

An English-speaking tourist, or any tourist for that matter, is something of a curiosity in southern Algeria. We were said to be the second party of "Englishmen" who had passed over the Ghardaia-Ouargla country in twenty-five years.

Leaving Algiers in October, diligence was taken to Ghardaia, the most important town in southern Algeria and the end of the diligence service. Beyond Ghardaia travel is by camel only. The diligence journey, if made without stop, requires six days, running night and day, except the first day's run, which is by day only. Pauses in the journey to Ghardaia were made at the leading towns or stage stations (bordj), thus affording opportunity to observe several localities in the High Plateau as well as the portion of the desert just south of the Saharan Atlas. Stop-overs were made thus at Medea, Boghari, Djelfa, Laghouat, and Tilrempt. A fortnight was passed at Ghardaia, where the environs of the city were quite thoroughly explored. As there are no roads between Ghardaia and Ouargla, or between Ouargla and Touggourt, it was necessary to organize a small camel-train, engage a cameleer (sokhrar) and servants, and make special arrangements for the trip. Nine days were required for the portion of the journey to Touggourt via Ouargla. At Touggourt diligence was again taken for Biskra, two days' journey. The return journey to Algiers from Biskra was broken at Batna for the purpose of visiting the fine forest of cedar (*Cedrus atlantica*) in the mountains not far from the town. When Biskra was revisited, in the spring of 1911, the northern portion of Algeria was crossed on the way from Tunis, this affording an opportunity to observe something of the picturesqueness of the mountainous regions as well as the spring flora.

I wish to take this early opportunity to acknowledge my appreciation of assistance received from different persons during the course of the Algerian study, or as a means of preparing for it. I am especially indebted to Prof. H. J. Hall, of Leland Stanford University, who was my companion in Algeria and whose knowledge of the American deserts made his advice doubly valuable. Dr. Keltie, secretary of the Royal Geographical Society, provided letters and information of much use. Dr. Trabut, government botanist of Algeria, whose acquaintance with the country is extensive, very kindly identified all plants sent him and gave valuable aid in other ways. The map (plate A) was prepared expressly for this study by Mr. Godfrey Sykes.

In a country where travel away from the beaten path is not without discomfort, it is important that the way be made as smooth as possible, not alone for comfort but for personal safety as well, and it is therefore a pleasure to acknowledge the many kindnesses shown by the civil and military authorities of the French colony, as also by the American consul and vice-consul at Algiers.

GEOGRAPHICAL CHARACTERISTICS OF ALGERIA.

The French colony of Algeria is of large extent and possesses a highly varied topography and great range in climate. With an all-land connection with the continent of Europe in earlier geologic times, the flora and fauna of this portion of northern Africa are closely allied to the fauna and flora of southern Spain, France, and Italy.

Algeria lies to the south of the Mediterranean Sea, between Tunis to the east and Morocco to the west. The northern portion extends somewhat beyond latitude 37°, or that of southern Spain, southern Greece, and the southern part of Asia Minor. The limit of the colony on the south is indefinite, reaching to about latitude 21°. Thus east and west the extent is about 650 miles, and north and south 1,200 miles.

The most important topographical features of the northern part of Algeria are the several mountain masses which together constitute the Atlas range. Lowest in Tunis, where the Atlas Mountains do not exceed 5,000 feet altitude, they attain their greatest height in Morocco, over 13,000 feet. In Algeria an altitude of about 7,500 feet is reached in the Aurés, Dj. Chelia, and in the Great Kabylies. In the eastern portion of Algeria the mountains extend to the coast, but farther west a narrow strip of lowland separates them from the sea. In the east (in the department of Constantine) they constitute a single general uplift, although made up of several groups, but as one proceeds westward the mountains separate into two ranges, which at the Morocco border are about 125 miles apart. The two ranges have been called by various names, among which are the Great Atlas for the southern range and the Little or Maritime Atlas for the northern one. But it seems best to use the names Atlas of the Sahara or Saharan

Atlas and Atlas of the Tell or the Tellian Atlas, names which are self-explanatory. The Tellian Atlas and all territory between this range and the Mediterranean Sea is known as the Tell, or the land of hills. This is the most important part of Algeria from an agricultural standpoint, and furnishes grain and other products. Here also are the most important forests, oak, pine, and cedar. Between the two ranges of the Atlas lies the region of the steppes or plateaus, in this study referred to as the High Plateau, inasmuch as the average altitude is over 3,000 feet. The steppe region is highest in the west and is wedge-shaped, in conformity to the bounding mountains. In the eastern portion it breaks up into mountain valleys. The topography of the High Plateau is monotonous. The surface is gently rolling, and here and there are undrained depressions, or *chotts*, where salts accumulate. In rainy seasons the chotts contain water, but in the arid summers they are dry. The region of the steppes is of no agricultural value, although, as will appear below, the harvesting of the alfa grass, which occupies vast areas, is of considerable importance.

South of the Saharan Atlas lies the desert, comprising about 2,000,000 square miles, the topography of which is extremely varied. For present purposes it is sufficient to say that in the extreme southern portion of the Algerian Sahara, and crossed by the Tropic, there is an extensive highland, the plateau of Idghagh, where an elevation exceeding 5,000 feet is reached. All of the Sahara to the west of this plateau, or to the west of a line drawn north from it, appears to be above sea-level (much of it having an altitude of 1,000 feet), and of greater geological age than that portion of the desert lying to the east. North from the plateau of Idghagh the country gradually descends to the depression of which the great Chott Melghir is a part, a region below the level of the sea. Here extends also one of the longest oueds of the Sahara, the Oued Igharghar, which takes its rise in the plateau of Idghagh and empties in the Chott Melghir, an entire length exceeding 700 miles. In the western part of the Sahara the surface descends to the Atlantic, but in the eastern part it falls away to the Mediterranean.

Turning now to consider the part of southern Algeria with which this study especially deals—lying between Laghouat and Ghardaia, between Ghardaia and Ouargla, and between the latter place and Biskra, all to the south of the Saharan Atlas—we find topographical details which are probably representative of much of the rest of the Great Desert. Laghouat has an elevation of 2,400 feet. It lies on the northern edge of the region of the dayas. This region is characterized by the poor development of its drainage and has a slightly undulating surface with frequent depressions, each the center of an area of rather small extent, from which it receives flood-waters. The dayas differ from the other undrained areas, the chotts, in that they do not contain an excess of salt, owing probably

to efficient subdrainage. In the region of the dayas the surface falls away to the south or the southeast until the region of the Chebka is reached, which extends to the territory of the Beni M'Zab. In the Chebka low and flat-topped mountains are so irregularly disposed as to give rise to the name, meaning a net; they are separated by valleys, narrow toward the northern portion of the region, but expanding into small plains as one proceeds towards Ghardaia. Ghardaia, the country of the Beni M'Zab, marks the southern limit of the Chebka. At Ghardaia the altitude is 1,600 feet. Between Ghardaia and Ouargla are undulating stony plains, the Gantara (*hamada*), large salt spots, the chotts, and a prominent range of sand mountains, *areg* desert, possibly 1,000 feet high. At the eastern edge of the Gantara the general level of the country drops suddenly about 200 feet to the Ouargla plain (*reg* desert), with an altitude less than 500 feet; this is an eroded flood-plain of the Oued Igharghar or its tributaries.

There are no navigable rivers in Algeria. The most important river is the Chelif, which takes its origin in the Saharan Atlas, crosses the High Plateau, breaks through the Atlas of the Tell, and, turning westward, traverses obliquely the Tell for a distance of about 108 miles before discharging into the sea. The Chelif is the only stream which rises in the Saharan Atlas and pierces the northern range. To the south of the Saharan Atlas are several important oueds. One, the Oued Djedi, rises near Aflou and goes easterly, past Laghouat, until it reaches the Chott Melrir, south of Biskra; two others, the M'Zab and the Nessa, drain the region of the Chebka, and taking an easterly or a southeasterly direction reach the Oued Rirh or its upper extension. The Oued Rirh constitutes the northern portion of the great Oued Igharghar, or a tributary of this oued, and extends about 60 miles north from Touggourt to the Chott Merouan. The region of the Oued Rirh is of great economic importance from the production of dates, made possible through the development of artesian wells by the French government. The oueds as a whole are very like the arroyos of the southwestern portion of the United States, in that they carry water for a small portion of the year only, when the torrential rains fill them with a muddy, rushing flood.

In the plains adjacent to the oueds, at Ghardaia especially, the natives usually dig their wells, from which water for domestic as well as for irrigating purposes is obtained. The flood-water of the oueds is also diverted into ditches, or impounded for later use, although the latter has not met with uniform success. The depths at which water has been found vary greatly. At Ouargla the water lies within 3 feet of the surface, although there are also very deep artesian wells, and at Ghardaia it varies from 10 to 50 feet or more. At the daya of Tilrempt the water in the deepest wells stands as deep as 300 feet; it is drawn in a very primitive fashion for purposes of watering flocks and for the bordj. The heaviest vegetation is to

be found along the oueds and the nearby flood-plains. Here the water relations are the most favorable and the oueds constitute highways along which plants venture into the desert from the more humid regions.

Very little study appears to have been given the soils of Algeria. It has been stated that there are vast areas of light, sandy soils, and also extensive tracts of marls, clays, and alluvial soils.* Gypsum is an important element in the soils, both those of the oases and probably of the open desert also; it occurs in great quantity in the large chotts of the desert, along with common salt and other salts. In the soils of the oases it acts as a cementing material, "uniting the finer soil-grains into aggregates which give the soil a much more sandy appearance than would be suspected from the results of mechanical analysis." At Laghouat and at Ghardaia a light-colored, hard substance, closely resembling the "caliche" of the southwestern United States, was seen incrusting stones, filling cracks in rocks and crevices between rocks, and in places forming a stratum, horizontally placed (15 cm. more or less in thickness) underneath the superficial soils. This is extremely hard and can be broken or cut with difficulty. In the valley of the M'Zab, where it constitutes a heavy substratum, it appears to be impervious to water. This hardpan is used as threshing floors by removing the superficial soils.

An unexpectedly small amount of sand was observed over the route traversed. Near the southern edge of the High Plateau a sand belt was encountered and a long stretch of low dunes was seen leading to the eastward, which were said to reach nearly to Bou Saada; and again at Laghouat there are dunes to the east of town as well as to the west. Low dunes were seen in the valley of the Oued M'Zab, and sand mountains, possibly 250 meters high, were passed on the way from Ghardaia to Ouargla. Between Ouargla and Touggourt, also, sand was encountered and the way lay across about 12 miles of low dunes; to the north of Touggourt dunes are also to be seen; and finally, some sand is to be found in the neighborhood of Biskra. Although, thus, relatively little sand was met, much of the entire portion of southern Algeria is covered by sand. Large areas of sand-covered country lie to the east of the Oued Rirh, and especially southeast of Touggourt, and also to the west of Ghardaia there is said to be a large dune-covered territory. For the most part, however, the surface of the plains crossed is covered with large or small stones, mingled with which, or beneath which, there is a rather fine clay-like soil. This constitutes the hamada, or stony desert, of which the largest portion of the surface of the Sahara is probably composed. Where stones are largely absent and the soil is fine, usually of fluvian origin, the formation is known as "reg." Reg desert was encountered at and north of Ouargla, in the drainage of the Igharghar or its tributaries, and south of Biskra. The latter may not,

*Kearney and Means, Agricultural explorations in Algeria, Bul. No. 80, Bur. Plant Ind., U. S. Dept. Agric., 1905.

strictly speaking, be reg, but a wide-stretching bajada, and the soil is probably only in small part deposited by rivers.

CLIMATE OF ALGERIA.

The climate of Algeria is mild and temperate. This is due to several factors, among which are its situation relative to the Mediterranean on the north and to the Atlantic on the west, as well as to the great desert which constitutes its southern portion, the great variation in topography, and the fairly low latitude. Taking the colony as a whole, there is a great range in temperature, precipitation, relative humidity, and evaporation, to mention only such climatic features as have been reduced and are recorded; and the range in the intensity and in the quality of the light must also be great. The climate of the northern portion of Algeria is coastal, while that of the southern portion is continental.

The distribution in time and in space and the amount of precipitation are of the greatest importance as climatic features of Algeria. The rainfall is heaviest on the littoral, and especially heavy in the eastern portion of the littoral. An average of 1,000 mm. is reported from the immediate vicinity of the sea,* and as one goes southward the amount of precipitation rapidly becomes less. In the Tell the average rainfall is 570 mm., while on the High Plateau it is 310 mm. On the desert the rainfall is uncertain both in amount and in time, except that when rains occur the time coincides with the rainy season of northern Algeria. At Biskra the annual precipitation is 199 mm., at Laghouat it is 198 mm., at Ghardaia it is 114 mm., and at El Golea it is 47 mm. In many places in the western Sahara, five years or more go by without fall of rain.

The differences in the geographical distribution of precipitation vary from year to year, as may be illustrated by referring to that for the year 1908, which may be compared with the normal usual distribution as given above. In the northern portion of the country more rain than usual was reported; for example, there was over 1,000 mm. on the littoral east of Algiers, and over 500 mm. on the High Plateau, but on the desert the amount was somewhat less. At Laghouat it was 161 mm., at Ghardaia it was 89.2 mm., and at Ouargla it was 28 mm.

Besides the differences in amount of yearly rainfall, well-marked seasonal amounts of precipitation are also to be noted. In the northern portion of the colony rains are likely to occur in winter and spring, the summer and early autumn being dry; and as one goes south of the Saharan Atlas nearly the same conditions obtain; that is, the rains usually fall during the rainy season of the coast. The seasonal distribution of rain for the Tell, including the stations of the littoral, the High Plateau, the Saharan Atlas, and the desert, for a series of years including 1908, is given in table 1.

* A. Engler, Die Vegetation der Erde IX. Die Pflanzenwelt Afrikas. 1 Bd., 1910, page 902.

TABLE I.—*Seasonal distribution of rain.*

Season.	Tell (10).	High Plateau (8).	Saharan Atlas (10).	Desert (6).	Remarks.
	mm.	*mm.*	*mm.*	*mm.*	
Winter..	469.9	119.3 (50.8)	113.5	37.4	The Tell is represented by Fort National; the High Plateau by Geryville (with Ain Sefra, for 6 years, in parentheses); the Saharan Atlas by Djelfa; the desert by Ouargla. The number of yearly records on which averages are computed are given at the head of each column in parentheses.
Spring..	300.0	80.5 (95.0)	88.2	39.0	
Summer	38.1	66.5 (35.8)	50.4	3.7	
Autumn	287.2	139.5 (58.5)	123.1	19.6	

The seasonal percentages of precipitation give a more graphic conception of the rainfall conditions for the four physiographic provinces. In the Tell this percentage in winter is 42, in spring 27, in summer 4, and in autumn 27. On the High Plateau the percentages are 30, 20, 16, and 34 for the four seasons respectively. In the Saharan Atlas 30 per cent of the rain occurs in winter, 24 in spring, 13 in summer, and 33 in autumn. In the desert the percentages of rainfall are 37, 39, 4, and 20* for the four seasons.

It is of interest also to note the number of days on which the rain fell on an average each year over a period running from 7 to 12 years. Thus at two typical stations on the Tell rain was reported on 102 and 118 days; at two stations on the High Plateau it rained 65 and 83.8 days; at a station in the Saharan Atlas rain was reported on 70 days; at desert stations, at Ouargla rain fell on an average 14.2, and at Laghouat 49 days each year. As a comparison, it may be mentioned that for ten years at Wady Halfi, Egyptian Sudan, there were only 22 days on which rain-drops were seen to fall. (Engler, *loc. cit.*)

The amount of precipitation varies greatly for the different desert stations, usually becoming less as one goes south from the High Plateau. As has already been mentioned, the average rainfall at Laghouat, which lies at the southern base of the Saharan Atlas, is 198 mm., the average at Ghardaia is 114 mm., while that at El Golea is 47 mm. The latter station is about 225 miles south of Laghouat, in the midst of the Sahara. The amount of rainfall, however, is greatly influenced by altitude, although lack of adequate precipitation data for the desert makes impossible a detailed presentation of this phase of the subject. As the amount of the yearly precipitation is less in the extreme southern part of Algeria than it is nearer the Saharan Atlas, where the altitude also is greater, it might be expected that the number of rainy days would vary in a like manner. Such records as are at hand, however, do not show this to be the case. For instance, at Ouargla rain falls on an average 14.2 days, average of 7 years,

* The seasonal distribution of rain (by percentages) is somewhat different from that given by Engler, which is given in the accompanying table.

Season.	Littoral.	Tell.	High plateau.
Winter..	41	36	45
Spring..	27	32	46
Summer.	4	7	11

while the rainfall is 90.2 mm.; yet at El Golea, with a rainfall of 47 mm., there are 23.4 rainy days each year.*

On the desert the rains are often of a torrential nature, as facts presented above would indicate, and sometimes as much rain falls within a few hours, or even a few minutes, as usually occurs in an entire year. How much of the annual precipitation is of this character and how much is of the non-torrential kind the usual summaries leave entirely out of the account. It is well known that the former type of storm is more destructive and less useful to plants than the latter type. To illustrate the irregularity of the rainfall in the northern Sahara the monthly precipitation at Ouargla for several years is presented in table 2.

TABLE 2.—*Rainfall at Ouargla, in millimeters.*

Year	Amt.	No. of days rain	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1900	0	1	0	0	0	0	0	0	0	0	0	0	0	0
1901	...	18	...	...	...	...	...	...	..	...	...	...	...	...
1902	70.5	8	0	0	11.3	0	0	0	0	1.8	0	46.4	11.0	0
1903	135.6	14	55.0	0	0	0	0	0	0	0	0	0	30.6	50.0
1904	35.0	26	20.0	0	0	0	0	0	0	0	0	9.0	4.0	2.0
1905	...	...	...	...	...	...	...	...	..	...	...	...	...	...
1906	...	...	15.0	0	2.0	4.0	0	0	4.0	80.0	41.0	80.0	...	...
1907	210.0	18	0	68.2	67	325.0	16.2	20.0	0	0	5.0	3.3	3.8	1.3

The seasonal distribution of rainfall at four desert stations shows also marked irregularities. The distribution (in percentages) is given in table 3.

TABLE 3.—*Seasonal distribution, in percentages, of rain.*

Station.	Winter.	Spring.	Summer.	Autumn.
Ouargla.....	37	39	4	20
Laghouat.....	11	27	31	31
Ghardaia.....	15	23	13	49
Touggourt.....	13	30	3	53

The relative humidity at the desert stations is often very low, sometimes running in midsummer between 7 and 9 per cent for 6 days, and occasionally being too low to measure with the instruments employed. The mean relative humidity (table 4) shows the general very dry condition of the air of the desert as contrasted with a station in the Tell, and also indicates something of the monthly variations in this factor experienced among the desert stations themselves. The averages given are from 4 to 8 years, except the mean annual for In Salah, which is for 2 years only.

TABLE 4.—*Mean relative humidity, in percentages.*

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Ouargla.....	61.0	58.6	60.3	51.2	52.0	49.0	44.1	44.7	50.7	56.8	59.1	52.7	54.6
El Golea.....	60.8	56.8	41.3	41.3	41.0	31.3	28.5	31.8	34.8	37.1	58.1	65.1	45.5
In Salah.....	51.5	48.0	45.5	40.4	34.6	32.0	23.4	24.6	17.2	38.0	52.2	58.7	42.6
Ft. National.....	87.4	80.3	87.6	86.6	96.6	80.4	75.8	62.8	80.2	87.7	92.8	88.4	85.1

* The most recent records available, 1897–1908, do not give a satisfactory account of the precipitation on the desert. For instance, meteorological records covering eight years for El Golea do not report on the rainfall. Records of five years at In Salah take the rainfall into account on one year only, and on that year no precipitation occurred.

A consideration of the evaporation statistics of Algeria for the year 1908 shows some interesting relations. It has already been observed that the rainfall along the coast is less in the west than in the east, and it will appear below that as a rule the temperature of the western portion is lower than that of the corresponding regions lying to the east. In both rainfall and temperature, however, the greatest variation is to be found as one goes inland, when decreasing rainfall and higher temperatures are encountered. A similar relation obtains in evaporation, which becomes continuously greater as the distance from the coast increases; that is, the average evaporation for stations on the High Plateau is greater than for stations in the Tell, and the evaporation at desert stations is greater than the evaporation on the High Plateau. The total average evaporation for the year, in millimeters, for 5 stations on the littoral, was 1,365.3; for 7 stations in the Tell it was 1,378.6; for 4 stations on the High Plateau 2,352.2, and for 3 stations in the desert, 3,977.5. The least evaporation reported was at Bouzarea, which was 989.9 mm., and the greatest was at Ghardaia, 5,309.7 mm.*

Table 5 gives in detail the monthly as well as the total evaporation for the year at three desert stations and at Algiers for 1908.

TABLE 5.—*Evaporation in millimeters*, 1908.

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Laghouat.....	88.9	102.3	143.4	203.1	289.2	373.9	421.2	379.6	264.8	173.9	153.8	159.2	2753
Ghardaia.....	172.4	233.4	340.7	528.7	611.7	699.1	749.2	693.0	468.8	329.4	257.7	225.5	5309
Touggourt.....	....	163.9	240.5	274.3	385.2	459.4	565.8	487.3	329.4	222.6	166.1	142.3	....
Algiers.....	84.2	96.8	90.5	118.3	151.8	158.6	175.0	205.0	165.5	129.0	136.1	143.2	1654

For a better personal appreciation of the rate of evaporation, as well as for the purpose of comparison, I arranged an apparatus to tell the water-loss from a free water-surface. It was also desirable to determine the relative evaporation of the day and night. As employed, the apparatus consisted of a flat tin dish, with parallel sides, 10 cm. in diameter. To the side was attached, by means of a rubber stopper, a bent glass tube of small diameter. The water-loss was read on this tube. Observations were made at Laghouat and at Ghardaia. Following is a summary of the results obtained at Ghardaia: For a period of 7 days, after November 10, the daily water-loss between 7 a.m. and 7 p.m. was as follows: 5, 8, 8.5, 10.5, 13, 9, and 7.5 mm. The evaporation between 7 p.m. and 7 a.m. was so slight, 1 mm. more or less, that it could not be well determined by the apparatus used.

A good idea of the intensely arid character of the Algerian climate, taken as a whole, is to be obtained by a study of the relation between the total

* Unless otherwise stated, the climatological statistics given in this paper were taken or compiled from Observations Météorologiques du Riseau Africain, 1907–1908. The evaporation data are based on readings of the Piche evaporimeter. The amount of evaporation given in the text can be reduced to the evaporation from a free-water surface by multiplying by 0.737 (Meteorological Notes, J. I. Craig. Cairo Scientific Journal, vol. VI, May 1912).

rainfall and the total evaporation, based on the official climatic reports. In tables 6 and 7 the report for the year 1908 is used. The figures represent the ratio $\left(\frac{e}{r}\right)$ between evaporation and rainfall, in which the amount of evaporation is used as the numerator and the amount of precipitation as the denominator. In the monthly evaporation-rainfall table (table 6), in all cases where no rainfall was reported for the month it was called 1 mm. In table 7, however, which gives the seasonal evaporation-rainfall ratio, the actual figures of the government report were in all cases employed, since there was no season during the year 1908, even in southern Algeria, when no precipitation occurred.*

TABLE 6.—*Evaporation-rainfall ratio, monthly*, 1908.

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Nemours	1.07	1.3	1.39	1.9	131	5.4	23.6	43.3	8.6	3.1	10.6	5.7
Cape Falcon	1.5	1.8	1.46	16.0	8.8	10.3	29.7	136.0	38.1	1.9	8.9	2.2
Oran	1.3	1.9	1.6	1.3	17.4	8.5	59.0	146.0	18.0	2.45	3.4	4.4
Algiers	0.63	1.3	0.5	1.1	22.3	11.7	219.0	28.8	5.07	1.06	1.2	1.1
Bouzarea	0.57	0.67	0.22	0.56	8.3	4.8	53.7	27.1	3.4	0.2	0.76	0.5
Maison-Carée	0.72	0.64	0.55	1.1	13.5	11.8	149.0	12.0	5.2	0.9	0.35	0.51
Ft. National	0.72	0.29	0.34	0.58	3.7	192	42.5	15.5	2.7	1.6	0.71	0.16
Sidi-bel-Abbès	0.63	0.76	0.6	1.1	18.8	18.5	77.8	37.8	14.8	1.4	1.9	0.8
Saida	0.67	0.64	0.36	0.83	2.2	6.9	86.7	12.1	4.7	5.8	1.2	0.78
Batna	1.6	2.3	1.5	2.5	46.5	33.4	24.4	7.6	3.5	4.9	2.6	1.6
Tebessa	4.6	6.05	21.2	3.9	252.0	2.8	9.8	14.8	1.1	3.9	3.5	3.7
Bou Saada	4.05	5.4	12.1	2.9	6.1	165	43.5	19.5	8.3	13.9	5.6	8.3
Barika	2.4	8.7	9.9	5.0	5.03	270	6.1	4.1	11.4	3.7	90.6	1.3
Ain Sefra	9.2	21.5	1.5	23.8	12.4	63.1	16.4	124.0	328.0	14.7	13.2	1.2
Geryville	6.3	1.9	2.1	23.9	2.5	16.7	22.5	23.4	3.4	2.1	4.1	3.9
Laghouat	3.09	4.7	9.8	203.0	7.0	373	421.0	21.0	25.9	14.2	154.0	104.0
Ghardaia	8.9	233.0	81.4	529.0	38.9	699	166.0	25.6	66.9	23.2	49.7	225.0
El Oued	53.9	27.7	67.0	629.0	369.0	465	509.0	482.0	68.6	46.1	215.0	123.0

TABLE 7.—*Evaporation-rainfall ratio, seasonal*, 1908.

Station.	Winter.	Spring.	Summer.	Autumn.	Annual.
Littoral:					
Nemours	2.69	44.09	24.1	7.4	3.0
Cape Falcon	1.83	8.75	58.6	16.3	3.7
Oran	2.54	3.7	71.0	7.95	4.2
Algiers	1.0	7.96	86.4	2.44	1.8
Bouzarea	0.58	3.0	28.5	1.45	0.93
Maison-Carée	0.62	5.0	117.4	1.48	1.5
Tell:					
Ft. National	0.39	1.4	83.2	1.67	1.1
Sidi-bel-Abbès	0.73	8.2	38.3	6.0	2.2
Saida	0.69	1.0	3.5	3.9	1.9
Batna	1.8	2.1	0.35	3.6	4.4
Tebessa	4.7	4.05	88.2	2.8	6.0
High Plateau:					
Bou Saada	5.9	7.0	76.0	9.2	11.0
Barika	4.1	6.6	93.5	35.2	12.2
Ain Sefra	1.4	12.5	67.9	18.5	11.1
Geryville	7.0	9.8	20.8	3.2	3.5
Desert:					
Laghouat	6.0	73.2	271.6	64.6	17.0
Ghardaia	154.9	416.3	293.7	195.9	59.7
El Oued	68.3	354.0	485.2	109.5	63.0

When we reduce the evaporation-rainfall ratios of the different physiographic provinces to simple expressions we gain a comprehensive view of

* At Touggourt, however, no rain was reported during the summer season of 1908.

this important climatic factor for the colony as a whole. Thus the annual evaporation-rainfall ratios are as follows: the littoral, 2.5; the Tell, 3.5; the High Plateau, 9.4; the desert, 46.5. The relation of these expressions may also be given thus: 1 : 1.4 : 3.7 : 18.6, for the several regions above given, by which we see how rapidly the aridity of the country increases as the desert is entered. The present custom of considering the southern base of the Sahara Atlas as the northern edge of the desert, in place of including the High Plateau, as was done earlier, is thus well grounded.

The temperatures of the air vary greatly for the different regions, and usually the variation is to be directly related to the positions of the stations as regards the coast and the altitude. Along the coast, however, the temperatures vary even if the stations are at approximately the same elevation. The mean annual temperature at Oran is 16.9° C. and at La Calle 17.7° C., while a study of the January temperatures shows that a similar relation holds good for the entire south coast of the Mediterranean, between Oran and Alexandria. Algiers furnishes one exception to this statement, in that the mean annual temperature is 18.1° C. On the High Plateau the mean temperature falls to 12.7° C. (Batna) and 13.5° (Setif). No records appear to have been made for the high mountains of eastern Algeria, although the fact that snow may remain in sheltered places as late as the latter part of July* would indicate that the mean temperature at 2,000 meters elevation is much lower than any above given. On the Algerian Sahara the mean annual temperature is usually higher than at any point nearer the coast, but even here there is considerable variation, depending, among other factors, on the altitude of the stations and their relation to the Atlas. The mean temperature is given by Engler as 20.5° C. for Biskra, 21.0° C. for Ghardaia, and 22.2° C. for El Golea. As increased temperature means increased evaporation, we have in this one factor a powerful agent making for aridity, and when this is associated with decreasing rainfall, as one leaves the coast region, its influence as a determinative factor in the environment of plants is thus seen to be of great importance.

The annual variations in the temperature of the air are very considerable throughout the colony and are especially great on the desert and the High Plateau. At Algiers the variation is 40.7° C., at Setif it is 48.2° C., and at Ghardaia it is 47.9° C. An annual absolute variation of 50° C. is not uncommon on the desert, and Engler cites a range of 57.0° C. at Ghardaia.

The daily range of the temperature is also considerable for all stations, but is especially marked in those of the High Plateau and the desert. The daily range as given by Engler for the former is 17.4° C., and for the latter 20.0° C., but the range on the High Plateau may be greater than 17.4° C., especially during the summer months. For example, at Batna, in 1904, a

* Kearney and Means, *loc. cit.*

range of 19.4° C. was reported in April, 20.2° C. in June, 21.8° C. in July, and 20.2° C. in December. Except in December, the great ranges in temperature here cited were on days when the sirocco was blowing from the desert; hence, the usual daily range in temperature would be much less. In the Tell, and especially along the coast, the range in temperature recorded for any day is relatively little, although at the time of the sirocco, as well as during the season of drought, the daily range is not inconsiderable. Table 8 gives the maximum daily range for the months of 1904, for two stations, along the coast, including the Tell, and two stations on the High Plateau. The daily range reported for Batna in June, July, and August, 1902, was somewhat larger than the maxima given in table 8. In 1902 the maximum daily ranges in temperature for the three months at Batna were 23.9° C., 25.3° C., and 24.4° C.

TABLE 8.—*Maximum daily range in temperature*, 1904.

Station.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Algiers	9.0	13.0	13.0	13.6	12.7	13.0	15.0	15.4	11.2	14.0	10.8	10.6
Ft. National	10.4	13.8	13.0	12.4	13.0	12.8	12.4	14.8	16.4	11.2	11.6	11.0
Batna	11.5	15.4	16.4	19.4	...	20.2	21.8	16.4	16.0	19.4	...	20.2
Saida	14.0	17.0	14.0	18.0	18.0	19.0	19.0	18.0	18.0	14.0	13.0	13.0

The temperature conditions for the year 1908 will serve very well to further illustrate this phase of the climate of Algeria. No freezing temperatures were reported from the coast stations, although at the northern base of the Atlas of the Tell several degrees of frost were recorded. At Blida, for example, the thermometer registered −4.0° C. as the minimum. Away from the littoral at every station whose records were seen the lowest temperatures were zero centigrade, or below. The coldest weather was felt at Aflou, at the north base of the Dj. Amours, of the Saharan Atlas, where −11.0° C. was reported. The summer was warm along the coast and hot in the interior. The records of temperature of 23 stations of the Tell were seen, and of this number, at only 8 was a temperature of 40° C. reached or exceeded. On the other hand, at 44 out of 56 stations on the High Plateau and the desert, the temperatures reported are as great or greater than 40° C. Where temperatures below this figure were recorded the stations were situated in the mountains.

The western portion of the Sahara is apparently not so hot as the eastern portion. The mean annual temperature for Biskra is 20.3° C.; for Ghardaia it is 21° C.; for El Golea it is 22.2° C.; and for Touggourt it is 23.4° C. The mean temperature at Cairo is 21.3° C.; for Suez it is 21.5° C.; and for Djedda, on the Red Sea, it is 27.3° C. The absolute maximum temperatures in southern Algeria for as many years and for two of the most southern army posts, El Golea and In Salah, are as follows: El Golea, 47°, 46.5°, 48°, and 49.2° C.; In Salah, 50.0°, 49.2°, 50.2°, and 48° C.; at Ouargla the

maxima are 50.2°, 51°, 52°, 49°, and 48.4° C. On account of the fact that in the western Sahara at these stations in winter there are usually freezing temperatures, the yearly range of temperature is 50.0° C., or over. The greatest range reported for the western Sahara is that for Ghardaia as given by Engler, namely, 57°, from −7° to 50° C. At Timmimoun, 1904, the range was from −3.0° to 53.1° C., or one of 56.1° C. The extreme absolute daily range in temperature on the desert appears not to exceed that of certain stations on the High Plateau, although, as shown below, the temperature variations on the desert may be much larger than the records indicate. At Laghouat and at Ghardaia the thermometers which I exposed showed a daily range of from 10.5° to 12.5° C. only. The instruments were placed on the outside of buildings, and usually on the second story. As a contrast to this observed diurnal variation, an opportunity was given to take temperatures on the open desert at a time when the days were fairly warm and the nights were rather cold. The place was between Touggourt and Ouargla. At 3 o'clock on the afternoon of November 26, 1910, the shade temperature at the place in question was 23° C. During the night the thermometer registered −1.7° C. as the minimum, thus showing a drop of 24.7° C. in something over 12 hours. Table 9 gives the extreme daily range in temperature for three years observed at the stations named.

TABLE 9.—*Absolute daily range in temperature.*

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
In Salah.....	21.6	23.0	24.4	24.6	22.0	23.2	23.4	22.0	29.0	20.0	23.4	22.6
Ouargla.....	20.8	25.4	24.0	25.0	27.0	26.0	26.0	27.8	24.6	23.0	20.0	23.8

A further examination of the maximum temperatures shows certain climatic features of interest and of great importance as factors in the environment of the desert plants, especially the high average maxima and the large amount of heat received in the desert, as indicated by a summation of the maximal temperatures. That the greatest daily temperatures must be high is indicated by table 10, which gives the average maxima for three to five years at three typical desert stations.

TABLE 10.—*Average maximum temperatures.*

Station.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
Ouargla.....	21.9	18.3	30.9	37.8	41.1	47.1	49.4	47.7	44.3	40.0	31.0	25.0
El Golea.....	23.0	25.8	35.6	27.5	40.9	44.4	47.5	46.0	43.8	36.7	29.9	22.4
In Salah.....	27.4	30.1	37.2	41.0	43.4	47.6	44.3	47.1	45.9	41.3	37.0	27.1

The maximum temperatures show that the total amount of heat received on the desert, as compared to that received in the climatic provinces nearer the sea, is not only great, but also that the amount is variable on

the desert itself, one station receiving much more heat at certain times of the year than another station. The total heat for each station is arrived at by adding up the daily maxima for the midseasonal months, January, April, July, and October, and dividing by the number of years whose records were consulted. The amounts given in table 11 are the averages for three to four years, for three desert stations and for one station in the Tell.

TABLE 11.—*Sums of the daily maximum temperatures.*

Station.	January.	April.	July.	October.
	° C.	° C.	° C.	° C.
Laghouat	439	476	1,135	668
In Salah	641	1,027	1,455	1,121
Ouargla	570	909	1,444	923
Ft. National	230	470	697	564

The variation in total heat received at the three desert stations may probably be explained partly at least by their differences in latitude and in elevation above the sea, as well as the different relations they hold to the highlands of the northern portion of the colony. Laghouat lies immediately south of the Saharan Atlas, latitude 33°48′, and at an elevation of 780 meters. Ouargla is approximately 200 miles south of the mountains, latitude 31°55′, and altitude 150 meters. In Salah is in the midst of the western Sahara, latitude 27°17′, and about 300 meters above the sea. Fort National lies in the Tell about 30 miles from the sea, and at an altitude of 916.3 meters. The latitude of Fort National is 36°38′.

There are no published records of the soil temperatures of southern Algeria. In the following table is given soil-temperature data taken at Ghardaia by M. Buret. Maximum and minimum standard chemical thermometers were used. They were placed in a horizontal position in fixed tubes which were about 30 cm. in length. Precautions were taken to properly insolate the instruments. The depth was 15 cm.

TABLE 12.—*Soil and air temperatures, Ghardaia, July 2–11, 1911.*

Date.	Soil.		Air.	
	Maximum.	Minimum.	Maximum.	Minimum.
	° C.	° C.	° C.	° C.
July 2	36.0	31.0	41.0	21.0
July 3	36.0	31.0	41.0	22.0
July 4	36.0	31.0	41.0	23.0
July 5	36.5	31.5	41.0	25.5
July 6	33.7	32.0	41.0	25.0
July 7	36.0	32.5	40.0	26.0
July 8	36.0	32.5	38.0	26.5
July 9	37.0	...	...	25.0
July 10	37.0	32.5	40.0	24.0
July 11	...	33.0	...	23.0

An examination of the meteorological reports for Algeria shows that the direction of the prevailing winds varies considerably, although the variation is possibly greater near the coast than in the interior. The winds un-

doubtedly play an important rôle in the environment of the vegetation of the country At Algiers, in 1907, winds were reported from the north 288 times, from the east 203 times, from the west 224 times, and from the south 51 times. At Barika, on the High Plateau, the number of times and the directions of the winds for the same year are as follows: northeast, 203 times; east 242; south 21, west 89, and southwest 93. At El Golea, on the desert, the winds were as follows: north 192, northeast 614, southeast 107. The winds from the north, or northerly winds, are cool and laden with moisture, but they are most effective in regions near the coast or in the mountains. Winds from the south are dry winds, and are probably of great importance in limiting the distribution of plants through the increased aridity caused by them.

The most important of these desert winds is the sirocco, a wind that is most likely to blow in spring and summer, although occurring in autumn also, and to a very limited degree in the winter season. The sirocco crosses the Mediterranean and is felt in the southern portions of France, on the Italian Riviera, and in other parts of southern Europe. It is especially common on the High Plateau; for example, during five years it was reported on an average of 28.4 days each year. It does not generally last more than three days, but at Batna, in July, 1902, it was recorded on eight consecutive days. The sirocco operates to lower the relative humidity and to raise the temperature. For instance, on the first day of the eight-day sirocco above alluded to, the average relative humidity was 16 per cent, while the average on the preceding day was 25.6 per cent. It has already been remarked that on the days of the greatest temperature variation the sirocco was usually blowing. In the desert the winds often bring with them much dust and sometimes last during several days; for example, one is reported at In Salah, in May, 1904, for six consecutive days. Such winds on the desert may come from the north, or at least may be northerly, and when storms of this character are in progress, although possibly destructive of animal life or at least comfort, the effects as regards decreasing the relative humidity and raising the air temperature are not so marked as is the case when the sirocco is blowing.

SOME CHARACTERISTICS OF THE VEGETATION OF THE TELL.

Because of the similarity in the flora of Algeria and southern Europe, a very good introduction to Algeria is by the way of southern Spain, France, or Italy. As one approaches southern France, for instance, he begins to see evidences of increasing aridity. Upon passing Lyons grassy fields and heavy forests are left behind, the hills become bare or covered with a chaparral-like growth, and the practice of irrigation is observed on the plains. The vegetation, especially of the region between Avignon and Nimes, recalls that of portions of California, and one sees the mulberry, the olive, and the pomegranate in abundance, and occasionally the orange.

Very much the same conditions greet one when he arrives in Algiers, except that along the littoral, at and in the vicinity of Algiers, there is a wealth of native and especially of introduced plants, which give little hint of the arid regions close at hand. The hills which make a part of the beautiful city of Algiers contain fine plantations of foreign trees, such as eucalyptus, conifers of various species, acacias, figs, and a variety of fruit trees like the apricot, peach, plum, apple, almond, orange, and others. In the fine public squares one sees large palms also, and in the botanical garden are bamboos, palms, bananas, India-rubber trees, and a large number of forms from the subtropics. The great variety of introduced plants which appear to thrive on the littoral again recalls portions of California, where the kinds and numbers of introduced plants which grow well are likewise large, and where the floral strangers are gathered from the antipodes. But among the species there are also many natives to the colony and which one will see when he begins to travel away from the coast; for example, the cedar from the higher mountains (*Cedrus atlantica*) and the fine pine (*Pinus halepensis*) from lower altitudes; there are junipers and oaks, among the latter the cork oak (*Quercus suber*), and fine specimens of *Pistacia atlantica* and its protector the jujube (*Zizyphus lotus*), the relationship of which will be given later in this paper. Both of the last-named species are native to the Sahara and are of rather frequent occurrence in the regions visited.

Upon leaving Algiers one soon encounters a striking change in the character of the vegetation, evidences of a rather small rainfall and a low humidity, and one appreciates the fact that even near the coast the climate of the colony is fairly arid. A fine general view of the region about Algiers, giving at a glance its setting and these features, is to be had from the heights behind the city. In the words of Tristram (The Great Sahara):

> Here we turned to observe the magnificent panorama of the city and the harbour below, with the bay stretching far beyond, the slopes of Mustapha on the right studded with villas, the Sahel range terminating beyond the massive tower of the seminary of Kouba, the conspicuous Maison Carée . . . planted where the plain of the Metidjeh opens to the sea, the range of the lesser Atlas in the distance beyond, and the peaks of the Djudjura, the last stronghold of the Kabyles, behind them, capped with snow.

Crossing the plain of the Mitidja (Metidjeh), the route runs through a country devoted largely to the raising of wine grapes, with bare hillsides, or hills covered with low shrubs and small trees, and, following a custom derived from France, with either side of the highway lined with trees, mulberry and ash. At the base of the Atlas we see large orange-groves and numerous fig trees. The lower slopes of the mountains are covered with a chaparral-like growth, and as one penetrates the mountains, ascending gradually alongside the Oued Chiffa, he sees, among other forms, extensive areas of dwarf palm, doum (*Chamærops humilis*), which resembles remotely the familiar saw-palmetto of the southern portion of the United States. The leaves of the doum are gathered by the Arabs for making into baskets, rope, and other useful articles, and several donkeys laden with

doum bales were observed being vigorously driven marketward by their small bournoused masters. On the sides of the gorge one sees species of delicate ferns, bunch-grass in tumbling masses (very luxuriant where there is moisture), chestnut, arbutus, and masses of evergreen ivy overhanging the way in places. At one place, fairly high in the mountains, a colony of native monkeys has found a safe retreat and may be frequently seen gamboling among the rocks and the shrubs near the stream. They were seen and described by Tristram about 50 years ago, who states that they "are of the same species as those of the rock of Gibraltar." Here are a few oaks, myrtles, some "dherou" (*Pistacia* sp.), and a few and scattering specimens of *Pinus halepensis*. The upper portion of the mountain, at least of the part seen, is nearly treeless, and is under some cultivation. After leaving the pass a drive of a few minutes brought us to the old Roman town of Medea, which appears from the character of the vegetation, both native and introduced, to have a cooler as well as drier climate than Algiers. Conspicuous among the ornamentals are the Judas tree and the plane, both planted much about the town; among the fruits the apple is cultivated extensively.

From Medea to Berrouaghia the mountain range is broken up into large rounded hills, in part cultivated, but almost wholly open, scantily covered with shrubs or trees and mainly grazed over by large flocks of sheep and goats. About midway between the two places we pass through an open forest of oaks, from whose boles the bark has been removed. A chance acquaintance told us that the cork was removed about once in four years, but this is probably not the true cork oak (*Quercus suber*), which grows under more moist conditions, as between Tunis and Constantine, or between the latter place and Algiers, along the littoral. The altitude of this region is somewhat under 4,000 feet.

From Berrouaghia to Boghari, which is on the northern edge of the High Plateau, the route runs through an open grazing country, with scattering oaks (*Quercus bollota*), juniper (*Juniperus oxycedrus*), and "dherou" (*Pistacia lentiscus*), and, among other herbaceous plants, not a little bunch-grass, whose species I did not learn. On the northern slopes of Mount Gorno, 3,500 feet, is an open forest of oak of the species named, the formation recalling the chaparral of California. Upon reaching the crest of the mountain one is suddenly brought to a forest of pine (*Pinus halepensis*) which covers the entire southern slope to the exclusion of other species of trees. Spreading over the slope on the upper levels, it avoids the gulches near the base and reaches out on the crests of the ridges for a considerable distance. The width of forest where crossed is about 50 kilometers. In its habitat, which comprises the lower Atlas Mountains, *Pinus halepensis* forms a rather small tree, shapely, with rounded summit. When growing somewhat apart from its fellows it is of a more squat appearance than when in the forest, although the forest of the species is by no means a dense one.

THE FORESTS OF ALGERIA.

There are estimated to be between 5,000,000 and 8,000,000 acres of forested land in Algeria. Although the forests lie mainly in the Tell, certain species, notably *Pinus halepensis*, occur in the Saharan Atlas as well. Trees also grow along the oueds, especially on the High Plateau, but not in sufficient abundance to constitute forests proper. The leading species are, among the conifers, *Cedrus atlantica* and *Pinus halepensis*. The junipers are of importance mainly as a fuel, but do not form forests. Three oaks, namely, *Quercus ballota*, *Q. suber*, and *Q. lusitanica*, are forest-making species, but several other common forms, such as the olive, the plane, the ash, and the betoum (*Pistacia*), may share in the making of a mixed forest, but do not occur in sufficiently large numbers each to constitute a forest. In 1908 in the civil domain the acreage of the leading kinds of forest trees was as follows: oak, 1,853,520; pine (*Pinus halepensis*), 1,398,470; juniper (about one-half being *Juniperus communis*), 444,780; and *Cedrus atlantica*, 85,000.

The species of trees are distributed in well-defined zones, because of which they may to a large degree be segregated, or at least the specific composition of the forest, if a mixed one, may be determined. In altitudinal range, the oaks are found from sea-level to 6,000 feet, within which each species may have its characteristic range. For example, *Quercus suber* reaches from sea-level to 2,500 feet; *Q. ballota* from 2,500 to 4,000 feet; and *Q. lusitanica* from 3,500 to 6,000 feet. *Pinus halepensis* grows from the sea-level to 3,600 feet, and probably much higher in the Saharan Atlas, while *Cedrus atlantica* is to be found from 4,000 to 6,000 feet. *Abies barborensis* is said to attain a higher altitude than the cedar.

Among the definitive physical factors by which the composition of a forest is determined—the rainfall, the temperature, the soil, and the altitude—probably of the first rank should be considered the rainfall and the temperature, which are affected by the altitude. In the case of the distribution of the cork oak, however, the character of the soil plays an important rôle. This species grows only on sandy soil, and where the rainfall exceeds 600 mm. Because of the latter requirement the larger part of the cork-oak forested area is east of Algiers, the annual rainfall to the west of that place falling for the most part under 600 mm. Similarly the minor features of distribution, inside of the specific range, may be explained. For example, in the upper limits of its range, *Pinus halepensis* appears chiefly on southern slopes, as on Mount Gorno, while at the low altitudes it is to be found on the northern face; temperature reactions apparently—familiar phenomena in mountainous districts.

Because of the unison of response to common environmental factors, much of the forested area, especially at the higher altitudes, is composed

of one species or one species largely predominates. This is true of the pine and the cedar forests to a marked degree; *e.g.*, in the pine forests on Mount Gorno and the cedar near Batna.

Commercially speaking, the cork oak is at present the most important species in Algeria. It occupies about 600,000 acres, and the yearly yield is valued at nearly $1,000,000. It may be seen along the railroad between Tunis and Constantine and east of Algiers. When old the species has a peculiarly gnarled appearance, with a short, stout bole, usually hollow, which may become 10 feet in diameter, with irregular, straggling branches. It is less symmetrical in nature than under cultivation, as in the Santa Clara Valley and Santa Barbara, California, where a few specimens may be found. Another species of oak, *Quercus ballota*, of no great commercial importance, provides the source of the acorns in general use among the natives for food. The acorns are found in all markets, even (as in Ouargla and Ghardaia) where transportation for considerable distance is necessary; they are less astringent and hence more pleasant than those of most species. Although *Q. ballota* appears not to be planted for its fruit, it has been stated (Kearney and Means, *loc. cit.*) that the Kabyles preserve such selected trees as have superior fruit, which would perpetuate the best-liked varieties. It may be remarked in passing that the seeds of the pine are also in common use among the Arabs as a food, although not employed so generally nor in so many ways as the acorn.

The cedar (*Cedrus atlantica*), the most beautiful tree in Algeria, is found in high altitudes only and on mountains separated from one another, but always in the more northern Atlas ranges. In the following mountain groups are to be found the main cedar forests, namely: Ouarensis, Teniet, Blida, Babor, Maadid, and the Aurés. The forest seen was that near Batna, near the western base of the most important range in Algeria, the Aurés. Somewhat below the lower limit of the Batna cedar forest is an open forest of oaks (*Quercus mirbeckii*), *Juniperus oxycedrus*, and *J. phœnicea*, mingled with which are shrubs suggesting those of the desert, such as *Acanthyllis numidica* and *Retama sphærocarpa*, as each genus is represented south of the Saharan Atlas on the open desert. These species are mainly confined to the southern facing, and hence on the side of the mountains opposite the beginning of the cedar. By the roadside are to be seen also several specimens of *Juniperus oxycedrus* badly infested with the mistletoe (*Arceuthobium oxycedri*). In one instance the unusual condition was observed of a mistletoe group remaining alive on a host branch which appeared to be dead for several inches below the point of attachment.

The first representatives of the cedar forest were encountered as stragglers in the dry wash at the north base of the mountain on which the forest is situated. In part these trees were shapely, with a taper summit, and in part they were short, with a summit broad and flat, in effect like an inverted cone. When the main forest was entered the trees were mainly of the type

first characterized, with widely reaching lower branches and slender summits. In exposed places or in older parts of the forest the trees of the second type were often seen; and on the crest of the mountain the most bizarre shapes (induced by wind action), the trunks nearly parallel to the ground and the branches hugging the ground. In the upper portion of the forest the trees were more widely separated than in the lower portion, and here and there we met with really large specimens, which must have been very ancient. One of the large trees had a bole which 1 meter above the ground was about 5 meters in circumference. The trees were fruiting freely, but we did not see many seedlings. Why, was not apparent. There were no indications that fires had swept over the mountain recently.

THE HIGH PLATEAU.

The vegetation of the High Plateau, taken as a whole, is sparse, due in part to rather light annual precipitation, but largely to the lack of efficient drainage, for which reason large areas are so heavily charged with salts as to be inimical to most plants. Halophytes form an important element in the flora of this region. In the most intense salt areas no plants are to be found at any season. Along the oueds such shrubs as species of *Tamarix* and *Zizyphus* occur, and juniper may be seen in the more elevated places, such as near Guelt-es-Stel or further toward Djelfa.

The route followed across the High Plateau ran from Boghari to Ain Ossera, Guelt-es-Stel, and Djelfa, which is in the midst of the Saharan Atlas, and from thence to Laghouat.

BOGHARI TO LAGHOUAT.

Boghari, situated at the place where the Oued Chelif, having come across the High Plateau, enters the Tellian Atlas on its way through them to the Mediterranean, lies on the northern edge of the High Plateau and in what appears to be a fairly arid region. The oued at this place is rather narrow and has low banks. In its bed, in October, were a few pools of water. On either side is the flood-plain of the oued, several meters in width, sometimes partly under cultivation. Tilled fields are to be seen to the west and not far from the town. From the low mountains immediately to the west of the town the steppes stretch unbroken (save by low hills) to mountains bounding the southern horizon, possibly 100 miles straight away. The mountains are the Dj. Sahari, the Saharan Atlas, beyond which lies the desert.

The vegetation in the neighborhood of Boghari is at present meager in amount and of small size. Along the banks of the Chelif are a few tamarisks, and on the plain not far from the oued are a few specimens of *Zizyphus vulgaris* and *Pistacia lentiscus* and other low-growing shrubs. Owing to the large number of sheep, goats, and camels which are driven through the pass of the Chelif, or which are kept in the neighborhood by their Boghari owners, few plants thereabouts fail to exhibit indications of being

eaten. In fact, at Boghari the effects of grazing were first noticed, though afterwards repeatedly seen. Only such plants as are poisonous, distasteful, or heavily armed survive the predatory attacks of the countless numbers of domestic animals.

The habitat of *Pinus halepensis*, which thus extends to the very edge of the steppes, is to the east and west of the town. To the west it forms an open forest and is associated with *Quercus ballota*, growing on the crest and on the northern slopes of the low mountains. Its abundant fruit, together with acorns, is gathered assiduously by the Arabs for food. *Juniperus oxycedrus* and *J. phœnicea* also occur.

After leaving Boghari and the plain by the Oued Chelif, the route goes among low, rounded hills for a distance of about 24 kilometers, when it strikes boldly across the wide-extending plain. The general appearance of the vegetation, away from the intensely salty chotts, is that of low-growing shrubs on the plain, and of somewhat higher shrubs or low trees along oueds. Of the former, perhaps the most abundant are *Noœa spinosissima* and *Haloxylon* sp., and by the oueds *Tamarix* sp. and *Zizyphus* sp. Near Ain Oussera is a wide belt of *Stipa tenacissima*, the alfa grass, which occurs nearly to the exclusion of other species, and a second belt of alfa, several kilometers in width where crossed, was seen very soon after leaving Guelt-es-Stel. At each of these places were seen large piles of the grass baled ready for hauling to Algiers.

The alfa, or bunch-grass, covers large areas in Algeria as also in Spain. In November the long leaves of the grass are dry, tightly rolled, and rush-formed, in place of being flat as during the rainy season or period of growth. The species reproduces largely by means of much-branched rhizomes, from which spring the young, fleshy leaves, enlarged at the base. In Algeria, "situées en territoire civil," there are 543,620 acres of alfa, mostly on the High Plateau, but a part along the littoral in the province of Oran, west of Algiers. The leading environmental influence upon the peculiar distribution of the species is apparently that of rainfall, reacting in this respect very like plants with storage organs, avoiding alike regions where the rainfall is excessively heavy or where it is so little as to cause marked desertic conditions. It is apparently confined to sandy soils and is replaced by others wherever the soil of a region (otherwise appropriate for its growth) is of clay or is charged with any considerable amounts of salts. It is an important article of export from Algeria. Its total tonnage is said to amount to 80,000 each year, bringing approximately $1,500,000. It is sent to England, Belgium, and France, and used in the manufacture of fine grades of paper, light, strong, and of a silky texture; also in making baskets, hats, and mats, for which a superior grade of the grass, commanding especially high prices, is employed (Kearney and Means, *loc. cit.*).

Among other species commonly seen in crossing the steppes are various salt-bushes, such as *Haloxylon articulatum* and *Anabasis articulata* and

especially *Artemisia herba-alba*, with *Tamarix* and a few specimens of *Pistacia* along the oueds or where water conditions are most favorable. Between the belt of alfa last mentioned and El Masserane, a bordj, there is a broad plain surrounded by low mountains, which are really the northern extension of the broad Saharan Atlas, where salt-bushes occur in a formation several kilometers, possibly 24, across. Here in the summer the nomads, coming up out of the desert, find grazing for their flocks, and even in October we saw countless numbers of sheep and goats, and hundreds of camels, browsing the shrubs.

At El Masserane are specimens of large *Tamarix*, really the size of small trees, growing near the bordj; and to the south of the bordj we passed the first dunes encountered on the plateau. These are part of a series of dunes which were seen to extend to the horizon to the northeast, as we approached El Masserane, and which, we were informed, reached as far as Bou Saada, nearly 90 kilometers distant. The dune flora was quite different from that of the surrounding plain, owing to the total absence of salt plants, and to the presence, among other species, of a *Tamarix* and a large grass, the "drinn" (*Aristida pungens*), which was subsequently frequently seen.

Soon after passing the dunes the way lay through a country with low mountains, almost bare of vegetation, where scattering oaks and junipers constitute the only species of plants, until we reached the walled town of Djelfa.

DJELFA TO LAGHOUAT.

The bleakness and the bareness of the environs of Djelfa come with a surprise when one considers that the rainfall of the place is not inconsiderable, about 375 mm., and that the altitude is about 1,110 meters, which insures a fairly low temperature and hence a relatively low evaporation rate. The sparseness of the vegetation is probably partly due to the fact that the rainfall does not occur at one or at two seasons, as nearer the coast, but is distributed fairly evenly between the four seasons, and also to the long occupancy by the Arabs and the French, by which possibly most of the useful native plants, large and small, have long since been destroyed. Somewhat removed from the town, particularly on the mountains to the west, is a forest of pines. Along the streets are many shade trees, as Lombardy poplar, ash, locust, and others, and within the town limits is a small but fine public park and experimental garden with a large variety of shrubs and trees.

From Djelfa to Laghouat the road runs through barren mountain passes, and is dreary and of little interest. Tristram's description of the approach to Laghouat, written about 1860, gives very well the present condition of things:

> The next day's journey was through a rocky desert country. . . . We afterwards passed a low-lying strip of sand-hills on the west, with the marks of an ancient ocean beach; on the east a high range of mountains, with the stratification regular and horizontal. . . . Our next day's ride was by a base of a continuous chain of steep ridges,

again with an even water-line very near the crest, and presenting a singular serrated appearance (the Djebel Lazareg). I counted no less than 127 little peaks rising above this straight horizontal line, almost all of them of equal height, like the crests of a long sea-reef; and lower down the sides were many tidal strings, if I may so term them. Turning around to our left and crossing the dry channel of an evaporated and aged "Wed," we had some low headlands close behind us—Ras Ainyah of the Arabs, " Prise d'eau " of the French—the scene of a bloody combat under General Yusuf. Through an opening between the mountains we debouched on a wide plain, and suddenly before us stood an isolated rock. Two cliffs facing each other bore each a bastioned tower, and in a depression between these lay a town.

The town, whose situation is thus so graphically presented, is Laghouat, of which the leading present interest lies in the fact that it is on the very edge of the Sahara proper. From the rocky hills by the town one can see the serrated Saharan Atlas to the north, extending northeast and southwest, and, turning, to the south, an expansive and gently undulating bare plain, stretching without a break to the horizon.

LAGHOUAT.

The ancient Arab town of Laghouat, which is also an important military post, is a very favorable place from which to begin a study of the plants and the environment of the plants of the northern Sahara. Its altitude (780 meters) is greater than that of Ghardaia (520 meters), as also that of the latter place is greater than the altitude of Ouargla (150 meters). The annual rainfall of Laghouat is more than that at either of the places mentioned and more dependable. The surface of the desert at Laghouat is, for example, not of one type only, but characteristic of much of the Sahara; that is, it is mainly stony, a hamada, but there are also sand areas, a oued and its flood-plain. Finally, the plants growing in the vicinity of Laghouat are largely typical of those found farther to the south, as at Ghardaia and Ouargla, or even deeper in the desert. It is of great interest to observe the change in the habits of the plants, in their number, distribution, and other features, when one leaves a less arid region and goes toward a region of gradually increasing aridity, as when passing southward from Laghouat.

The leading plant habitats are the oasis, the arid plain, and the dunes. It is not likely that any of these habitats have been greatly changed because of the settlement by Arabs. The arid plain and the dunes surely have *per se* not suffered marked alteration, and the oasis itself is probably not so different from what it was formerly, as the great difference in plants growing in it might at first lead one to suspect. More water is brought to the surface at present than in primitive times, but if it were possible to remove all introduced plants, and restore all native plants peculiar to the oasis, there is no apparent reason why they should not live there quite as successfully as in earlier times. It does not follow that there has been no modification of the flora itself, a result of the founding of a town at the oasis, and it will be pointed out later that such has surely been the case, but to what extent or in what way does not appear.

THE OASIS OF LAGHOUAT.

The oasis of Laghouat is situated on the Oued Mzi, the upper portion of the Oued Djedi, one of the most important oueds of Algeria. The Oued Djedi runs in an easterly direction from Laghouat, receiving many tributary oueds *en route*, by a rather long course to the great Chott Melrirh, which is southeast of Biskra. Like other desert rivers, the Oued Djedi is dry most of the year, but is occasionally filled to overflowing with a rushing flood, which is of great erosive power and may be very dangerous to the traveler. Above the town of Laghouat, where the Oued breaks through the last pass of the Atlas, the flood-plain is narrow, but upon leaving the pass the plain widens until in the immediate proximity of the town it is about 1.5 kilometers in width. On either side of the flood-plain stretches the arid plain (hamada), usually stony, but near the mountains covered with low, slowly moving sand ridges. To the south of the oasis, the arid plain merges into the topography characteristic of the region of the dayas.

The portion of the oasis devoted to the cultivation of date and other trees, and to gardens, is about 3 square kilometers in size, but arable land extends above and below the town, so that outside of the oasis, as delimited above, there are about 6 square kilometers, all of which have at times been under cultivation. The last referred to is the flood-plain of the oued and is used mainly for growing barley. By the edge of the oued, or along the irrigating ditches, are several characteristic species of plants, which may point to the character of the primitive flora; for example, willows, oleander, and *Tamarix*, with a few palms. The betoum (*Pistacia atlantica*), which must surely have been an inhabitant of the oasis formerly, is now apparently wholly absent. The species just mentioned are to be found between the town and the pass above; but below the oasis, owing to an apparently poorer water-supply, there are fewer large species. Among those found are a few specimens of *Rhus oxycantha* and *Zizyphus vulgaris*, and it was probably below the town that the betoum was to be found in earlier times.

The oasis is under intensive cultivation (see fig. 1). There are about 300 gardens, each bounded by mud walls, and often separated by picturesque, meandering lanes. The plant life, almost wholly introduced, is luxuriant. In some gardens the effect is tropical, where vines reach from tree to tree, making a canopy nearly sun-proof and separating the spreading tops of the palms from the wealth of shrubbery and herbaceous plants beneath. First among the trees of the gardens, in numbers as well as in economic importance, is the date palm, of which there are said to be about 30,000. Although this is small in comparison to the number of date palms at Ouargla, Touggourt, or the Oued Rirh, the dates are of great importance to the dwellers at Laghouat, where the products of the gardens are almost all consumed. The living tree provides shelter against the intense heat and light of the desert, and the dead leaves constitute an important source of fuel in a land where fuel is extremely hard to obtain. The flesh of the date fruit is eaten by the Arab and the cracked seeds are given to the camels. With-

out the date a continuous occupancy of a remote oasis by the Arab is clearly impossible. Besides the date palm fruit trees of other kinds are abundant, among them the apricot, fig, mulberry, peach, pear, and orange. The pomegranate and the table grape are also very generally grown. The lowest story of the vegetation of the gardens is composed of garden vegetables, such as artichoke, bean, carrot, melon, pea, potato, squash, and radish. Among the ornamentals one sees roses, asters, and chrysanthemums, and occasionally very luxuriant cannas. One or two parks contain interesting introduced trees and shrubs. We recognized among the trees *Ailanthus*, *Eucalyptus*, umbrella, plane, poplar, pine, cypress, ash, locust, willow, and St. John's tree. The Barbary fig (*Opuntia ficus indica*) is also common, but does not stray away from the best-watered situations.

THE PLAIN.

The part of the plain (hamada) studied lies to the west of the oasis, between it and the adjacent hills, Mountains of the Nomads, which are to the west of the pass of the Oued Mzi. Emerging from the oasis, one finds himself on the arid plain, the transition from the one to the other being abrupt. The plain, at first view, with a covering of small stones and pebbles, gives the impression of total barrenness. Not a tree, shrub, or herb appears to hide the bare ground. The mountains are naked rock, while the harsh outline of desert ranges and the distant low sand ridges give no evidence of plant life. But a closer examination of plain, dune, and mountains reveals the presence either of living forms or of the dried remains of plants of a preceding moist season, in numbers and in kinds not at first suspected.

Close to the oasis the plain forms the highway for caravans as well as the drilling ground for army recruits, so that the herbage is either trodden under foot or eaten to the roots. Somewhat farther away, where the plain rises to meet the mountains, we first encounter perennials large enough and abundant enough for consideration, the most prominent being quedad (*Acanthyllis tragacanthoides*), adhidh (*Zollikoferia spinosa*), rempt (*Haloxylon articulatum*), and drinn (*Artistida pungens*); *Acanthyllis* is perhaps the most numerous.

Quedad is the most striking plant native to Laghouat. It is a shrub, related to *Astragalus*, usually not over 40 cm. high. A single specimen consists of a group of unbranched or little-branched stems, rather stout, of a grayish-green color, and provided with long and stout spines. As a whole the plant has a very close resemblance to small specimens of ocotillo (*Fouquieria splendens*) of the southwestern United States. During dry seasons the stems are bare, but when the rains return leaves are put out in the axils of the spines, which are the rachides of the leaves. The habit of quedad is shown in figs. 4 and 6. Although the species is so well protected against attack by animals that it rarely, if ever, suffers on that account, it is made a supplemental food through the burning off of the spines. When thus prepared the half-woody stems are eaten with avidity by camels.

The census of *Acanthyllis* was taken on the upper portion of the arid plain at a place where the plant seemed to be most abundant. On an area 16 by 16 meters, 92 specimens were found living. This was the dominant species. Other species, present in less number, were so badly eaten by animals as to be quite unrecognizable.

The root-system of *Acanthyllis* offered some points of interest and a short study of it was made in the field. All of the specimens whose roots were examined were growing in the habitat above referred to and within a meter of one another. The leading results of the observation are as follows: The largest specimen studied possessed a tap-root 3 cm. in diameter at the crown. Growing rapidly smaller as it ran downward, the root gave off four laterals, of which a portion dipped at an acute angle to a depth of 20 to 30 cm., sending off branches by the way. One of the largest of the laterals was traced 75 cm. and where left was 2 cm. beneath the surface. The branches, at least of the main laterals, that is, the roots of the tertiary order, for the most of their course ran thus near the surface of the ground. One of the leading laterals was followed to the base of a neighboring specimen of quedad, where it lay close to the crown of the main root. The depth of the penetration of the tap-root of this specimen was not learned. The tap-root of a neighboring specimen ran directly downward 20 cm.; then, turning sharply, it extended in a horizontal direction for a distance of 70 cm. As the large laterals were wholly lacking on this plant, the tap-root was the entire system—surely an anomalous condition. On a third plant the tap-root penetrated the ground about 4 cm. only, after which it turned and ran the rest of its course within 4 cm. of the surface. The more superficial of the roots of a fourth specimen were found to extend to the base of the last plant mentioned. Thus it was found that the root-system of *Acanthyllis*, as growing naturally, extends both widely and deeply for a considerable distance, and that it is flexible to a degree; in short, is generalized* and closely resembles that of certain species of the Tucson region, particularly *Covillea tridentata*, which grows under similar conditions.

The root-systems of three or four other species were also examined. Of these *Zollikoferia spinosa* and *Artemisia campestris* were growing in a little hollow in the plain close by the habitat of *Acanthyllis*. *Zollikoferia* has a very close habit of growth with dichotomous branching (compare figs. 5 and 7). When dry the branches are slender and of a woody hardness. The root-system of this species is characterized by a pronounced tap-root and

* The Root Habits of Desert Plants, W. A. Cannon. Carnegie Institution of Washington Publication No. 131. 1911. This paper gives a descriptive classification of the main root-types in the deserts of the southwest, in which such a root as found in *Acanthyllis* is called *generalized*, in distinction to roots like those of most of the cacti, or *Zizyphus*, the former having a system wholly superficial and the latter a system wholly deeply placed, as *specialized*. The specialized root-systems appear to be so fixed in character as to be not easily changed, while the generalized type is flexible. It will be self-evident that the type of root-systems may be of great importance in determining the local distribution of a species.

by the absence of large laterals, at least near the surface. The leading feature of the root-system is, in short, its tap-root. A root-system of a similar type was found in *Artemisia herba-alba*.

Rempt (*Haloxylon articulatum*) also occurs on the plain. This is a shrubby perennial (half shrub?) which is possibly the most often met of any species, or at least genus, in southern Algeria. It is capable of enduring very arid conditions, is unarmed, and is much eaten by all herbivorous animals. The plant will be figured and especially referred to later in this study, so that at this time only a brief definition will be given of its root-system, which is a typically generalized one, penetrating the ground fairly deeply if the character of the soil permits, but also lying near the surface; there is also a relatively large number of secondary and tertiary roots, characteristic of the generalized type.*

Inspection of the soil showed it to be a sandy clay with a large percentage of pebbles and stones and with greater depth of earth in the hollows on the plain than on low ridges. It probably contains some gypsum, since an outcropping of it occurs on the southern face of the low mountains to the north. Taken as a whole, the soil appeared very like that of the plain by Tilrempt and Ghardaia, as well as between Ghardaia and Ouargla (Gantara). The soil will be described later in this paper.

THE DUNES NEAR LAGHOUAT.

Dunes are not present in large enough numbers, or of large enough size, to figure very prominently in the topography of the environs of Laghouat; but they occur both to the east and to the west of the town, those to the east being the larger. Sand is found facing the south side of the Rocher des Chiens, a rocky hill on the western edge of the oasis, and the south side of a portion of the Nomad Mountains, to the north. There is also a succession of low dunes between the Nomad Mountains and the oasis. The Rocher des Chiens dune is moving from west to east, but the dune along the face of the Nomad Mountains is probably stationary. The series of dunes on the plain are moving toward the northeast.

An inspection of the dunes shows that the number of individuals, as well as the number of species, is very limited. In fact there are apparently fewer plants here than on the dunes of large size subsequently encountered between Ouargla and Touggourt. The most characteristic plant is "drinn" (*Aristida pungens*), but it is by no means common; there are also a few specimens of *Tamarix* growing near the Nomad Mountains. As frequently happens where there are moving dunes, the passage of the dune greatly changes the character of the flora. Although this feature was not especially studied, it was noted that the number of grasses where the dune had swept was greater than it was before this. *Acanthyllis tragacanthoides*, a plant typical of the plain, was found to survive the passage of the sand, although changed in appearance in a characteristic manner. It will

* Compare the root-system of *H. scoparium* at Biskra, p. 64.

be recalled that the species has a top consisting of several shoots, springing from the root-crown at the level of the ground, and a root-system in which the laterals and the main root are alike well developed. In order that a plant, already established, can maintain this general relation during the heaping up of the sand, the main root must grow at the crown as fast as the sand encroaches. This is exactly what happens, so that, when the dune has passed on, the shoot of the species is elevated for a space equaling the depth of the sand, which is half a meter or more. From the probability that *Acanthyllis* is of very slow growth and that the dunes are low, it follows that the rate of dune movement must be slow.

THE MOUNTAINS ABOUT LAGHOUAT.

The southern spurs of the Saharan Atlas lie to the north of Laghouat, within 3 miles of the oasis. This range (the Nomad Mountains) is not over 266 meters in height. Higher mountains extend both to the west and to the east, but only the Nomads are visited. There are also two high, rocky hills on opposite edges of the oasis, the town lying between, and it is perhaps because of their presence that the water is forced to the surface, or near the surface, and the oasis is formed. The hill to the west of the town is called the Rocher des Chiens. On the south side of the Nomad Mountains is a long outcropping of gypsum; the south face of these mountains is also abrupt, carrying little soil; but on the northern face the slope is gradual and there is much soil, although rocks are abundant.

Two localities only in the Nomad Mountains were seen. One was in a pass through which caravans travel *en route* to Laghouat, from the High Plateau or the more distant Tell; the second to the east of the pass is much less often visited by flocks. The physical plant conditions appeared to be the same in both locations. As one approaches the mountains from the south the number of plants grows less until on the south face they quite disappear, but on attaining the crest they quickly increase and form a noticeable element in the landscape. In fact, the flora of the northern gentle slope, where the soil conditions are relatively favorable, is much richer than on the plain or the dunes. Had the shrubs been of good size they would have been very conspicuous.*

A certain area on the north slope of the Nomad Mountains, not far from the pass through which the Oued Mzi goes, was selected for making

* The most striking change in the general character of the vegetation which the traveler notices as he goes from the less arid to the more arid portion of southern Algeria is its decrease in amount. This occurs through dwarfing effects of whatever cause and through a decrease in the number of individuals. Within certain limits the results observed are to be attributed mainly to the first of these, since there is often a surprisingly large number of perennials on any given area. But in other and more intensely arid regions (as portions of the Arabian-Egyptian desert, and indeed a limited area on the hamada between Ghardaia and Ouargla) plants are wholly wanting. Whether such is generally the case on the reg or the hamada farther south in southern Algeria is not known.

a census of the plant population. Here the number of individuals, as well as their size, showed that the moisture relations were good as compared with those of the plain. On an area 16 meters square 422 living perennials were found, mainly of the following species: *Acanthyllis tragacanthoides*, *Asparagus spinosa*, *Deverra scoparia*, and *Zollikoferia spinosa*. The most numerous, *Zollikoferia*, was represented by 96 individuals. The general character of the habitat and the plants is sufficiently well shown in fig. 8 and does not need further mention in this place.

EFFECTS OF GRAZING ON VEGETATION NEAR LAGHOUAT.

It is generally recognized that a potent influence is exerted by man, and the lower animals, in shaping the flora of an arid region, not only as regards the kind and number of plants, but also as concerns certain of the leading characteristics of the plants themselves. The action is largely such as brings about a survival of the "useless" forms, so that we do not know, from the plants we meet in the desert to-day, how many or what kinds of plants it might support. It also may be true that no desert shows the modifying effects of the causes suggested more than the northern Sahara.

The gazelle (*Gazella dorcas*) is the leading wild animal preying upon the desert plants in the northern Sahara. It is frequently seen by the traveler to-day and was present in large numbers no longer ago than 50 years (Tristram). It is said by the Arabs to feed on the fresh shoots and leaves of many species of shrubs and trees, especially the betoum (*Pistacia atlantica*), as well as on the annual vegetation for the relatively short period when it is to be had. Other species of gazelle, according to Tristram, range farther to the south. Other herbivorous animals of the region are hares, antelope, moufflon, and bubale. The moufflon, at the time of Tristram's visit, was "far from uncommon throughout the whole of the mountain districts, whether wooded or bare," but the bubale, "the wildest of the wild game of North Africa," appears not to go north of the Oued Rirh, while its home is farther south. It is impossible to know the number of wild animals subsisting on native desert vegetation, but the list given, which might be extended, suggests that it is by no means small. Although the population of wild herbivorous animals is at present considerable, it was probably much greater a few years ago, the decrease being due, as Tristram says, not so much to the greatly increased population as to the more efficient weapons used by the Arabs in hunting.*

* Tristram remarks that it "seems that the larger wild animals have been rapidly decreasing in numbers and are in process of speedy extinction. Dr. Shaw, 150 years since, enumerates in his travels . . . five species of ruminants, which from his descriptions must be the bubale, the aoudad or wild sheep, the addax, and the gazelle, as well as the stag. . . . As the population has not increased, but rather retrograded, we can only surmise that the substitution of the flint and steel gun for the matchlock of the Bedouin . . . has been fatal in its results to all larger game." It may be remarked that the French impose such restrictions on the Arab as regards the character of the guns he may use (only the army and certain officials of the government employing modern arms) that for the region visited Tristram's description holds fairly well for to-day.

Laghouat has been inhabited by the Arabs continuously for about 1,000 years, during which time the oasis and its environs have been the source of supply of all of the fuel used and for much, if not the most, of the food consumed both by the Arab and his flocks. Naturally, the food for the inhabitants of the oasis is won from the oasis itself, but that for the beasts is derived from the desert. While it is impossible to learn the number of sheep, camels, and goats which from century to century have ranged over the desert pastures, there is no reason for supposing it was not large, as at present is the case. For example, in the department of Algiers, in 1907–08, the number of sheep is reported to have been 2,109,071; of goats 1,156,500, and of camels 23,912.* Of these a large percentage is to be found in and to the south of the Saharan Atlas Mountains. In portions of the colony farther south, or in regions even more desertic than at Laghouat, the number of camels, sheep, and goats is surprisingly large. The statistics for 1907–08 give the population of the three classes of animals in the southern territories, that is, the territories of Ain-Sefra, Ghardaia, Touggourt, and the oases of the Sahara, as follows: sheep, 1,932,392; goats, 588,121; camels, 126,088.

The flocks of sheep and goats range at various distances from the source of their water-supply. It is quite usual for the goatherds to gather their flocks in early morning, returning to the oasis in the evening to distribute the goats to their various owners; but probably in most cases the flocks of sheep, with some goats, return to water once in two or three days, thus being able to stray from 20 to 40 kilometers into the desert. Being less dependent on water, the camels range a much greater distance. It thus appears that the area grazed over by the flocks of the Arabs is fairly circular in form, with a radius of 40 or more kilometers from the wells, and that the range of the camels may be much greater than this. It should also be noted that the caravan routes are broad tracts where all vegetation fit for fuel or food has been utilized. Between the two sources of destruction referred to, the stationary and continuous and the frequent but not continuous, little territory passes untouched as a source of food-supply.

A visit to the wood markets of the town indicates to what ends the natives resort to obtain fuel. (See figs. 2 and 3.) Among many kinds of wood, some are from the oasis itself, such as the willow, plane, and palm; some from the mountains, like juniper, pine, and oak; and some from the oued, like the jujube and *Tamarix*. Much of the fuel is at present brought three days' journey by camel. Usually the subaerial portions only of the plants are used, but in the case of the jujube both root and branches are gathered. The fuel requirements have apparently brought about the extinction of some species from certain of their earlier habitats;

* Statistique Générale de l'Algérie, 1908.

for example, the betoum (*Pistacia atlantica*) probably formerly either grew in the oasis of Laghouat or near by, since it was formerly in common use as a fuel. Tristram mentions the betoum, and no other species, as a source of fuel, but inquiry failed to show that at present this species is in general use for this purpose; but the betoum is a familiar sight in the region of the dayas south of Laghouat, where it is the only arboreal species of the region.

From what has been said regarding the large numbers of domestic animals that gain their entire living on the desert, it follows that of plants growing within the range of the flocks only such as are poisonous, distasteful, armed, or otherwise protected, escape partial or complete consumption. Only such species as are too small for fuel or can not be eaten by animals attain to the usual development year by year. In the vicinity of Laghouat the most prominent of the immune plants is the quedad (*Acanthyllis tragacanthoides*), which is well protected by its stout spines; and even this species is not wholly undisturbed. The jujube, also, although not common here, is provided with short spines. It is stated by Massart* that the camels used by him, not having eaten for five days, consumed the branches of the jujube in spite of the spines, and that *Anvillea radiata*, a composite with acrid juice, was passed by. Perhaps the plants most frequently eaten are of the genus *Haloxylon*, generally distributed from the High Plateau southward into the region of the M'Zab. That this genus is not exterminated is interesting, since it is rarely permitted to come into flower and fruit, and it appears not to reproduce to any extent, if at all, in a vegetative way.

FROM LAGHOUAT TO GHARDAIA.

REGION OF THE DAYAS.

From Laghouat the way lay through a gently rolling country, ever dipping to the south and southeast. No mountains relieved the monotonous horizon. "A hard stony desert alternated with rolling sandhills," followed by a "vast level plain dotted with dayas," to quote again from Tristram's narrative. Somewhat to the south of Laghouat depressions are met here and there, separated from each other by the low ridges of the plain, which receive the drainage each of a limited territory. (See figs. 10 and 11.) These are dayas, and are in fact oases with an uncertain water-supply but with favorable soil conditions, so that such rain as falls on them, or is conducted to them from higher ground, sinks deeply and creates relatively favorable conditions for plants. In that the daya is the center of a drainage system, and has no visible outlet, it is comparable to the chott or salt-spot, but it is to be distinguished from the chott by the absence of salts in excessive amounts. That salts are not present in the dayas in quantity is probably due to subterranean drainage, the daya being in fact similar to the bolsons

* Un voyage botanique au Sahara, Bull. Soc. Bot. Belg., 1898.

of western America. On the plain in the northern portion of the daya region the following may be observed: *

Echinops spinosus.	Citrullus colocynthis.	Teucrium polium.
Acanthyllis tragacanthoides.	Artemisia herba-alba.	Aristida obtusa.
Thymelæa microphylla.	Artemisia campestris.	Stipa gigantea.
Peganum harmala.	Haloxylon articulata.	Noæa spinosissima.
Euphorbia guyoniana.	Anabasis articulata.	Astericus pygmæus.

In the dayas one sees *Zilla macroptera*, *Peganum harmala*, but chiefly *Zizyphus lotus* and the betoum (*Pistacia atlantica*), which is perhaps the only species of tree outside of the oasis in this portion of the Sahara. Massart mentions not seeing any tree away from oases from the time he left Biskra until he reached the region north of Berrian, the northern portion of the Chebka. As the betoum is so conspicuous among the Saharan plants, and also from the very remarkable relationship existing between it and the jujube, the species is of very great interest. The relationship will be described under an account of one of the largest dayas of the region, that of Tilrempt.

DAYA OF TILREMPT.

The daya of Tilrempt is one of the largest (about 103 hectares) and is the most southerly of all. It lies near the southern margin of the daya region, and is surrounded by a gently undulating plain (hamada), whose surface is strewn with stones and pebbles, with apparently an underlying stratum of impervious material, since such is to be seen wherever erosions have laid it bare. The floor of the daya is free from stones, being composed of soils of a fine texture which have been washed or blown by the wind from the surrounding higher country, and is apparently not underlaid by a hardpan. Judging from the depth of the two wells at the daya (which were dug, not bored), the deeper of which is said to be 95 meters, there is an abundance of earth for the roots of the plants. Besides the wells there is a cistern, sunk below the general level of the daya floor, which receives and stores up flood-water; it is rarely filled, but occasionally contains considerable water, possibly up to one-fourth of its capacity; its filling is very uncertain, depending on the rare and scant rains. According to Massart, no rain had fallen during the two years previous to his visit, and the cistern was empty when we were there. These observations are given to show under what intensely arid conditions such a tree as the betoum (mature specimens of which carry an immense evaporating area) can become of large size, giving but slight evidence of a severe struggle against such adverse conditions. The altitude of the daya is about 600 meters.

As one crosses the plains in the vicinity of Tilrempt he notes the scantiness of the vegetation. (See fig. 9.) Here and there in the depressions are a few betoums, often only one specimen, but usually more, and in the erosion channels leading to the dayas is a sparse population of low, gray shrubs.

* Massart, *loc. cit.*

Over the higher portions of the plain, one is aware that small perennials, 20 to 30 cm. high, are widely scattered, but it is the bare ground which gives the character to the landscape. Among other forms are species of *Aristida* and *Stipa*, *Anabasis* and *Haloxylon*, with dwarfed specimens of *Zizyphus lotus* in the washes near the dayas. The leading species, *Haloxylon articulatum*, is much eaten by the flocks of sheep and goats (over 7,000 sheep are said to obtain water at the daya), but occasionally it is present in surprising numbers. For example, on a slope to the northeast of the daya, and but a few meters distant, 227 living specimens of *Haloxylon* were counted on an area of 16 meters square; in another place, near the crest of a low hill to the west of Tilrempt, where the conditions were probably as unfavorable as any in the region, 118 specimens were found on an area of the same size. In both squares there appeared to be no other species present. Tilrempt is said to contain 2,400 betoum trees, although the visitor would not be likely to estimate the number at nearly so high a figure.* Numerous specimens of jujube are also scattered through the daya, with some *Peganum harmala* and *Francœuria crispa*.

As a person visits the floor of the daya he is struck by the great beauty of the betoums. They are of a compact habit of growth, shapely, and cast a dense shade, an unusual feature in a desert tree. Attaining a height of 15 meters or more, the tree may have a spread equaling or exceeding this amount. The bole of the largest specimens is of large size; one was found 4.56 meters in circumference, another 4 meters, while a third measured 3.36 meters. All measurements were made 1 meter from the surface of the ground. No betoums, however, were seen to have developed in a perfectly normal way, and this observation applies not only to Tilrempt but to all other dayas seen, but they were disfigured in a peculiar manner, the lower branches giving the appearance of having been cut and removed at a height of 2.85 meters. In fact, this had been done, and the lowest existing branches marked the highest point to which a browsing camel can reach.

The leaves of the betoum are compound, consisting of 7 to 9 large leaflets. The branches are unarmed and the twigs, younger branches, and leaves are eagerly eaten by whatever herbivorous animals can reach them. (Fig. 12.) So much is the betoum sought after as a food that it would be exterminated if it were not protected by another plant, namely, the jujube.† The character of the leaves and young shoots of the betoum may be seen in fig. 15.

In considering the main characteristics of the jujube we find that it is

* Joan's Guide de l'Algérie et de la Tunisie.

† Massart, *loc. cit.*, p. 314, suggests that the Sahara may be gradually becoming more arid and says that as a result the betoum is becoming more and more rare and may become extinct. He says "L'extinction du Pistacia atlantica présente le caractère, tout à fait exceptionnel, d'être uniquement l'effet du climat." It will appear from what is said in this study regarding the effects of grazing in general, as well as the especial effects on the betoum, that if the betoum is becoming extinct the sole cause, or perhaps the main cause, is not the adverse climate.

a spreading shrub, frequently attaining a height of 3 to 4 meters, with branches well armed with stout spines. The leaves are small, simple, and leathery. (Compare fig. 14.) The spines are so efficient as a means of protection that the shrub shows no signs of being eaten by animals, although, as quoted above, Massart remarks that after his camels had gone five days without food they ate the jujube branches in spite of the spines.

The unarmed betoum and the armed jujube have a very interesting relationship, which is as follows: When the seeds of the betoum germinate the seedling is eagerly eaten by animals if it chances, as is usually the case, that the germination occurs on the open daya floor; but if the seeds are carried to a *Zizyphus* and germinate in its midst, the young plants may attain to a considerable height before being seen by animals, and, being protected by the encircling jujube, will continue growing until they are too large to be easily killed through grazing. It usually happens that once the betoum plant appears above the top of the protecting shrub the camels attempt to reach the attractive shoots and the jujube is trodden under foot. The jujube is thus ultimately destroyed and a mound around the base of the young betoum is all of it that remains. If the jujube is relatively small and the developing betoum is discovered while still small, it will be much eaten, and probably killed; but if it reaches a considerable height before the discovery is made, only the lower branches will be devoured and the specimen will survive. Massart was unable to find any young betoums, but when my visit to Tilrempt was made, November, 1910, there were several, although so well hidden as to cause much trouble in finding them. A view of one of these is shown in fig. 13.

The betoum is eaten by the gazelle as well as by domestic animals, which are abundant enough in this region, and this fact is probably of great influence in restricting its distribution. Fairly numerous on the desert at present, according to Tristram the gazelle was very abundant in earlier times; he speaks of their tracks marking the plain like sheep-walks.

From what we have already seen regarding the ill effect of grazing, it will appear that the relation between the betoum and the jujube is a very vital one to the former; and it probably is not too much to say that the distribution of the betoum in the daya region is entirely dependent on that of the jujube, since there is no other armed shrub in the region to afford the protection essential to its survival; with relatively favorable moisture conditions, considerable depth of soil, and a protecting jujube, the betoum will flourish and reproduce now quite as well as in former years.

THE CHEBKA.

No dayas were seen after leaving Tilrempt, and the aspect of the country changed markedly and suddenly as the drainage became better defined. The hills were more abrupt and in systems, and the valleys became broad and continuous. At first the valleys were wide and shallow, the hills being

low and with flat summits, but as the distance from the daya region increased, the valleys became deeper, until at Ghardaia the effect was that of low, flat-topped mountains with broad valleys between, thus remotely suggesting the topography of southern Arizona. However, in southern Algeria the mountains are not so high nor is the "mesa" (hamada) so extensive as in Arizona. The general level of the daya region is prolonged as the summits of the mountains of this the chebka region, while the valleys are eroded to a new level, that of the plain of the M'Zab. A similar condition is seen as one goes from Ghardaia to Ouargla, so that in fact there are several immense terraces, reminders of that remote period when there was more rainfall in this portion of the Sahara than at present.

Although the drainage to the south of the daya region is well developed, the valleys and mountains run in a rather confused way, so as to give to the fancifully inclined Arab the idea of a net, from which the name "chebka" is said to be derived.

The country from Tilrempt to Ghardaia is characterized by a continuously decreasing amount of vegetation. In place of the country as a whole having a covering, however sparse, as in the daya region, one is apt to consider the chebka a barren desert, absolutely devoid of plant life; but closer inspection dispels this illusion and reveals the presence, in the more favorable situations, of not a little vegetation.

In the northern portion of the chebka region one sees here and there, on the bottoms, specimens of the jujube and the betoum, as well as *Zilla macroptera*, *Petama spherocarpa*, and *Coronilla juncea*. On the rocks at Settafa, Massart reports finding lichens, the first he had seen after leaving Biskra. However, crustaceous lichens occur on the flat tops of the low mountains by Ghardaia. Massart suggests that the absence of lichens in the Sahara (possibly they are not to be found south of Ghardaia) is because of the intense dryness and the great heat, the temperature of the rocks becoming from 60 to 70° C.*

At Berriane, one of the M'Zab cities, there are over 30,000 palms of a superior sort, watered from over 400 wells. The surroundings of this oasis are extremely desertic and a casual survey of the route between this place and Ghardaia, 44 kilometers distant, reveals almost no vegetation. Here the calcareous plain of Cretaceous origin, the Chebka, is even more eroded than in the portion farther to the north, and the valleys are wider. The soil is a fine clay without an admixture of sand. It is only in the most favorable places, along the washes, that plants are to be found, and here are *Deverra chlorantha*, *Anabasis articulata*, *Gymnocarpon fruticosum*, *Artemisia herba-alba*, *Ononis angustissima*, *Linaria fruticosa*, *Antirrhinum ramosissima*, and *Haloxylon articulatum* (Massart, *loc. cit.*). *Peganum harmala*

* Dr. Charles Amat, Le M'Zab et les M'Zabites, p. 70, gives a somewhat higher temperature for the rocks of the southern Chebka, placing it at 90° to 100° C., or even higher.

occurs very sparingly by the roadside. The habits and the habitats of certain of the above-mentioned species will be described in greater detail later in this paper.

GHARDAIA.

The Ghardaia region can be characterized as a vast plain, broken to the north by low, irregularly disposed mountains, and stretching for a great distance to the south and southeast with a fairly monotonous surface, diversified only by oueds, chotts, or occasional dunes, which may be the size of small mountains. Thus on the one hand one finds the fairly diversified and stony Chebka and on the other the hamada, which has been aptly described by Brunhes* as "le désert par excellence, la vrai désert . . . les grandes plaques pierreuses indéfinies des hamadas!"

The leading oued of this region is the M'Zab, which extends for about 270 kilometers in a direction south of east across the southern part of the Chebka. It takes its origin about 80 kilometers west of Ghardaia and extends to the vicinity of Ouargla, where it debouches on the Ouargla plain. At Ghardaia the oued lies in a valley, with abrupt sides, which is sunk about 60 meters below the surrounding plain and which at this place is about 3 kilometers in width. (See fig. 16.) There are four main tributaries of this oued, all of which join it from the north or the Chebka side. The valley of the M'Zab becomes more and more shallow as one proceeds eastward and at last lies but little below the general level of the country. Like the other deeper valleys of the Chebka, the M'Zab Valley represents the work of erosion by water at an earlier geological epoch, when the great terraces were formed. The filling of the eroded valleys has perhaps taken place during the long arid period since that time and has probably proceeded very slowly.

It appears to be uncertain how long the M'Zab has been inhabited by man, or, more accurately, by the race now dwelling there;† but it has probably been not less than nine centuries.‡

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* Les Oasis du Souf et du M'Zab, La Géographie, 1902.

† Foureau, d'Alger au Congo par le Tchad, 1902, mentions having met with indications of early settlement of the Sahara by people now forgotten, and whose tombs, inscriptions, and other remains, were well known by his Touareg servants, although not at all understood by them. So far as I have learned, however, it is not supposed that the region of the M'Zab was inhabited before the coming of the Beni M'Zabs.

‡ There are seven cities of the Beni M'Zab, of which five lie in the M'Zab Valley, close to one another. These are El Ateuf, Ben Noura, Melika, Beni Isguen, and Ghardaia. In the pre-French times these cities were bound together in a confederacy with Ghardaia as the capital. The M'Zabites are at present, and probably always have been, a peaceful trading folk. They are heterodox Moslems. In an early time they aroused the antagonism of their more warlike as well as more orthodox Arab neighbors of the Tell, who drove them away from the coast region, and again from Ouargla and other places settled by them, until safety was at last secured in the eleventh century in the "inhospitable Chebka." Palm gardens were established which for centuries have been irrigated laboriously by very primitive methods, and the inhabitants have accumulated wealth in flocks and by barter. The relatively large population (there were 92,761 inhabitants in 1908), the really great number of domestic animals, and the great length of time which the region has been occupied, are all factors of importance in bringing about a modification in whatever way of the primitive flora.

At Ghardaia are several well-defined plant habitats, which may or may not be distinct topographical areas, and which differ from one another in exposure, soil conditions, and water relations. These are the plain of the Chebka (hamada), the low and flat-topped mountains resting on the plain of the Chebka, the walls of the M'Zab Valley, and the valley floor with its gardens, cemeteries, and waste lands.

The soil conditions of the areas mentioned are very diverse. On the valley walls and the mountains there are bold rock outcrops with soil in the interstices only, and here the most intensely arid conditions prevail. The soil on the hamada also is exceedingly meager. Rocks of various sizes strew the surface. It is only between them, as well as in the washes of gentle gradient, that the best soil conditions of the plain are to be found. Here a cursory examination shows a large admixture of small stones to the fine clay, the prevailing soil type, and that at a depth less than 50 cm. A white hardpan, similar in appearance to the caliche of the southwestern United States, may usually be encountered. In the drainage depressions the soil is relatively more coarse than on the more level portions of the hamada. There is also great variation in the character of the soils of the valley. Above the upper palm gardens, which are about 2 kilometers above the town of Ghardaia, will be found much sand and fairly large stationary dunes, while smaller dunes, shifted by the winds, are to be found at various places in the valley. About 10 kilometers down the valley, toward the east, the sand is blown against the valley sides, and in certain places where the walls are low it has been sifted in a thin layer over the plain itself. At the sister city of El Ateuf the drifting sand is a continuous menace to the gardens.

Between Ghardaia and the upper palm gardens, and also between this city and Beni Isguen and Melika, are bare areas, free from sand or clay, where the soil is so hard as to be used for threshing floors and where the small amount of grain grown in the valley is threshed and winnowed. The hardpan is similar in appearance to the caliche of the southwestern United States and may be essentially the same. It is of wide extent in the valley and probably underlies the largest portion of it. Near the threshing floors the upper portion of the hardpan stratum is from 2 to 3 meters above the bed of the oued M'Zab; the stratum is about 30 centimeters in thickness and is of fairly uniform structure throughout. Beneath this is another stratum, less well defined perhaps, of approximately the same thickness, and with nearly the same character, but carrying a noticeably large percentage of sand. The lower stratum is less hard than the upper one. Underneath the second stratum is soil, largely sand, containing rocks of various sizes. Where erosion of the oued banks has occurred the soft lower hardpan stratum and the yet more soft underlying soil are both removed, leaving the upper stratum projecting as a shelf, sometimes as large as 2 by 4 meters in extent. When the shelving banks break they remain practically intact, partly buried by the sandy floor of the oued. (See fig. 17.)

Along the sides of the valley, and at a distance more remote from the oued, there are occasional washed-out areas, really box cañons, where the banks show a slightly different condition of the hardpan from that just described. Here there may be three strata of hardpan. The uppermost is of the same stratum as the top stratum by the oued, and the second stratum also resembles the lower one just described. There is also a third hardpan stratum of a much different character, in that it has a very large admixture of sand and gravel, and large as well as small stones, making it more easily eroded than either of the upper strata. The soil in which the roots studied were found varied from a fine sand, with waterworn pebbles, near the oued, to a clay mixed with sand nearer the sides of the valley. In places the sand is cemented so as to resemble one of the hardpan strata above described, but it is less hard and apparently is penetrated by water without great difficulty.

The Oued M'Zab, whose channel is 15 meters more or less in width, is dry most of the year, containing water for only a few hours following the rare storms. Wells are very numerous in the valley and furnish a good supply of water. At the time of my visit to Ghardaia the water lay from 10 to 25 meters from the surface, depending on the position of the wells. The depth to water in a single well is said to vary from 1 or 2 meters to 15 meters; in other words, the water-table of the valley varies 13 to 15 meters between the dry and the moist seasons. No analysis of the water is available, but it is reputed to be noticeably saline near and below the town of Ghardaia, while above the town this quality is not apparent to the taste. The water relations of the plain are much less favorable for plants than those of the M'Zab Valley. In addition to the fact that the soil of this area receives only such water as falls directly on it, there is so little depth that the water escapes shortly after it falls, leaving only the most favorably situated soils, for example, those beneath shallowly placed rocks, or between rocks, or in deeply penetrating cracks or the depressions, with sufficient moisture for long use by plants. The depth to water on the hamada is so great that successful wells have never been dug.

THE OASIS OF GHARDAIA.

Each of the cities of the M'Zab has its palm gardens as well as gardens in which grains of various sorts and vegetables are grown. Intensive gardening is practised and the fruits of the soil, although won with great labor, are nevertheless not inconsiderable.*

Perhaps the most palms are to be found about 2 kilometers above Ghardaia, where they are so abundant as to form a small forest. Here,

* In 1908, according to the Statique générale de l'Algérie, there were cultivated in the territory of Ghardaia 572,114 fruit trees, among which were: almond, 5,850; fig, 101,722; date palm, 209,898; other sorts of fruits, 211,761. There were also 17,268 hectares of grain under cultivation.

in the most thickly planted portions, one finds a veritable jungle in which the desert glare is softened by the spreading tops of the palms and by the close canopy of grape-vines which reach from one palm-stem to another. There is a second story of apricots, peaches, almonds, and figs, and on the floor one finds a variety of vegetables. Outside of the palm gardens, and adjacent to them, are the plots in which cereals are grown. These gardens are divided into diminutive fields, frequently not larger than 1 by 1.5 meters, which are separated by small irrigating ditches and smaller laterals, from which they are given water (fig. 19). Here barley, oats, and wheat are raised, and often with them are planted carrots, turnips, or other vegetables. The main ditches are rendered impermeable by heavy coats of plaster, making it possible to use with the least waste the difficultly acquired water.

THE PLAIN (HAMADA) OF GHARDAIA.

A superficial view of the plain (hamada) which lies both to the north and to the south of the M'Zab Valley does not suggest any vegetation whatever, at least during the dry season. The desert is quite as barren in appearance, as, for example, portions of the Libyan Desert are in reality. In every direction one sees grayish-brown stones and bowlders, with little earth, and in some places blackened stones, blackened by "fires from heaven" the Arabs believe, but nothing to indicate the presence of plants. Tristram has described the plain as "one mass of naked rock, rough stone, and coarse débris, from the neighboring mountain, but without a scrap of earth or a vestige of the minutest vegetation." But close study of the plain makes out a better case than this; in fact, where the soil has accumulated in pockets, where there is a slight drainage depression, or where spaces between the rocks are filled with soil, careful examination shows the remains of annuals and not a few living perennials; but like other intense deserts, plants, even when relatively numerous, are not present in sufficient numbers and not of sufficient size to give character to the landscape or to hide the surface of the ground.

The plain on both sides of the valley was studied and a few areas carefully examined with results which are summarized in the following paragraphs.

It has already been mentioned that the walls of the M'Zab Valley at Ghardaia are precipitous, rising between 60 and 100 meters from the valley floor, their summits being the general level of the plain. Both to the north and to the south of the valley there are short but steep tributary gulches. In these gulches, and especially at the heads of the gulches, are pockets filled with earth, and here may be found some perennial vegetation. For example, at the head of such a ravine, 3 kilometers north of the valley, 10 undetermined living species were found, of which 6 were perennials and the balance were long-lived annuals or biennials. (See fig. 20.) In an analogous situation, but on the plain to the south of the valley, the aspect being sim-

ilar, a larger number of plants were found, including, among other species, *Aristida* sp., *Centaurea pubescens*, *Deverra scoparia*, *Fagonia bruguieri*, *Peganum harmala*, and *Teucrium pseudo-chamæpitys*. A census of plants was taken, where the individuals were most numerous, with the following result: On an area 16 by 16 meters there were 330 living specimens. The three dominant species were *Aristida* sp., *Deverra scoparia*, and *Helianthemum sessiliflorum*.

On the level portions of the plain one sees almost no perennials and only the dried remains of annuals, although here and there may be found an isolated specimen of *Peganum harmala* or even of *Citrullus colocynthis*, the latter strangely out of its proper surroundings. In one place, also, a small date palm was found surviving the extremely arid conditions. But on the hamada it is only in relatively favorable situations that plants are to be found. One such was given above and another was found on the open plain, but near the base of a low mountain, where there was a slight depression and where some water was received from the mountain run-off. The area alluded to is 10 kilometers north of the north valley wall; the south base of the nearest mountain is 100 meters to the north of the area. The ground inclines gently to the south, and rises slightly both to the east and to the west. The surface is thickly strewn with stones and the soil is clay mixed with sand, the latter predominating in the center of the depression, where there is also a relatively large proportion of small pebbles. The area studied, 16 meters square, was so selected that the depression crossed the middle portion, leaving the two sides as representing the larger part of the plain. (Fig. 21.) In a country where the conditions of plant life are so severe it is of interest to observe how slight advantages of whatever kind, such as in the square under consideration, work for the betterment of the vegetation. The dominating species was a bunch-grass, probably *Aristida* sp., but there was also present *Haloxylon* sp. (eaten to the surface of the ground by the passing flocks) with other undetermined forms. On the area given 414 living perennials were found with numerous dead annuals. All of the plants were growing in the depression, there being, in fact, none on the adjacent but somewhat higher parts of the hamada. The character of the soil of this square and a discussion of the root characters of plants growing in it are given in another place.

How far the paucity of plants on the plain is owing to the arid conditions obtaining there, apparently a sufficient explanation in itself, and how far to the fact that herbivorous animals, wild as well as domestic, for several centuries have been gaining their food from the plain, can not at present be well told. Observations given below, however, indicate that if areas are protected against the depredations of animals, the plants are noticeably more numerous and of a larger size than when there is no protection. This conclusion applies to portions of the plain as well as to the other habitats under discussion.

THE MOUNTAINS ABOUT GHARDAIA.

The vegetation of the low mountains and of the rocky valley walls is extremely meager, mainly on account of the small amount or total absence of soil. In certain places (for example, near Melika) the plants of the hamada descend the rocky gulch nearly to the floor of the valley, and a similar condition has already been noted at the heads of two of the larger gulches. In such places we find species of grass and *Haloxylon articulatum* mainly, but these species are not typical of this habitat. Only two forms appear to occur on the walls of the valley or on the mountains, and nowhere else. These are the "kabar," *Capparis spinosa*, and one or more crustaceous lichens. (See figs. 22 and 23.) The kabar is a large shrub, 1 to 2 meters high, which bears persistent and fairly large leaves. The shrub is uneaten by animals, owing to some disagreeable flavor,* but is provided with small spines. The species is poorly represented, there being but few individuals, and it does not exhibit exposure preference, but grows in crevices between rocks, sometimes at the base of the walls, or wherever it can attain a foothold. I have seen lichens on the flat and horizontal upper surfaces only of a ridge of low mountains about 4 kilometers north of the valley of the M'Zab; search failed to reveal any on the north surface of the mountains or on any rocks vertically placed; their position would thus subject them to the greatest temperature ranges and to the most intense aridity (fig. 26).

THE VALLEY OF THE M'ZAB.

The bottom lands, as already has been shown, are relatively favorable for plant life; here the soil is the deepest and the water relations are the best. Accordingly we should expect to find in the valley of the M'Zab more plants than we have seen on the plain, and we will not be disappointed in these expectations; but it is almost certain that in primitive times the vegetation of the valley was even richer than at present. In fact we now find in the unprotected places only such plants as are too small for fuel or are not good for food, and the useful sorts are largely wanting. In other and similar valleys, which have not been so much disturbed by man as the M'Zab and where primitive conditions still largely obtain, there is a surprising wealth of vegetation. Such conditions were seen between Ghardaia and Ouargla and will be specially noted on another page.

At present no trees occur naturally in the valley in the vicinity of Ghardaia or any of the sister cities. The French portion of Ghardaia contains ornamental or shade trees, such as the ash, sycamore, and betoum. The largest native shrubs are a species of *Tamarix*, growing by the oued, and a few specimens of *Zizyphus lotus*, the latter confined to the side gulches and numbering half a dozen specimens. Among the most generally dis-

* We were informed by our Arab attendant that the kabar, particularly the fruit, made such animals as ate it insane. The spicy flavor of the plant might otherwise be distasteful to animals.

tributed plants in the valley are *Peganum harmala* (figs. 27 and 28) and *Haloxylon articulatum;* the former is a half-shrub of wide distribution in southern Algeria, occurring from Biskra on the north, and although not strictly confined to the flood-plains of the oued is most abundant where the soil is relatively deep. The leaves are rather large and do not appear to have unusual protection against drought.* Like its relative in the southwestern portion of the United States, the creosote bush (*Covillea tridentata*), it is not eaten by any animals, although not armed and not poisonous. This species, therefore, is one of the few which to-day probably retains essentially the same distribution and appearance it had before the country was inhabited. It is interesting to note that *Peganum* is generally distributed through the M'Zab Valley, being especially abundant between Ben Isguen and Melika. Here in November *Peganum*, except where trodden under foot by the flocks and caravans, retained much of its foliage, although rain was said not to have fallen for twelve months. In the protected areas also, as will be mentioned below, this species was found to be fresh green, showing little or no indication of the long drought. Of other species found in unprotected places in the valley, *Haloxylon articulatum* and *Henophyton deserti*, although eaten by animals so as to be recognized only with difficulty, were also fairly abundant. There were found also *Euphorbia guyoniana*, called "le bain" by our French-speaking Arab helper, because it is used by the natives as a soap, and *Nolletia chrysocomoides*, *Æluropus* sp., and others.

PROTECTED AREAS NEAR GHARDAIA.

Of the plant habitats whose leading characteristics have been briefly given above, only the oasis and its gardens are secure against the inroads of animals. However, owing to the long settlement of the region, rather large tracts of land are at present in what must nearly approach their primitive condition. The areas referred to are the cemeteries, which, for the reason suggested, possess special interest to the botanist, showing briefly what plants might be expected to occur in the region naturally. The typical M'Zab cemetery is of varying size and surrounded by a stone wall. No plants are introduced to decorate it and no irrigation is practised within its walls. The only disturbance of the natural condition of the land is in the use for which it is set aside. The interments are so conducted that the ground appears to be always used progressively, that is, there is

* Fitting (Die Wasserversorgung und die osmotischen Druckverhältnisse der Wüstenpflanzen, Zeitschr. f. Bot., 4, 209–275, 1911) states that water-storage tissue is wanting, that in addition to being large, the leaves are much divided, without trichomes, and provided with thin cuticle. The stomata are fairly large, rather numerous, and not sunk. The leaves transpire rapidly and wilt soon after being removed from the stem. The osmotic pressure of the cell-sap of the leaves was found to equal 35.3 to 64 atmospheres, from which it is assumed that this plant, like others growing under desertic conditions, has a root cell-sap of great osmotic pressure, which permits it to extract water from a fairly dry soil or at a rather rapid rate. But neither at Biskra nor elsewhere, so far as I know, does *Peganum* grow where the conditions are extreme, as might be concluded from the habit of the plant as given above.

always an older portion and always a newer portion, and the part once used is never afterwards made use of again. From this fact, as well as others which need not be entered into, the more ancient portion of the cemeteries, after a lapse of several centuries, or even several decades, without disturbance, must be in essentially the same condition as regards the soil and water relations, which would be most affected by the fact of interment, that they were in in pre-M'Zabite times.

Several cemeteries near Ghardaia and the other M'Zab towns vary greatly in their position as well as exposure; some are on the valley floor below the town of Ghardaia, and others are in side cañons; one is on the south wall of the valley with a northern exposure, and another is on the opposite wall and hence with a southern facing; one cemetery is on the edge of the plain iteslf. So far, therefore, as the flora of the older portions of these areas represent the ancient vegetation of the same areas, we have in them at present a means of learning something of the kinds as well as the abundance and the habits of the plants which formerly occurred here, and (by inference) of the plants which were in the region in primitive times.

Below and not far from Ghardaia, in the valley floor, is a very ancient cemetery, or rather a cemetery with a very ancient part. In the old portion the drifting sand has obliterated all traces of graves, which have long since been forgotten by the citizens of the town. In the newer portion, farther from the edge of the oued and on higher ground, the sand gives place to clay. In the older portion of the cemetery may be found a fairly rich flora and rather large plants—a striking contrast to the vegetation of the unprotected area immediately without the wall. Here one finds *Haloxylon articulatum* and *Henophyton deserti*, both species eagerly eaten by animals, as well as *Deverra scoparia*, *Lithospermum callosum*, *Zilla macroptera*, and *Helianthemum sessiliflorum;* also grasses and other plants which I did not know. Something of the abundance and the large size of the plants is indicated in figs. 29, 31, and 32.

In one of the cemeteries situated against the south wall of the valley, but not including the wall, the conditions are somewhat different from those just sketched; the soil is a sandy loam, with rocks of various sizes in abundance, and here may be found a fairly rich flora. In the ancient portion of this cemetery the most numerous species is perhaps *Haloxylon articulatum*, also *Fagonia glutinosa*, *Fagonia bruguieri*, *Cleome arabica*, *Echinopsilon muricatus*, *Helianthemum sessiliflorum*, *Zollikoferia resediflora*, *Salsola* sp., and others. The plants are relatively abundant and of fairly large size.

In a cemetery on the north wall of the valley, reaching from the floor to the plain above, the wall is less precipitous than at other places and there is a small amount of earth. The number of species here is very limited, being confined almost wholly to *Haloxylon articulatum*, which is fairly abundant; but in the upper portion of the cemetery are also found *Peganum harmala* and *Capparis spinosa*.

The cemetery situated wholly on the edge of the plain has an unexpectedly large number of plants, almost all of them *Haloxylon articulatum*, which is of good size. Outside this protected area the species is neither large nor abundant, since it is eagerly sought after by camels, sheep, and goats, and a shoot no sooner appears than it is eaten to the base.

The sentiments of the residents of Ghardaia, which led to the establishment and protection of the cemeteries, made a close botanical study of them injudicious. Enough was seen, however, to establish several points, the most important being, at least for the areas considered, that there is growing in them, without irrigation, a somewhat rich flora composed of relatively large perennials. And from this fact it seems probable, if also protected against the predatory attacks of animals, that other areas under the present rainfall and other physical environmental conditions now obtaining would support a much heavier vegetation than is generally the case. How far the presence of man and of his flocks has otherwise modified the flora, especially as regards its composition, is another question, but it certainly has not been without its effect. In the portions of the M'Zab region, except certain areas rather remote from the towns, where there is no protection, the only forms which are at all abundant, or at least conspicuous, are such as are armed, poisonous or distasteful, or too small for use as fuel. Among these are *Peganum harmala*, *Zilla macroptera*, *Tamarix*, and others seen later. However, *Haloxylon articulatum*, although eaten by all animals so as never to develop in a normal manner, is surprisingly abundant, although by no means conspicuous.

ROOT-HABITS IN THE GHARDAIA REGION.

Owing to the small amount of soil, close observation of the root-systems of the plants growing on the mountains and the plain was difficult; examination of the roots in the field was therefore carried on mostly in the valley, although enough was seen of the roots of plants in the other habitats to permit a characterization of them. The roots of several species growing on the hamada close to the valley were examined with the following as the leading results: *Deverra scoparia* was found to have a main root running directly downward 20 cm. without giving off large laterals; at that depth it forked, the resultant branches running thereafter in a horizontal direction. (See fig. 33.) *Teucrium pseudo-chamæpitys*, *Centaurea pubescens*, and *Salvia ægyptica*, all from the hamada to the north of the M'Zab Valley, have pronounced main roots. A similar type of root was seen in *Zollikoferia resedifolia* and *Fagonia bruguieri* from the plain to the south of the valley. Grasses growing on the plain had roots which, as usual with grasses, showed more diversity, but on the whole penetrated rather deeply. The root-system of *Haloxylon articulatum* is of the modified generalized type, penetrating deeply also, and will be best described as an inhabitant of the valley.

From these observations it would appear that the roots of most of the plants growing on the plain have a well-developed main root, and that few, if any, perennial roots lie near the surface of the ground. This condition is rather different from that seen at Laghouat, where the root-system of typical inhabitants of a similar habitat is of the strictly generalized type and may point to a difference in some character of the habitat—for instance, the precipitation at Ghardaia.*

In certain portions of the floor of the M'Zab Valley the soil conditions favor full and normal development of all forms of root-systems, but in other portions, because of the presence of an impervious hardpan, such development is not possible. Where there is hardpan the presence of species with obligate tap-roots is precluded, while such as have a more flexible root-system (e.g., *Peganum harmala*) can to a degree accommodate themselves to the unfavorable soil conditions. However, one instance was seen, which will be reported below, where a plant with a tap-root was found growing on a hardpan stratum so hard as to be excavated with the greatest difficulty. The character of the root is very greatly modified by the presence of the hardpan. Following is a sketch of the root-systems of a few plants growing naturally in the valley.

Peganum harmala is one of the most characteristic plants of the floor of the M'Zab Valley; so far as my observations go, it usually occurs where there is much soil and where the water relations are the most favorable. Several studies of it were carried out on plants growing in different parts of the valley. In order to make the leading study of its roots, a typical habitat was selected east of Ghardaia and nearly in the midst of the valley. Here the upper soil, to a depth of about 20 cm., is a fine sand carrying water-worn pebbles and coarse stones. Below the sand is a denser stratum a few centimeters in thickness, but not the hardpan described in another place. Below the harder stratum, to an undetermined depth, are mingled sand and gravel coarser in texture than the superficial sand.

The first specimen of *Peganum* studied in this habitat was about 30 cm. high and in full leaf. Its roots were fibrous, that is, they were not fleshy. The root-system consisted of a main root, which ran directly downward 17 cm., and several laterals. Probably owing to the influence of the hard stratum, the main root at length turned abruptly and maintained a hori-

* It has already been shown that the number of days on which rain may be expected to fall each year is greater at Laghouat than at Ouargla, and probably at Ghardaia also. According to reports, the rainy days at Laghouat vary from 20 to 84 (seven years' observation), with an average of 49 each year. The average number of days on which rain falls at Ouargla is 14.2. The amount of rain at Laghouat is 200 mm., at Ouargla 90.2 mm. It would appear, therefore, that the average rain at Laghouat is less in amount than the average rain at Ouargla; or, in other words, it points to the torrential as being the type of the desert storm. Since, other things being equal, the greater storms would penetrate the ground the most deeply, we may here have an explanation of the emphasis at Ghardaia on the tap-root as against the generalized root as the type of the root-system.

zontal course for 1.5 meters. It was 1.35 cm. in diameter at the crown and 2 mm. in diameter where left, at a depth approximating 27 cm. The main root gave off a lateral 5.5 cm. from the surface of the ground, which also branched; the ultimate branches followed a fairly level course for 45 cm. At the sharp bend of the main root another branch arose and this branched in turn, the daughter branches going somewhat downward for over 43 cm. Branches from the latter roots descended to within 8 cm. of the surface. (See fig. 35.)

Differing in details, the roots of other individuals of the same species in the same habitat have on the whole a root-system essentially like the one just sketched. Even in relatively or actually deep soil the roots of this species do not penetrate deeply, but reach rather widely. They are of the generalized type,* similar in many ways to the root-system of *Covillea tridentata* of the Tucson region. When growing in a habitat where hardpan comes close to the surface, the main root is not so well developed, but there is a better development of laterals than in the specimen more favorably situated as regards soil, in the habitat above alluded to.

Growing in or near the habitat of *Peganum harmala*, whose root-system has been sketched, were other species whose roots were also examined. Among these were *Haloxylon articulatum* and *Euphorbia guyoniana;* the former is one of the native plants most eagerly sought by animals for food, for which reason it was not found possible to secure for study specimens whose shoots were entirely normal; but the plants finally chosen were the least damaged of any found outside of the protected areas. The shoot of the specimen of *Haloxylon* examined was about 50 cm. high; its gnarled base showed that it had been subject to intermittent attacks by animals. It was found to have a main root which ran directly downward more than 30 cm.; at a depth of 10 to 15 cm. a few small laterals took their origin. (Fig. 36.) The other specimens studied showed the same type of root-system, so that *Haloxylon* has here a well-developed main root.†

Growing not far from the two species whose root-systems have just been sketched, and under similar soil conditions, were several specimens of *Euphorbia guyoniana*, whose roots were also examined. This plant has a habit of growing in groups whose members are more or less widely separated. The first specimen studied was one of a colony of a half-dozen whose habit of growth is shown in fig. 38. Its shoot was about 15 cm. high and bore several narrow, smooth leaves, and was 2.5 mm. in diameter at the base. The shoot was found to go directly downward until it joined a horizontally placed fleshy root, from which the other individuals of the colony were seen to take their origin. This, apparently a root-stock, was 8 mm. in diameter and gave off two branches, 3 and 5 mm. in cross-section, which were also horizontally placed.

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* The Root Habits of Desert Plants, *l. c.*

† Compare the root-system of the species at Biskra, p. 64.

On the southern side of the oued, where the soil is cemented into a sort of hardpan, *E. guyoniana* grows in greater abundance, frequently in groups but also singly. Other observations confirm those above reported, namely, that the species reproduces largely vegetatively, new plants springing from old roots, which at Ghardaia are essentially water- and food-storage organs. Only two other species were seen to have water-storage capacity, namely, *Citrullus colocynthis*, to be described directly, and *Phelypæa violacea*, which was seen at Biskra and will be described later.

In the habitat of *Peganum*, and a few meters distant, was found a specimen of *Henophyton deserti*, which had been little injured by flocks. The shoot of the plant was about 30 cm. high, and, in spite of the long dry season, was in full leaf. It possessed a long tap-root, of which 75 cm. was recovered. No laterals were given off along the portion of the root seen. Other specimens of the same species were also examined, and in every instance a similar type of root was found.

Somewhat nearer the side of the valley, but growing where there was considerable depth of sand, were several specimens of *Tamarix*, the roots of one of which were partly exposed. The plant studied was over 3 meters high and had not been injured by animals. Its root was of the tap-root type, since the main root went unbranched directly downward.

There occur in the valley a few specimens of *Citrullus colocynthis* described by Schimper, in "Plant Geography," as follows:

> A cucurbitaceous plant resembling our cultivated pumpkin, and its long, juicy, relatively thick-foliaged and large-leaved shoots remain green throughout the summer, producing fruits as large as a child's head. It presents, therefore, the appearance of being protected in an unusual manner against the loss of water. As a matter of fact, however, severed shoots dry up in a few minutes. The extraordinary length of the roots of colocynth alone renders its existence possible in the desert.

While the description of Schimper is a good one, it conveys the idea of much greater luxuriance of growth than was observed for the species at Ghardaia. As a matter of fact, the leaves of this plant are small and much dissected, and the fruit is the size of an orange. How deeply the roots penetrate the ground, or their length, was not learned, but a very striking characteristic of the root is its fleshiness, which is shown by fig. 37, and the ability of the species to successfully withstand drought may lie in the fact that it is thus provided with a very well-developed and very well-protected water-storage organ, as much as in having a great length of root. *Citrullus* occurs typically where there is considerable depth of earth, especially close to oueds, although it is rarely to be found on the plain and only where the soil is deepest. In the latter habitat the possibility of a permanent connection with a perennial water-supply is without question excluded. The species is rather to be considered one of the forms, rare to the Sahara, which possess a water-balance, and which has the power of storing sufficient water during the widely separated rainy seasons to last it during the period

of drought. It can be pointed out here that plants having hypogeous water-storage organs have a very different relation to the climate of the desert than such as have such organs above ground. The inclosing soil is a protection, nearly perfect, against drying. Where the soil is removed the protected parts quickly become dry.* Given two species, both having water-balance, but one with the storage epigeous and the other hypogeous, other conditions being equal, the latter should survive under more arid conditions than the former. It is rather surprising, therefore, that there are not more of the latter type in the Sahara.

A few measurements of the root of a typical *Citrullus* from the M'Zab Valley will give a concrete idea of the water-storage capacity of the species. A specimen growing in the oued near Ben Isguen was selected for examination (see fig. 37); it had a luxurious shoot and several fruits. The shoot was found to arise from a large and aged root 26 cm. in diameter at the crown, but tapering rapidly, it was only 12 cm. in circumference at a point 14 cm. beneath the surface, where it forked, giving off one branch which was 1.7 cm. and another 1.8 cm. in diameter; several smaller ones took their origin close to the surface of the ground. In its general appearance the main root of *Citrullus* is very like that of *Cucurbita digitata*, which grows on the domain of the Desert Laboratory and in a similar habitat.

Up to this point the plants whose roots have been described were found growing where the soil was favorable to a fairly normal development, but the soil of the valley is not all of this character, and where hardpan is present the substratum is often extremely hard and, one would think from inspection, impermeable to water as well as impenetrable to roots. In such habitats the number of individuals and also of species is very naturally limited.

About 2 kilometers west of Ghardaia is an area where the hardpan reaches nearly or quite to the surface. Here *Peganum harmala* is to be found, since its generalized type of root-system is capable of not a little variation, adjusting the species to a variety of soil conditions not otherwise possible. Associated with *Peganum* was a single specimen, of dwarfed and badly eaten form, growing out of the hardpan itself. The position of the plant was so unusual that its root-system was in part excavated. The form, an undetermined chenepod, was found to have the exceptional form of root, thus proving the rule just suggested, for it had a well-marked tap-root. A gnarled main root was found to take a zigzag course through 27 cm. of

* In the vicinity of Tucson (see The Root Habits of Desert Plants) is to be found a slender-stemmed *Opuntia* whose roots are fleshy and are placed within 2 to 4 cm. of the surface of the ground. It has been observed that if the roots are examined in the midst of a dry season, as in June, they are gorged with water, but if the soil is removed for a few hours they become shriveled. A similar habit was seen in another species of the same genus. Two other genera of the cacti from the Tucson region have the water-storage organs wholly or partly protected by the soil. In *Cereus greggii* the subterranean portion forms an organ 15 to 30 cm. in diameter, and in the other form the fleshy subaerial stem is partly drawn under the surface of the soil, so that only the flat upper surface is visible.

hardpan to the softer stratum beneath. The root did not follow a crack, but struck boldly downward through soil so hard that it was removed by the use of a sharp iron instrument and only with great difficulty.

LEAF-HABITS IN THE GHARDAIA REGION.

Observations of the leaf characters of the desert perennials, as shown in November, offer some points of interest, especially since there had been no rain for a year previous to the visit. As would be expected, the leaf-habit is various, ranging from scale-like or none to fair size. Several species appear to be evergreen, including *Artemisia herba-alba*, *Capparis spinosa*, *Echium humilis*, *Fagonia bruguieri*, *Gymnocarpon* sp., *Haloxylon articulatum*, *Helianthemum sessiliflorum*, *Henophyton deserti*, *Herniaria fruticosa*, and *Salsola*. Certain plants probably, as *Henophyton*, are facultative evergreens, retaining the leaves if the season is moist and dropping them if it is excessively dry; several of this genus were seen without leaves, but with green stems. (See, also, figs. 39, 40, and 41.)

Some idea of the variation in size of the leaves of a single species, as well as the average size of the leaves, will be had from the results of a few measurements. The leaves of *Henophyton deserti* range in length from 2 to 3.1 cm., and in breadth from 0.2 to 0.5 cm. The average length of 12 leaves from a single branch 7 inches in length was found to be 2.82 cm.; the average breadth was 0.35 cm. On another branch, 23 cm. long, were 35 mature leaves which averaged almost exactly the size of those just given. Since these leaves are rather numerous and of good size, it will appear at once that the species has a relatively large leaf-surface, even if the area can not be stated more definitely. (Fig. 30.)

The evergreen shrub *Capparis spinosa* has the largest leaves of any plant native to the Ghardaia region, and probably of southern Algeria. Its leaves are bilateral and nearly round and are placed upright on the branches; a series of 29 leaves from one branch 33 cm. long varied from 2 to 3.2 cm. in length and slightly less in width, the average being, length 2.9 cm., breadth 2.2 cm.

Euphorbia guyoniana has a deciduous leaf-habit. Its leaves are rather small but numerous. A shoot 22 cm. long bore 40 leaves varying in length from 1.5 to 2.1 cm. and in breadth from 1.2 to 2.0 mm., with the average length and average breadth 1.7 cm. and 1.6 mm. respectively.

It is worth noting that the surface of the leaves, as shown by inspection, is, possibly, most often smooth, as, for example, in *Capparis*, *Henophyton*, and *Haloxylon*. Dense hairiness is an exception among the species seen, *Lithospermum callosum* being the only plant striking in this regard.

GROWTH AND FLOWERING HABITS IN THE GHARDAIA REGION.

Upon arriving at Ghardaia in November, it was surprising to find several species of perennials, under strictly desert conditions, putting on new growth, forming fresh leaves, or coming into flower. Especially was this

unexpected in view of the fact that no rain had fallen in the region for twelve months. A study of the roots in relation to the depth to water showed also that most of the native plants, during the dry season, could not have penetrated to a depth anywhere near that of the water-table of the valley, and the water relations of the plants growing on the plain above the M'Zab Valley were even more severe. Further, most of the species do not possess water-storage faculty. It should be noted that the only apparent difference in the water relation between November and in early autumn, or summer, was that of raising the relative humidity of the air through the lower temperature. In a preceding section it has been stated that little or no evaporation took place at night in November at Ghardaia, and possibly less in the daytime than would have been supposed. The leading environmental changes were, of course, the lower daily temperature and the really cool nights.

It is not uncommon in the Arizona desert for a species to form flowers or leaves, following a change in temperature, the moisture conditions being not otherwise changed, but, so far as I know, the temperature changes bringing about this result are always from a cooler to a warmer condition and not the reverse. It would not be expected, consequently, that in the present instance a renewal of vegetative activities would follow as a *direct* result of a lower temperature, although analogous changes are necessary before certain species, after rest, will start development. Whatever may be the immediate cause of the renewal of activity on the part of the plants at Ghardaia as noted, the following species were seen to have formed new leaves: *Henophyton deserti* and *Zilla macroptera;* also the following fresh flowers with or without shoot growth: *Fagonia bruguieri*, *Haloxylon articulatum*, *Henophyton deserti*, *Ononis polyclada*, and *Zillikoferia resedifolia*, and three other species not determined.

GHARDAIA TO TOUGGOURT.

From Ghardaia the route, consisting of camel trails only, pursued a course south of east to Ouargla, and from Ouargla a direction east of north to Touggourt, over 400 kilometers, Ouargla being about half-way. There are no villages between Ghardaia and Ouargla and none between this place and a point 20 kilometers south of Touggourt, so that in accounts of the vegetation or the topography, lacking convenient points around which to center descriptions, the device will be adopted of using distance estimations to or from the three chief towns.

The trail followed the valley of the Oued M'Zab, or kept close to it, for 63 to 73 kilometers before finally leaving it. It passed the sister towns of Ghardaia and crossed short intervals of plain, descending occasionally to the oued. The walls of the M'Zab Valley, 60 meters more or less at Ghardaia, become lower and less precipitous as one goes down the drainage, until at length they become little more than rounded banks. The

low, flat-topped mountains, which are a feature of the topography about Ghardaia, were soon left behind, and nothing similar was encountered until the vicinity of Ouargla was reached. Between Ghardaia and El Ateuf are small dunes in the valley and sand is drifted along the base of the walls at various places. Near and immediately east of this town the sand is especially abundant and, being shifted by the winds, constitutes an ever-present menace to the small gardens belonging to the inhabitants of the place; in order to control its drifting, fences of palm leaves are made or the sand is removed when it becomes too abundant. Often the gardens are abandoned, leaving the palm fences to mark their sites after the sand has gone beyond. Where the air-currents are most powerful or most consistent, or the walls are broken down, the sand may be carried in small quantities onto the plain, where it constitutes a mulch, influencing in a striking manner the character of the vegetation (fig. 42).

Finally leaving the valley of the M'Zab about 73 kilometers from Ghardaia, the trails wound upwards through low rounded hills to the hamada. This is the northern edge of the region of the Gantara, 100 by 150 kilometers or more in extent, reaching from the valley of the M'Zab on the north to the region of the dunes to the south. It slopes towards the Oued Igharghar, or the drainage depression connected with this great oued. The Gantara has a few chotts and is crossed by three oueds in the southern portion. It is probably the most arid part of southern Algeria. About 60 kilometers of the plain were crossed and here it was gently rolling and stretched without a break to the horizon. The surface resembles that of the hamada at Ghardaia, that is, stones of various sizes, usually small, lie on its surface, but never forming a continuous cover, as in some portions of the Arizona desert. The soil is brown, of fine grain, and with little or no addition of sand. In the innumerable little hollows the soil is deeper than on the slight rounded ridges. Wind is apparently the most potent erosive agent.

Two chotts were encountered between Ghardaia and Ouargla, one unimportant, the other large and with many features of interest. The latter, the Chott Mellala, is about 10 by 15 kilometers in size. The trail descends from the plain, winding through a zone of rounded, cone-shaped hills or mamelons, to the floor of the chott, which lies about 60 meters lower than the general level of the plain. The chott was quite dry in November when we visited it, but at rare intervals water is said to flood the central portion. Toward the outer edges the floor is thrown into waves, where the heavy incrustation of salts is broken. In the center the salt crust forms an unbroken and level surface. Gypsum (calcium sulphate) is the predominant salt. On the eastern side a long and high ridge of sand rears its uneven summits. The height of this ridge was estimated to be 250 meters, and was said by Massart to be the largest seen by him in the Sahara. This dune we had seen lying on the eastern horizon for one or two days before reaching the chott.

The relation of the Chott Mellala to the country to the north or the south was not seen, but between it and Ouargla there lies a succession of smaller and more irregular chotts, which together form a fairly well-connected chain. These chotts are separated by low passes and flat-topped hills whose summits are on a level with the neighboring plain. Many of the hills are cone-shaped and in other topographic features the region shows the eroding action of wind. About 7 kilometers from Ouargla an opening in the mamelons gives a view of a plain extending on a lower level to the horizon. This is the reg, or fluvial desert. The Ouargla plain, or reg, is connected with the drainage of the great Oued Ighaghar and has a character which in many ways is different from the Gantara, over which we had just passed.

With the descent to the reg desert a more monotonous region is encountered. In the vicinity of Ouargla and for some kilometers to the north the topography is quite flat and gives the impression of a flood-plain. To the east it stretches unbroken to the horizon, but to the west it is bounded by a fairly abrupt wall, the Gantara escarpment. At intervals of several kilometers low sand ridges cross the route over the plain, and on the second day somewhat higher ground was traversed and a sand ridge about 4 kilometers across was encountered. The country then becomes somewhat more broken and presents the appearance of being the remains of an ancient and more elevated plain. About 56 kilometers from Ouargla are the largest dunes crossed; where traversed, these were 10 kilometers from north to south and extended beyond our vision both to the east and the west. This is apparently the edge of extensive dune regions which lie mainly east of Touggourt and of the Oued Rirh. For possibly the last 30 kilometers of the journey to Touggourt there are dunes and chotts in alternation.

A word should be said regarding the hydrography of the region whose surface features have been sketched above. Between the cities of Beni M'Zab and Ouargla two wells were passed, although a route could have been taken which could have included three wells. The wells are 125 meters or less in depth and are maintained by the government for the benefit of the caravans, as well as to provide water for the large number of goats and sheep pastured in the neighborhood. The situations of the wells are always in depressions, either along the Oued M'Zab or in similar although smaller drainage areas, and none are on the Gantara. At Ouargla and on the reg desert to the north of the town the water lies very close to the surface of the ground. It can be dipped with buckets and the roots of the palms reach to the water-table. The water from the shallow wells is strongly impregnated with salts. Before reaching Touggourt standing water was seen where the trail crossed certain chotts. Numerous artesian wells have been made by the government which penetrate the ground several hundred meters and give a large and continuous supply of sweet water.

GHARDAIA TO OUARGLA—VEGETATION.

The plants seen during the first day's march from Ghardaia were such as have already been observed to be characteristic of the valley of the Oued M'Zab or of the neighboring hamada. The vegetation of the hamada, usually very sparse, was noticeably more abundant wherever the sand had been drifted over it from the dunes of the valley, even if the thickness of the sand was so slight as to be little more than a mulch. Here low grasses, much eaten, were the prevailing forms. On the dunes in the valley of the M'Zab, 20 kilometers from Ghardaia, the number of species and individuals is relatively large, the most abundant species being drinn (*Aristida pungens*), although *Deverra scoparia* is also fairly numerous. Somewhat farther on the route, and in a sandy flat, besides these two species, there is much *Ephedra alata.* On the slopes leading from this flat and on the plain above, there is an almost pure stand of *Rhantherium adpressum.*

Crossing relatively small portions of the plain, in place of always following the bends of the Oued M'Zab, about noon of the second day we reached the bordj Zolfana, in the valley of the Oued amidst low and narrow dunes, which are moving slowly across the flats. (Fig. 441.) No vegetation appears on the dunes, but on the fixed sand between them, or on the stationary dunes at the border of the flats, some plants are to be found. Among these the most abundant, but really not numerous, are *Euphorbia guyoniana* and retam (*Retama retam*), which was often seen later along the line of march as well as in the vicinity of Biskra. Retam superficially resembles *Ephedra alata* in having rudimentary leaves and green, reed-like branches; it is carefully avoided by animals, although *Genista saharæ*, a very similar plant, which grows in like situations between Ghardaia and Ouargla, is said by Massart (*loc. cit.*) to be eaten greedily by them. (Fig. 43.)

A short distance beyond the bordj the bottoms suddenly widened, the dunes disappeared, and for the remainder of the day's march we passed through the richest vegetation we had seen since reaching the M'Zab region. (Figs. 45, 46, and 47.) Here the shrubs were of fair size and of sufficient abundance to give character to the landscape. About the 63 kilometers camp the leading species are *Retama retam*, *Ephedra alata*, and *Haloxylon schmidtianum.* On the hamada adjoining the flat are several species, including *Aristida ciliata*, *Artemisia herba-alba*, *Farsetia ægyptiaca*, *Farsetia linearis*, *Gymnocarpon fruticosum*, *Helianthemum eremophilum*, *Henophyton deserti*, *Marrubium deserti*, *Salsola vermiculata*, *Teucrium polium*, *Thymelæa microphylla*, and *Zollikoferia mucronata.* On the hamada just adjoining the place of our camp, however, there appeared to be *Haloxylon schmidtianum*, to the exclusion of other species.

After crossing the bottoms of the oued the trail climbed up to the hamada and we did not see the M'Zab Valley afterward. The vegetation of the hamada soon becomes very sparse and as far as the eye can reach the appearance is that of entire bareness. But, as was found to be the case near

Ghardaia, close examination revealed the presence of many living perennials as well as the remains of the previous annual flora. This plain, the Gantara, of wide extent, is the most arid region seen in southern Algeria. Massart estimates that there is an average precipitation of 15 cm. on the desert, but, from data previously cited, it would appear that this amount is rarely attained; indeed, several months, or even two or more years, may pass without any rainfall whatever. When one searches the hollows he finds a few small perennials; plants are almost wholly absent on the low ridges. But in some areas on the plain, where superficial examination does not show any plants, a surprising number were found. For example, on the level hamada, 96 kilometers from Ghardaia, on an area 16 meters square, 389 living plants were found, but only 24 were so large as to be seen from a distance; all were either eaten badly or trampled to the ground, so that it could not be learned what the flora of the area might have been had no animals interfered with its full development.

After leaving the 96 kilometer station the perennials were seen to diminish rapidly in numbers and to decrease in size, until the ridges of the low undulations were absolutely without plants, and there were but few in the hollows. There was no apparent change in the character of the hamada or in that of the soil. This sterile condition persisted for 26 kilometers, when vegetation similar in character to that previously seen was again encountered. The zone of better vegetation lasted for 3 kilometers, when the country became barren once more, which condition lasted for 10 kilometers. The presence of barren belts on the Gantara, where the plants at the best are insignificant in size as well as number and without change in topography or soil, points to an especially arid belt. This conclusion is further strengthened by the observation that the plants found were relatively of very small size.*

The flora was also sparse upon the route followed by Massart across the Gantara, which was apparently somewhat farther to the north than the one now being described. He mentions having found *Argyrolobium uniflorum*, *Astericus graveolens*, *Fagonia microphylla*, *Deverra chlorantha*, *Fagonia glutinosa*, *Halogeton alopecuroides*, *Helianthemum* sp., and *Herniaria fruticosa*. He says that *Deverra* is one of the rare glabrous forms on the hamada. It is said to have the odor of parsley, and the Arabs have a belief that camels which eat it become blind, but Massart's camels were not injured by eating the plant.

As we drew near the Chott Mellala, on the eastern edge of the barren zone mentioned in the preceding paragraph, we suddenly encountered a belt of *Ephedra alenda*, stretching to the north and to the south as far as

* In the case of annuals the differences in development of the shoot between plants well watered and those with only a meager supply are very striking. In one instance in the Tucson region specimens of *Parietaria debilis* growing in extreme conditions, one moist and the other arid, varied in length between 39 cm. and 8 mm., or a difference with a ratio of 49 to 1. (Root Habits of Desert Plants, *loc. cit.*)

could be seen (fig. 49). On one side was the barren zone, on the other the immense plantation. Upon examination it was found that the *Ephedra* was the only species of perennial. It had several points of interest, but the short time at our disposal precluded more than a superficial examination. Usually keen about the desert species, it is curious to note that the Arabs appear not to recognize this, called by them "alenda," as being related to the larger species of *Ephedra* with which they are well acquainted. It is a small species, growing from 30 to 40 cm. high. It does not occur singly, but has the habit of growing in groups of a half dozen or more. Between the *Ephedra* colonies were only the dried remains of the annual flora of the last rainy season. An examination of the root-system of the species showed that, like other species of the genus, it has a well-developed tap-root (fig. 50).

Alenda, however, has a root-habit which, although not peculiar to it, is at least very striking and of great importance to its survival. From the root-crown a stolon arises which extends away from the parent for a distance of about a meter. From this stolon there arise shoots which develop into daughter plants. Through this method of reproduction the small colonies of the species are formed and possibly the species mainly multiplied. From the stolons small roots arise, giving aid to the mother root in providing the offspring with moisture. This habit is very like that of *Kœberlinia spinosa* of the Arizona desert, which has a similar type of root-system and which reproduces vegetatively in a similar manner. *Alenda* continued to be the dominant species until near the edge of the big chott (Mellala), a few kilometers east of where it was first seen.

Practically no plants were seen when descending through the eroded portions of the hamada to the floor of the chott (fig. 52), but on reaching the bottom of the great chott a surprisingly large number was observed, including *Anabasis articulata*, *Aristida pungens*, *Ephedra alata*, *Limoniastrum guyonianum*, *Retama retam*, and *Traganum nudatum* (fig. 51). In the wide central part of the chott, where the salts are perhaps most dense, there are no plants; but on the eastern side are *Euphorbia guyoniana*, *Anabasis articulata*, and *Zygophyllum* sp. These small species were growing far apart and were badly injured, either by being trodden under foot or by being eaten by the passing animals. To the south of where we crossed the chott and also to the north the sand mountains arise. After leaving Chott Mellala we ascended gradually to go over a low pass separating it from a small chott to the east. Here we obtained a backward view of the sand mountains, low as seen from the pass, with sharp, wind-made ridges, and bearing a few specimens of *Aristida pungens*. Descending somewhat, another but smaller chott was crossed. Between the latter chott and the Ouargla plain the plants were very few and confined to the slopes and the higher ground, avoiding almost wholly the depressions. Of those recognized, *Tragonum nudatum* was the most abundant. This is the

"vamran" of the Arabs and is an inconspicuous shrub frequently seen later on the way to Touggourt.

OUARGLA TO TOUGGOURT—VEGETATION.

Ouargla is an ancient, rambling town, somewhat in decay, set in the midst of extensive palm gardens. There are said to be 500,000 date palms at the oasis. It was founded in the tenth century by the M'Zabites and later taken possession of by the Arabs. The town is peculiar in its situation and its gardens, lying, as before described, in the flood-plain of an ancient river. The plants cultivated in the town as ornamentals are fewer than at Ghardaia, but of the same kinds, and (besides dates) the gardens contain fewer fruits and apparently fewer kinds of vegetables. Between the gardens one finds *Tamarix* in some abundance.

Leaving Ouargla by the western gate and turning north, we soon passed through the crooked streets and reached the reg desert to the north. There is little vegetation near Ouargla, but on some low dunes extending over the reg we found *Aristida pungens* and *Phargmites* sp., growing in a hollow. On the flood-plain there were a large number of individuals and probably a large number of species. Among the most conspicuous of the shrubs were *Retama retam* and *Limoniastrum guyonianum*, the "zaita" of the Arabs. (See figs. 56 and 57.) Zaita is a handsome shrub with cylindrical leaves often covered with a fairly heavy salt incrustation. So abundant is the exudation that in localities where the species is especially abundant, as at our camp 32 kilometers south of Touggourt, the plants have the appearance of being covered with snow. Although, like many other species between Touggourt and Ouargla, zaita can live where there are salts in excess, it appears not to be an extreme type of halophyte and does not occur where the salts are most dense. It was seen both on the dunes and on the low lands. Other common halophytes are "souid" (*Salsola tetragona*), "belbel" (*Anabasis* sp.), and *Halocnemon strobilaceum*, which appears especially resistant. (See figs. 59, 60, 61, and 62.)

Other forms appear on the higher ground and on the plain about 50 kilometers from Ouargla, where *Ephedra alata* especially is common. There are no dunes on the plain, but some sand swept across it from the fluvial desert to the west passes eastward and augments the dunes farther east. The larger specimens of *Ephedra* are rather effective sand-binders and bring about the formation of diminutive dunes. The effect on the growth of the species by the piling sand is peculiar. As the sand accumulates it covers the lower branches of the shoot; these are stimulated to unusual growth and new branches may spring from them. Thus the effect is similar to that habitually occurring in *E. alenda*, but in *E. alata* the habit is not a fixed one. As an instance of the length which such submerged branches may attain, it may be mentioned that one, 2 to 3 cm. in diameter, was over 4 meters long.

About 75 kilometers from Ouargla, and on a plain similar to that just referred to, "dhamran" (*Traganum nudatum*) was the most common species, but was by no means abundant. The census of an area 16 by 16 meters, taken in a locality where dhamran was dominant, resulted in finding 31 living and a few dead plants, probably all *Traganum*. It is to be understood that the vegetation of the reg desert not far distant is much richer, not only in species but especially in individuals, and also that the plants are much larger.

From 56 kilometers to about 71 kilometers from Ouargla the route lay over more or less continuous dunes, where the leading species seen were *Aristida* sp., *Ephedra* sp., *Euphorbia guyoniana*, *Limoniastrum guyonianum*, and *Traganum nudatum*.

In or about the edges of the chotts, which are the leading topographical features of the region immediately south of Touggourt, the most common species are *Haloxylon* sp., *Salsola tetragona*, *Limoniastrum guyonianum*, and *Arabis aphyla*. Besides these forms, about 28 kilometers south of Touggourt fine specimens of *Halocnemon strobilaceum* were seen growing in an extremely salty situation, to the total exclusion of other species. *Tamarix* also is to be found in and about salt spots near Touggourt. (See fig. 64.)

Both Massart and Doumet-Adanson (Bull. Soc. Bot. France, 39, 1892) have discussed the flora of the Touggourt-Ouargla region. The following exhaustive list is given by the latter author as having been collected between the two desert towns:

Henophyton deserti.
Matthiola livida.
Malcolmia ægyptica var. linearis.
Maricandia cinerea.
Sisymbrium pendulum.
Savignya longistyla.
Reseda stricta.
R. arabica.
Helianthemum sessiliflorum.
H. ellipticum.
Randonia africana.
Frankenia pulverulenta.
Silene nicoeensis.
Monsonia nivea.
Erodium glaucophylum.
Fagonia glutinosa.
F. frutescens.
Polycarpæa fragilis.
Gymnocarpus decandrus,
Retama retam.
Genista saharæ.
Astragalus gumbo.
Anthyllis henoniana.
Neurada procumbens.
Ammodaucus leucotrichus.
Mesembryanthemum sp.
Deverra chlorantha.
Nolletia chrysocomoides.
Senecio coronopifolius.
Anthemis monilicostata.
Tanacetum cinereum.
Ifloga fontanesii.
Centaurea purpuracea.
Amberboa omphalodes.
Rhantherium adpressum.
Atractylis flava.
A. prolifera.
A. microcephala.
Tourneuxia variifolia.
Catananche arenaria.
Spitzelia saharæ.
Zollikoferia chondrilloides.
Z. squamosa.
Sorzonera nudulata.
Echium humile.
Echiochilon fruticosum.
Arnebia decumbens.
Statice pruinosa.
Limoniastrum guyonianum.
Plantago ciliata.
P. psyllium.
Scrophularia saharæ.
Linaria fruticosa.
Euphorbia guyoniana.
Atriplex dimorphostegius.
Caroxylon tetragonum.
Echinopsilon muricatus.
Calligonum comosum.
Haloxylon articulatum.
Anabasis articulata.
Cornulacea monocantha.
Thymelea hirsuta.
Th. microphylla.
Aristida flaccosa.
A. pungens.
Cyperus conglomeratus.
Ephedra fragilis.
Erythrostictus punctatus.
Scilla sp.
Dipcadi serotinum.
Asphodelus pendulinus.
Ruppia maritimus.
Chara fœtida.

TOUGGOURT TO BISKRA—PHYSICAL FEATURES AND VEGETATION.

From Ouargla to Touggourt we have found that the country gradually descends, the former place being 124 meters and the latter 77 meters above the level of the sea. From Touggourt, also, for a distance of about 120 kilometers, the descent along the route continues until at the Chott Merouan a level of 6 meters is attained. The lowest places in every case are of course the chotts and the connecting oueds. The most important chott of this series is Melrirh, 11 meters or more below sea-level. This drainage system is the northern culmination of the vast one of which the Oued Igharghar is the most important part. In an earlier age water came north in the oued from the highlands of central Sahara and poured into the Chott Melrirh, having passed successively through the lesser chotts farther south. At that time, also, the Chott Melrirh probably was connected with the Gulf of Gabes.

From Touggourt to Chott Merouan, the lowest portion of the route to Biskra, the topography is that of a region of chotts; that is, there are salt spots surrounded on every side by higher ground, which in many cases is of sand. From Chott Merouan the route passes over a higher desert of a different character, which in part bears a remote resemblance to the Gantara and in part to the Ouargla plain. It is a vast plain, with little topographical diversity, which rises to meet the Atlas Mountains to the west and north. In the eastern portion it is somewhat rolling, stones are strewn plentifully on its surface (hamada), and there has been considerable erosion, so that gullies are formed. In the portion nearer Biskra the surface is more level, the soil is fine (reg), and there has been comparatively little erosion.

The soil of the chott region is largely of sand; on the hamada there is much clay, while on the reg it is fine and easily blown by the wind, and this in spite of the fact that the most vegetation seen in the Sahara was in this region. A slight breeze picks up the dust and carries it long distances in dark clouds. It fills the throat, nose, and eyes of the traveler and makes crossing the reg exceedingly disagreeable.

The plant life as seen along the portion of the route through the chott region consists almost wholly of halophytes, as would be expected, in addition to which, where for short distances the hamada or dunes were crossed, there were forms characteristic of such areas. The *Tamarix* is especially common in the region and *Limoniastrum guyonianum* is also often met.

The date gardens of the Oued Rirh are justly famous. One passes numberless plantations where the date is cultivated, and in the neighborhood of each group of gardens one sees squalid Arab villages. Over 19,000 tons of dates are said to be carried each year by camel from the Oued Rirh to Biskra, whence they go to the markets of the world. One day we passed 700 camels laden with dates going to Biskra.

As soon as the chott region is left and the higher ground is reached a different as well as a richer flora is encountered. Here diversity of topography favors diversity of plant life. On the reg near Biskra vegetation is especially

abundant. Here, in fact, one passes through large thickets of *Tamarix* and other species, and sees that the desert is much less intense than that in the south, especially in the region of the M'Zab, where in many respects the topography is similar. The kinds of plants also, as the list below will indicate, are different in the main from those farther to the south. Where the surface is most rolling we find *Tamarix* sp. on the heights, *Zizyphus lotus* in the hollows, and the following grasses: *Stipa tortilis*, *Hordeum maritimum*, and *Phalaris minor*. A salsolaceous shrub (*Arthrocnemon macrostachyum*) may be found in washes, *Nitraria* and *Limoniastrum guyonianum* on sandy places, and *Odontospermum pygmæum* and *Anastatica hierochuntica* occur between rocks. On clay flats one finds *Halocnemon strobilaceum* and *Suæda vermiculata*, indicating the presence of salts.

The preceding notes are in part from Massart. The following species are given by Doumet-Adanson as having been collected by him between Biskra and Touggourt:

Savignya longistyla.
Eremobium lineare.
Lonchophora capiomontana.
Monsonia nivea.
Erodium pulverulentum.
Fagonia sinaica.
Haplophyllum tuberculatum.
Lœfflingia hispanica.
Paronychia nivea.
P. cossoniana.
Herniaria fruticosa.
Zygophyllum album.
Z. cornutum.
Peganum harmala.
Nitraria tridentata.
Astragalus gyzensis.
Ononis serrata.
Ammodaucus leucotrichus.
Cyrtolepis alexandrina.
Anacyclus clavatus.
Pyrethrum fuscatum.
Nolletia chrysocomoides.
Tanacetum cinereum.
Ifloga fontanesi.
Artemisia herba-alba.
Anvillæa radiata.
Atractylis flava.
A. prolifera.
Nonnæa micrantha.
Lithospermum callosum.
Heliotropium undulatum.
Plantago ciliata.
P. albans.
Limoniastrum guyonianum.
Statice pruinosa.
Echinopsilon muricatus.
Traganum nudatum.
Ephedra alata.
Cutandia memphitica.
Erythrostictus punctatus.
Asparagus albus.
Aristida pungens.

THE BISKRA REGION.

TOPOGRAPHY.*

Biskra lies immediately south of the Atlas Mountains, in the Department of Constantine, 220 kilometers from the Mediterranean and about 400 kilometers from Ouargla. To the northeast of the oasis lie the Aurés and to the west the beginning of the Saharan Atlas, which run south of west across Algeria into Morocco. Just north of the place are small hills and low, jagged mountains—detached spurs from the main ranges. These are the Djebel Bou Rhezal, running nearly northeast and southwest. The highest of them, directly west of Biskra and about 8 kilometers distant, has an altitude of 463 meters. The Bou Rhezal Mountains have a precipitous southern face, but fall away more gradually to the north, where the slope joins a wide and undulating plain. The latter extends to the base of the main Atlas ranges. Southwest of the oasis, and about 2 kilometers distant, a range of rocky hills extends for a distance of about 6 kilometers, or until they join the mountain range of the Saharan Atlas. These hills

* The vegetation in the vicinity of Biskra is so well known that a sketch will suffice as a basis of comparison with the flora and conditions of plant life farther south.

are called Ed Delouatt. To the south of Biskra, as has already been stated, there extends a vast plain, the reg, which dips gently to the south and drains into the Chott Melrirh, 50 kilometers or more distant. The situation of Biskra relative to the mountains on the one side and the desert on the other, together with its altitude, governs the climate of the place. Except Laghouat no vicinity in the desert proper was seen with so great an amount of precipitation (about 200 mm.) as Biskra, which is indicated by the relatively rich flora. One who has seen only Biskra can not draw conclusions regarding the vegetation or the conditions of plant life of those portions of the Sahara that lie farther to the south, where much more intense conditions of aridity obtain.

The soils of the vicinity of Biskra are various. That of the low hills between the town and the Djebel Bou Rhezal is only a few centimeters in thickness, but in the washes from the hills it is a meter or more. Here the soil is a sandy loam with an admixture of small stones and pebbles. On the flat ground to the north and to the south of these hills it is of a finer texture, approaching the adobe of the southwestern United States. On the reg to the south of the oasis the soil is also fine, and in some places, if not underlying the plain as a whole, there are strata of gravel at varying depths beneath the surface. This soil in places carries considerable salts. It dries to a powder during the long dry seasons and is easily blown by the winds. Owing to outcropping rock, the south face of the Bou Rhezal Mountains has but scant soil, but that of the northern side resembles the soil of the low hills to the south, which has already been characterized. Near the town are dunes of good size. Especially to the southwest the sand banks against Ed Delouatt hills is in large amount. In the opposite direction, but farther from the oasis, the dunes are fairly extensive.

The Oued Biskra is of great importance to the oasis, since it carries water for several weeks of the year and furnishes water for irrigation. Its channel lies about 3 meters, or possibly more, below the general level of the oasis, and possibly in earlier times may not have been so well defined as at present, spreading its waters over its flood-plain during high water. The oued is made up of several tributary oueds which cross the plain north of Djebel Bou Rhezal, unite where there is a pass in these mountains, and finally debouch on the reg to the south of the town, where the channel becomes continually less well defined. Another oued takes its origin in the Bou Rhezal Mountains in several independent branches which unite at a pass in Ed Delouatt hills and extend for a distance of 15 kilometers or more into the reg. One of the feeders of this oued is from hot springs, Hamman es Salahine, about 8 kilometers northwest of Biskra.

PLANT HABITATS OF THE BISKRA REGION.

From the preceding sketch of the leading topographical conditions of the vicinity of Biskra it will be seen that the plant habitats are more diverse than at any other place visited. For the present purpose the habitats may

be distinguished as follows: The alluvial desert (reg), which lies on every side of the oasis save the north; low hills adjoining the oasis on the north; Ed Delouatt hills, southwest; the oueds and their flood-plains; the Dj. Bou Rhezal; the hamada (?) lying both to the north and to the south of the latter.

VEGETATION OF THE BISKRA REGION.

A glance over the list of plants which grow naturally in the vicinity of Biskra* shows that many are the same as occur farther south, with many unlike these, having affinities outside of the desert proper; also, the number of plants as well as species is greater at Biskra than farther south. This would be expected from the greater rainfall and more diverse topography.

The flora of the Biskra oasis, according to the authors referred to above, consists of 175 or more species. Of cultivated plants there are 25 or more species, the most conspicuous being the date. The other species are mostly the same as have already been noted at other Algerian oases, except that both the peach and the apricot are wanting at Biskra, although cultivated at Laghouat, Ghardaia, etc. On the outskirts of the town the fairly extensive flood-plain is given over mainly to the cultivation of grain, barley predominating.

The hills and mountains, and the bajada at their base, as well as certain oueds with water relations, exposure, and soils different from those of the oasis, have also a very different flora, which, for the most part, is desertic in character. For purposes of comparison, some of the leading characteristics of the plants growing in a half-dozen localities will be given.

As stated above, to the southwest of Biskra there runs a range of hills, Ed Delouatt, to the south and the north of which may be found interesting plants and plant conditions. On the south side the slope (bajada) descends gradually to the great reg, and near the base of the range, in the vicinity of the place where tradition says a Roman town formerly existed, there is a wide, sandy plain, reaching from the Oued Melah, which pierces Ed Delouatt hills, nearly or quite to the western extension of the oasis. There are no large dunes here, but sand billows about a meter in height and sand hillocks diminutive in size. Between these the plain is fairly level. Over this whole tract there seemed to be only one species (*Euphorbia guyoniana*), but this was fairly abundant. (Fig. 65.) As at Ghardaia and elsewhere, this species grows in small colonies because of its suckering habit, and acts to a small degree as a sand-binder, each group being situated on a sandy hillock. It will be remembered that this species at Ghardaia, as well as at a certain bordj east of that place, had roots which were somewhat fleshy as well as roots which were fibrous, on one and the same plant. I was interested to learn whether similar conditions should obtain at Biskra, since it had been learned, in the case of two species of *Opuntia* in the Tucson region,

* Liste des plantes observées aux environs de Biskra et dans l'Aurés, Trabut *et al.*, Alger, 1892.

that a different habit followed certain differences in habitat. Several specimens of *Euphorbia* were removed with care from the soil and in no case was it found that the roots were fleshy, but in every instance they were entirely fibrous. It is supposed that the reason for the variation in behavior may possibly be traced to differences in the water relation, as was found to be the case of the variation in cactus roots cited, but no experiments have been made on *Euphorbia* to prove this.*

There is a variety of habitats on the opposite (north) side of the hills, ranging from the large dune (which reaches the summit to the west of the pass through which the oued passes and which must be 100 to 150 meters above the oued) to the flood-plain, with water very near the surface, during rainy season at least. There are rocky slopes, also, and sandy slopes apart from the dunes referred to, as well as a fine clay with sand admixture on the flood-plain. In all of these habitats, except the large dune, the vegetation is actually or relatively abundant. (See fig. 67.) Among the rocks are small shrubs or half-shrubs, and also on the plain below. Here one may find, among other species, *Echiochilon fruticosum*, *Helianthemum* sp., *Atractylis serratuloides*, *Gymnocarpos fruticosum*, *Thymelæa microphylla*, *Nitraria tridentata*, and *Acanthyllis tragacanthoides*. On the sandy slope was growing a very numerous population of liliaceous forms, mainly, perhaps wholly, *Asphodelus fistulosus* (fig. 72).

It has been noted that the oued which pierces Ed Delouatt is made up of the confluence of all of the small oueds lying between the Bou Rhezal Mountains to the north of Biskra and the hills lying directly north as well as those (Ed Delouatt) to the southwest. The united oueds reach the base of the hills nearly 1 kilometer east of the pass, and turning abruptly follow the base the remainder of the distance. At the place where the oued touches the range the soil is moist nearly to the surface of the plain (reg) and for several meters back from the oued. Here, then, the water relations of the plants are such as to favor, probably most of the year, the growth of mesophytes (?) or even of hydrophytes, but for some reason there is not much vegetation there; whether large species have been removed as for fuel, have been destroyed by animals, or never existed, was not learned. The most interesting plant found was the well-known parasite *Phelypæa violacea*, which grows, according to Mobius, on a salsolaceous host.† Only a few

* Briefly the case is as follows (see The root systems of desert plants, *loc. cit.*): *Opuntia arbuscula* growing near Tucson develops fleshy roots, but what is probably the same species growing about 100 miles distant has fibrous roots. Also, seedling opuntias have fleshy roots. *Opuntia vivipara*, which occurs naturally in the bottom of an arroyo (oued), may or may not have fleshy roots. By preliminary series of experiments it was learned that all opuntias tested which had an abundant water-supply developed fleshy roots, and it is assumed from this that the differences in this character as observed in nature had also such a physiological basis.

† Eine botanische Exkursion nach Algier and Tunis, Bericht der Senckenbergischen Naturforschenden Gesellschaft in Frankfort a. M., p. 76, 1910.

specimens were seen at the time of the second visit to Biskra, in March, and they were just appearing above the ground. (See figs. 69, 70, and 71.) When removed from the soil the longest specimen was found to have penetrated over 59 cm.; it was 6.5 cm. in diameter at a point 50 cm. from the tip. The plants were exceedingly heavy, being gorged with sap, and appeared to be able to absorb moisture from the wet soil through the white and delicate epidermis of the entire portion submerged. If this is the case the parasitical relation is of especial interest, as the species is wholly dependent on its host for organized foods, but not for water—a condition opposite that found in such semi-parasites as the mistletoes, which obtain water and unorganized foods in solution from the host, but which, save for the fact of attachment, are otherwise independent of it.

To the northeast of Ed Delouatt hills and north of Biskra, but immediately adjoining the town, is an irregular group of low, rounded hills, mostly very arid, which support a scant vegetation of typical desert plants. These hills, without a name, are eroded to a degree and have shallow washes leading from them in every direction. The soil appears to be thin, except in the washes, where it has accumulated to the depth of a meter or more. On the rounded summits it is rather fine, but in the washes there is much gravel and larger stones. Here one finds the greatest range in exposure, and probably also an accompanying difference in the temperature of the air and soil.

In considering the vegetation of the hills it must be remembered that no plants suitable for forage or large enough for fuel would be left untouched, as the biotic factor is quite as much in evidence in modifying the Biskra flora as that of the other regions visited. As the plants are at present, however, and for whatever definitive causes, there is a considerable variation in numbers and apparently also in kinds. An examination of different parts of the hills by which various exposures as well as other conditions are seen bears out the hypothesis. On the southern slopes, particularly the upper portions, the plant covering is especially poor. The population of an area 16 by 16 meters in the upper south slope included 134 perennials and numerous annuals. Of the species, *Haloxylon scoparium* was the most numerous; there were also *Dœmia cordata*, *Thymelœa microphylla*, and *Fagonia sinaica* (figs. 78 and 80). All of these species were small, so that from superficial examination the area appeared fairly barren (fig. 73).

When one crosses the hills to the north, so that northern and northwestern exposures are seen, a striking difference is immediately apparent. The northern slopes are much richer in perennials than the opposite facing. The population of an area of the size before taken shows this observation to be correct. On a square 16 by 16 meters, with north exposure, 536 living perennials and numerous annuals were found, with *Haloxylon scoparium* again the dominant species. The species second in number was *Ferula visciritensis*, which is to be found chiefly on the north exposure (figs. 74,

75, and 77). There were also a few specimens of *Acanthyllis numidica*, and many annuals, which, unlike those on the south facing, were not in flower.

On the lower slopes, in the small and open gulches and the lower portions of the washes and their flood-plains, the plants were most numerous and include a variety of forms, with *Peganum harmala* the most conspicuous and most numerous.

The roots of several species growing on the hills were studied with the following as perhaps the leading results: The root-system of *Haloxylon scoparium*, as has already been seen to be the case with an allied species in the country of the M'Zab, may be said to be a modification of the generalized type. One specimen, partly exposed by erosion in a wash, had a tap-root over 113 cm. in length (fig. 76). As this root was 4 mm. in diameter where left, and was 8 mm. in diameter at the crown, it may have penetrated much beyond the point where it was left, provided the soil conditions continued favorable. The main root gave off two large laterals, of which one left the parent root 8 cm. and the other 18 cm. beneath the surface of the ground, but there were also numerous filamentous roots about 2 cm. in length, which were borne in tufts. (See fig. 79.) These resembled the deciduous rootlets found on many perennials in the Tucson region and doubtless function quite as they, namely, they are organized at the beginning of the rainy season, operate to increase the water-absorbing area of the plant quickly and greatly, and die as soon as unbearably arid conditions set in.

In the same wash, where the soil was deep with an admixture of small stones and pebbles, the roots of other species were also examined. One of these was *Peganum harmala*, whose roots were examined at Ghardaia. The root-systems of the plant in the two regions were similar in being generalized. A main root was found extending downward over 61 cm. and it gave off three good-sized laterals, arising from 15 to 27 cm. beneath the surface. The uppermost lateral took a horizontal course. Figure 82 gives a fairly good idea of the general character of the root-system of the species.

There were many specimens of *Plantago albicans* growing in the same habitat as *Haloxylon* and *Peganum*. Its root-system was also studied with the following results: The tap-root is strongly developed. In one instance the slender main root was found to go straight down over 71 cm. Numerous laterals were borne between 8 and 20 cm. beneath the surface of the ground. The species has an interesting habit of propagating vegetatively by means of fleshy stolons. An examination of the stolons showed them to be of very unequal age, some having been lately formed, while others had been organized in previous years and were no longer living. Many specimens were examined to learn the probable service of the fleshiness of its stolons, and the conclusion was that this factor probably enables the species to pass over periods of excessive drought.

Running across country are the Bou Rhezal Mountains, of which the north and south faces were examined in one or two places, on each side somewhat in detail. The south face is precipitous and has little vegetation, but there are many plants on the opposite face, especially near the base, where the soil conditions are relatively favorable (fig. 84). Among the perennials were found a few specimens of *Rhus oxyacantha* and *Zizyphus lotus*, which, although dwarfed, were the largest plants seen away from the oasis, being about 1.5 meters high. In another gulch were found the following species: *Acanthyllis tragacanthoides*, *Dœmia cordata*, *Ferula vesciritensis*, *Haloxylon scoparium*, and other plants unknown. Toward the upper portions of the gulches *Haloxylon* was seen to be especially abundant, but in the bed of the washes and on their flood-plains *Peganum* grows in large numbers (fig. 83). In the most favorable places on the northern slope in March the annuals were the most abundant observed in the vicinity of Biskra, although even there they failed to completely conceal the ground. Where the situation was less favorable as regards soil and water conditions (for example, on the side of the gulches, on the summit of ridges, and the like) there were almost no annuals and those present were relatively small.

In this brief account of some of the most striking features of the Biskra flora it should be noted that several habitats are omitted as not being pertinent to the points in view. Especially, nothing has been said regarding the flora of the salt flats along the Oued el Hamman or that of the dunes, since the influences here are largely edaphic, while the present interest lies mainly in the relation between plants and climate; and the flora of the oasis has been largely neglected for similar reasons.

Not only is there in certain regards a larger number of plants in the Biskra region than had been previously seen in southern Algeria, but there are certain types, mostly new, which point to more favorable conditions of plant life. These are such forms as have a water-storage habit, like *Asphodelus*, *Ferula*, *Plantago*, and *Phelypæa*, which, although not wholly absent farther south, appear to be much more numerous near Biskra. The presence of bulbous plants is well known as being one of the floral characteristics of the High Plateau, and it is also known that similar forms are not to be found where the arid conditions are the most severe, which probably accounts for the facts noted. It may be pointed out also that plants at Biskra exhibit exposure preference where soil conditions appear to be parallel. This condition is not so marked farther in the desert as at Ghardaia, for example, where, provided there is sufficient depth of soil, apparently any species may be found on any exposure. In other words, exposure preference implies a certain amount of water as well as sufficient soil.

So far as shown by observations of the root-systems carried out on similar species growing in the Biskra region and at Ghardaia, the essential root characters of plants growing in the two regions are the same. The single exception to this so far noted is that of the roots of *Euphorbia guyoniana*,

which, contrary to the expectation, are apparently wholly fibrous at Biskra, although they are in part fleshy farther south, where the soil conditions are surely more arid. At Biskra, also, the only plant observed with typical generalized root-systems (*Peganum*) does not grow where the soil is shallowest, but where it is relatively deep. So far as seen, also, plants growing where the soil is shallow have either a generalized root-system or a root-system approaching this type, even if the branching is only relatively deep.

GENERAL SUMMARY AND CONCLUSIONS.

THE ENVIRONMENTAL CONDITIONS OF PLANTS IN ARID REGIONS.

The environmental conditions encountered by plants in the arid regions are widely different from those of moister regions. Precipitation is not only slight, but it shows an enormous range in variation from year to year; the rate of evaporation is high; the temperature of the air and soil varies widely both during the day and with the seasons; the light is of great intensity, and the soil is low in humus content and may contain an excess of salts. These, the most striking physical factors of deserts, are present in different combinations with resultant differences among deserts, and an arid region may be so large as to include such variation within its borders. Also, a desert may be so far from the ocean, or it may include such diversity of topography, as to show great variation in biological features as well as in its surface phenomena.

In the flora of any arid region, the mutual relations of the constituents of the flora and its general and detailed relation to the physical environment are quite different in the main from these features in the flora of the more humid regions. Thus, the leading relation is the relation to water, and on the response of the plants to this relation much of the phenomena associated with plant life in the desert directly depends. For example, in the extreme deserts it is probable that the elements of competition between the perennials, which is an important factor in the survival of a species in the moister regions, is wholly lacking. It should be noted, however, that in the less extreme deserts, as in the vicinity of the Desert Laboratory, competition exists between plants, although this is not at first apparent. In this case the competition is not for room, but for water, and is not manifest by palpable crowding, but by invisible competition of the roots. Thus the reactions are with the physical environment and are exhibited in a variety of ways, some of which concern the plants themselves in an intimate manner, being morphological and physiological, some being concerned with the flora as a whole. The environmental responses are often obscure and complex, but in other instances they are less obscure and apparently direct.

As is well known, a desert flora is in part perennial, lasting with but little outward change from season to season, and in part ephemeral, consisting of short-lived species which appear with the rains and which disappear with the return of the dry season. The ephemeral flora differs in no essential regard from annuals of the moister regions; also, the environment to which they are exposed closely resembles the environment of the annuals of such regions. But the perennial desert flora, on the other hand, offers very striking departures from the corresponding flora of the moister regions, just as the environment to which they are exposed for the most of the year is also different. It will be sufficient, for the purpose of bringing out the point of view, to notice a few of the leading characteristics of desert plants and of their physical environment and, in a few instances, to observe possible relations between the two.

The most obvious features of desert plants are associated, in whatever way, with the subaerial portions. Leaves are usually greatly reduced or wanting, during the dry seasons at least. Spines are frequently present and the exposed parts are often well covered with hairs. The stomata are sometimes deeply sunken, the cuticle often very heavy, and a waxy substance may cover leaves or stems. The chlorophyll-bearing cells are arranged with the long axis at right angles to the leaf or stem surface. All or most of these characters are associated with the low humidity of the air. In certain deserts plants are also to be found with greatly enlarged stems and branches which serve as water-storage organs. It should be noted, however, that plants which do not have a constant surface undergo many marked changes with a betterment of the water relations, particularly if this comes when the temperatures are favorable. For example, many cacti organize leaves which are unsuited in structure for periods of extreme drought, and which consequently fall away soon after the close of the rainy season. These leaves enormously increase the rate of transpiration at a time when this is not injurious.

It is not in the subaerial parts alone, however, that the plants of one desert are different from those of another, that plants are unlike in the same desert, or that plants of a desert are different from those of the more humid regions. The root-habits also exhibit not a little diversity and show marked reactions to the pressure of their environment. For instance, the desert shrubs of the region surrounding the Desert Laboratory at Tucson have well-marked root-systems, apparently constant under natural conditions, which may roughly be designated as the tap-root type, the superficial type, and the generalized type. Other conditions being equal, species with characteristic root-types have also characteristic distribution, or exhibit in other regards consistent reactions. Thus, the widely extending and superficial type of roots is confined, among independent plants, to such as have water-storage capacity. The relation of this root-type to the distribution will be mentioned later. Plants with a dominating tap-root

are confined to areas where the soil is relatively or actually deep, while species having generalized roots have a local distribution which may be considered the maximum.

The relation of the superficial type of root-system to the distribution of the species is not so apparent in this relation in plants as with the other types of roots, but is undoubtedly close and possibly definitive. The absorption roots of plants with water-balance mostly lie less than 10 cm. beneath the surface and are thus subject to extreme desiccation for the maximum time, or in other words they are exposed to favorable moisture conditions the minimum time. How long the optimum water-absorption time may be for such species is not known, but that it is longer than might be supposed (from the period certain species can survive without water) is highly probable from the facts concerning their distribution. In brief, the best development of the fleshy species in question occurs where the rainfall is periodic, occurring twice each year, and they are wanting or sparse where the rainfall is uncertain or occurs but once annually. Had these plants a deeply penetrating type of root-system the local as well as the general distribution would be very different from what it now is. Owing to the unfavorable character of the rainfall in southern Algeria, plants with a water-balance are wanting there, just as they are wanting in portions of southwestern United States where the amount or the character of the precipitation is likewise unfavorable.

Besides the characteristics of the root-systems of the desert perennials whose significance has been sketched, there are other features of importance. For example, the roots lying near the surface bear tufts of delicate roots, which are formed during periods of active growth and perish when such seasons cease. By the organization of deciduous rootlets the absorption area of the species is enormously increased, and quickly, without at the same time increasing the distance of water transport.

There need be mentioned here only one additional feature of the desert plants. It is now known, in brief, that the non-fleshy perennials of the desert, not halophytes, may possess a very dense cell-sap. This fact has been demonstrated in the subaerial parts of several species, and is assumed to hold for the roots also of the same species. As suggested, not all of the desert plants, however, are capable of developing dense juices. Thus, certain fleshy species, and such mesophytes of the desert as have been studied in this connection, do not have more highly concentrated cell-sap than the ordinary plants of the humid regions. Further, it appears that desert species which, under natural conditions and during the dry seasons, form extremely dense juices, lose this capacity when grown under humid conditions. So far as is now known, species capable of developing a cell-sap with high osmotic power have generalized roots, although this may be of no especial significance; but the relation of this capacity to survival in an arid substratum is apparent and vital.

ENVIRONMENTAL FEATURES OF THE FLORA OF ALGERIA.

The physical environment of the plants of southern Algeria is, in a few broad features, similar to that of the southwestern portion of the United States. These regions have about the same latitude, both are separated from a large sea by mountains, and the range in altitude is similar. There are other features, however, particularly as regards the amount and the distribution of the precipitation, in which the two widely separated regions are very unlike, and a correlated difference in the habit and composition of the floras of the two regions is apparent.

The Algerian climate as a whole is a mild, temperate one, but very diverse. The latitude and topography taken in connection with the presence of large seas to the north and west, and a large continent leading away to the south are its chief determinants. The climate, therefore, of the northern portion is coastal; that of the southern portion continental.

Probably the most important of the secondary factors which modify the climate of Algeria is its highly varied topography. An important mountain system, the Atlas, made up of many more or less detached groups and secondary systems, a plateau or steppe lying 3,000 feet more or less above the sea, and finally the northern edge of the Sahara, which has a very diverse topography of its own—such is the surface of Algeria.

Algeria is divided into three climatic provinces corresponding to the leading topographical differences: the Tell, including the littoral, or portion between the maritime Atlas and the Mediterranean; the High Plateau, or steppe, which lies between the Tellian Atlas and the Saharan Atlas; and the desert. These provinces have marked individual differences in rainfall, temperature, and other climatic features.

In the Tell and the High Plateau the winds from the sea deposit most of their moisture. Along the coast as much as 700 mm. of rain is recorded, while in other parts of the Tell it is about 570 mm. On the High Plateau the yearly precipitation sinks to 310 mm. In the desert south of the Saharan Atlas, however, where the altitude is lower and the temperature greater than in either of the other provinces, the yearly rainfall is 200 mm. and less. In some years, in fact, no precipitation whatever is reported in the desert.

The seasonal distribution of the rains in any arid or semi-arid region is of great importance as a factor in shaping the character of the vegetation. For example, in the semi-arid region of the southwestern part of the United States, in the Tucson region, there are two distinct rainy seasons—the rains of winter and those of summer—and here the plants with a water-balance are an important feature; but farther to the west, where there are no summer rains, there are no succulents. In Algeria, also, there is but one rainy season and it has already been noted that the absence of plants with water-storage facilities is one of the leading characteristics of its vegetation. The seasonal distribution of rains is as follows: In the Tell, in winter it is 42 per cent,

in spring 27 per cent, in autumn 27 per cent, and in summer only 4 per cent. On the High Plateau the percentages are 30, 20, and 34 for winter, spring, and autumn, and 16 for summer. In the desert the percentages for winter, spring, and autumn are 37, 39, and 20 respectively, while in summer 4 per cent of the entire rainfall occurs. On the High Plateau, however, and in the Saharan Atlas the distribution of rain is much more equable, since 16 per cent falls on the High Plateau in summer and 13 per cent in the Saharan Atlas the same season. We have, therefore, the interesting result that both in the Tell and on the desert there is a long, dry summer season, but in the intervening country more or less rain falls at this time of year. It seems very probable that a careful study of the plants of these regions would show reflected in the vegetation this peculiar character of climate.*

The mean relative humidity changes in a marked manner as one passes from the Tell, across the High Plateau, and enters the desert. For example, at Fort National the mean relative humidity is 85 per cent. On the desert it varies from 54.6 per cent at Ouargla to 42.6 per cent at In Salah. At times in midsummer the humidity in the desert is too low to measure with instruments; it is often 7 or 9 per cent. On the other hand, the humidity in autumn is surprisingly high, owing in part to the lower temperature and in part to the northerly winds. However, no dew is reported and probably its occurrence is rare.

With so great difference between the Tell and the desert in relative humidity is associated marked variation in the rate of evaporation. For example, at Algiers the total annual evaporation is 1,654 mm., while at Ghardaia it is 5,309 mm., which is possibly the greatest amount of evaporation thus far reported. Thus, the difference in evaporation between the Tell and the desert is nearly as the ratio 4 to 1.

The evaporation-rainfall ratios for the Tell, High Plateau, and the desert are of great interest. The seasonal evaporation-rainfall ratio for the littoral is 2.5 to 1; that of the Tell is 3.5 to 1; that of the High Plateau is 9.4 to 1; and that of the desert is 46.5 to 1. If we represent the evaporation-rainfall ratio as unity, the ratio for the Tell becomes 1.4 and the ratio of the High Plateau becomes 9 to 3.7, while the desert ratio is 18.6.

The annual and daily variations of temperatures in the desert are naturally relatively great. At Algiers the annual variation is approximately 40.7° C., while at Ghardaia it is 47.9° C. As great an annual variation as 57° C. has been observed at Ghardaia. The daily variation of temperature is especially marked on the High Plateau and the desert, ranging 17° C. more or less on the High Plateau, and 20° C. more or less on the desert. These figures are occasionally overstepped: for example, at Batna in July, 1904, when the maximum daily range was 21.8° C.; and an observation

* Plants with subterranean water-storage organs—bulbous plants—are said to be a feature of the High Plateau.

made by the writer in the open desert between Ouargla and Touggourt, in November, 1910, showed a variation of temperature of 24.7° C. between 3 o'clock in the afternoon and 6 o'clock the following morning.

The absolute maximum temperatures in southern Algeria are fairly high. At El Golea, for example, they are 47°, 46.5°, 48°, and 49.2° C., while at In Salah, about 700 miles from Algiers, the maximum temperatures for four years have been found to be 50°, 49.2°, 50°, and 48° C. It is interesting to note that at Ouargla, which is much nearer the coast than In Salah, even higher temperatures have been recorded. The maxima for as many years are as follows: 50.2°, 51.0°, 52°, 49°, and 48.4° C. Usually in winter freezing temperatures are experienced at all stations in southern Algeria.

Very little has been done on the soil temperatures in the desert region, but at Ghardaia, in July, 1911, the temperature of the soil 15 cm. beneath the surface of the soil ranged, maximum from 36° to 37° C., minimum from 31° to 33° C., giving an absolute range of 6° C.

In addition to the rainfall, the evaporation, and the temperature, there is another important climatic factor which should be taken into account, but which can not be stated in accurate terms, *i.e.*, air-currents. It is a matter of common experience that one rarely observes a calm day on the desert, but that usually the wind, which is often of considerable force, is found to be blowing. This is unquestionably an important factor in raising the total of evaporation and therefore in increasing the arid conditions of this region. The winds which are most effective in the direction mentioned are those which come from the desert and are known as the "sirocco;" these are most likely to blow in spring and summer, although they occur in autumn also, and to a very limited degree in winter. When the winds blow from the north cooler conditions occur, the relative humidity is lower, and therefore the evaporation rate is less. The sirocco, or desert wind, crosses the Mediterranean and is sometimes felt in southern Europe. It does not generally last more than three days at one time, but at Batna, in July, 1902, it was reported for eight consecutive days. When the sirocco blows the humidity is likely to be markedly affected; for example, at Batna during the eight-day sirocco alluded to, the relative humidity fell from 25.6 to 16 per cent on the first day.

SOME EFFECTS OF TEMPERATURE AND RAINFALL IN SOUTHERN ALGERIA.

While it is recognized that, generally speaking, climate shapes the character of the vegetation, its immediate effects can not well be measured, or, at least, have not been accurately measured, so that it seems necessary to confine one's observations to supposed or probable effects, however unsatisfactory this may be. So far as suits the present purpose, climatic effects may conveniently be separated into those which are direct and those which are not direct, remembering at the same time that the division is purely

arbitrary, since the climate is a complex of various factors and its effects on vegetation are also complex. Among the climatic factors whose effects are most striking are the air temperature and the rainfall, and only certain effects resulting from a variation of these will be commented on here.

In parts of the Sahara visited where the most rain is reported, especially Laghouat and Biskra, plants were observed to exhibit exposure preference. Here the south or southerly facing slopes may have a floral composition different from the opposite exposure. In each instance the soil conditions, and apparently the moisture conditions also, were alike. Exposure preference was not noticed in the southern portions of the colony. Another temperature relation was observed, namely, the renewal of growth in the autumn. This is probably direct effect, although the point is not certain. In Ghardaia it was seen that many of the perennials were taking on new growth and coming into flower, although no rain had fallen for 12 months. Analogous conditions, with a significant difference, occur each year in the Tucson region. Here with the change from a cooler to a warmer temperature, as from winter to spring, or from spring to summer, fairly independent of the rainfall, many perennials organize flowers or shoots. But, so far as is known, no species renews its vegetative activities with the coming of winter, or with a decreased temperature and also *independent* of the rains, although there are characteristic winter and summer plants. Judging from analogy, therefore, it would appear that the stimulus to development on the part of the M'Zabite plants may be from the relatively better water relations made possible by a lower temperature without rain. In November at Ghardaia the evaporation rate is much below that of summer, that during the night being very small. Further, it was told me by good authority that the same species seen growing in autumn renew growth whenever rain chances to come, whatever might be the season. But it should be remembered that rain most commonly occurs in this region in winter, so that the plants may have a rhythm to which they usually conform, but from which they may depart, and that both stimuli (better water relations and lower temperature) are the annually recurring factors by which it may have been induced. Reference, of course, is made to perennials only, as no annuals were seen until the rains of spring made conditions favorable for their appearance.

The effects of a varying amount of precipitation are naturally the most marked of any climatic factor. It is especially striking as one goes south from the Mediterranean, crossing the Tell and the High Plateau and entering the desert proper. Whether the effects would be increasingly striking with deeper penetration of the desert is doubtful. As is well known, a leading characteristic of the vegetation of the littoral and of the Atlas Mountains is the presence of forests of whatever species. As the littoral is left behind the forests disappear until on the High Plateau there are only straggling trees along the dried water-courses. This steppe bears mainly shrubs,

many of which are halophytes, with the perennial grass, *Stipa tenacissima*, and *Artemisia herba-alba* away from salt spots. Such low forms are present in sufficient numbers as to give character to the landscape and to conceal the surface of the ground fairly well.

South of the Saharan Atlas a marked change occurs. Here, with a rainfall of 200 mm. and less, the trees are confined to the dayas, a narrow belt, the vicinity of oueds, and the oases, exclusively. The shrubs of the hamada also decrease in numbers as one goes south, and where the annual precipitation is least, as on the Gantara between Ghardaia and Ouargla, large barren areas extend. At no place on the hamada of the M'Zabite region are the shrubs present in sufficient numbers or size to conceal the surface of the ground or to give character to the landscape.

Aside from the effects following a lessened annual precipitation there is also to be taken into account the increasing uncertainty of rain, or its irregularity, which is also a marked characteristic of the Saharan climate. In the desert, also, storms are likely to be of the torrential type. I did not observe vegetation characteristics which appeared directly traceable to the irregularity in rainfall, but Hayward reports an interesting condition observed by him in the southern Sahara, near Kidal, where large tracts of *Mimosa* had died from an unusually long period (five years) without rain.* It is not at all improbable that to the cause named much is directly traceable which is generally attributed to insufficient rainfall taken in the usual sense. It is probable that the vegetation of the desert—the amount as well as kind—is due to the capacity of desert forms to meet successfully the occasional, even rare, conditions, of whatever sort.

THE SOIL RELATION IN SOUTHERN ALGERIA.

A very important environmental factor, although one which can not at this time be adequately presented, is the soil relation. Nowhere is the edaphacic factor more important than in the desert, where quantity and quality are always important and occasionally even determining factors. In this connection I do not refer particularly to dunes or to chotts, but to country soils, that is, the sort most commonly to be found, which in southern Algeria is a clay with sand present in greater or less amount. So far as the relation of plant to soil refers to the presence or the absence of the plant, the problem can be briefly stated thus: Given similar kinds of soil and an equal precipitation, areas where, within limits, there is greatest depth of soil will have the largest number of plants, and areas with light soil covering will have few or no plants. Also, having given sufficient soil, the kind of plants present, together with certain root-types, will depend on the soil depth. It should be understood that these generalizations are supposed to apply to southern Algeria and not the deserts in general, or at least not

* Through Timbuctu and across the Great Sahara, 1912, p. 266.

to semi-deserts where in certain regards a very different condition obtains. The plant distribution thus dependent on soil depth, and the root character also having relation thereto, will be presented below; the soil conditions, so far as they are known to me, can be given briefly in this place.

From a few excavations on the hamada near Laghouat, on an analogous area by Tilrempt, on the hamada at Ghardaia, between Ghardaia and Ouargla (Gantara), and by Biskra, in each instance with analogous topographical conditions, it was learned, in short, that on formations of this sort the soil is usually less than 50 cm. in depth, although where there are rocks or in drainage depressions the depth may be greater. In the oueds, where a different type of soil occurs, greater soil depth is naturally found; also on the reg, or alluvial plain, frequently at least the flood-plain of oueds, the soil conditions are peculiar and the soil is deeper than on the higher hamada. The special significance lies not so much in the differences in the soil *per se*, but in the differences in the water relation occasioned by variation in depth. Owing to want of data in regard to penetration of water and its retention on the Algerian soils, the soil-moisture relation can only be gathered from inference. As regards rains, it is probable that light showers, those so slight as not to penetrate over 1.0 cm., have little or no direct influence on the perennial vegetation, but greater penetration directly benefits such plants. The first conclusion is drawn from the observation that filamentous rootlets (seemingly like the deciduous rootlets of the perennials of the Tucson region) on *Haloxylon* at Biskra were not found nearer the surface than 8 cm. Should the more superficial soil layer be moist for any considerable time, there would apparently be no reason why such temporary rootlets should not be formed nearer the surface. However, should there be sufficient moisture in the soil to permit absorption by roots, provided a slow rate was adequate to replace the transpiration loss, which rate was made lower by a more moist air, a slight rain would be of great significance, even if it did not penetrate to any appreciable depth. On the intensely arid desert such slight modifications of the water relations as the lowering of the temperature as winter approaches, causing decreased evaporation or rains, although actually small in amount, may be of large moment to plants. Such a condition was noted at Ghardaia,* where there had been

* Soil samples were taken from the plain about 3 kilometers north of Ghardaia from an area where the vegetation is relatively good (see p. 40). The surface of the soil at the place is slightly depressed. Soil samples from the depressed area and samples from portions of the plain adjacent to it were settled under water, with the result that the proportion of fine soil was found to be less in the depressed area. Samples of the soil from the lower area were placed in air-tight cans and the moisture content determined subsequently. The soil was found to contain 0.8 per cent water. Through the kindness of the Bureau of Soils, U. S. Department of Agriculture, the critical moisture-content of the same soil was determined, which was 5 per cent. The critical moisture-content of mesa soil, taken from the creosote-bush slope at the foot of Tumamoc Hill, Desert Laboratory, as determined by the Bureau of Soils, is 10.5 per cent, which forms an interesting comparison of nearly similar situations.

a drought for over twelve months, but on the return of the cool season, with a lower evaporation rate, growth was resumed and several plants came into flower. This appeared to be not wholly the stimulus of lower temperature, since I was informed by good authority that the plants renewed their various activities whenever rains chanced to come, whatever might be the season.

From the observations last given it appears that sufficient moisture persists in the soil to tide perennials over the long periods of drought, although not in sufficient amount to permit active growth during the dry seasons. This is not an uncommon occurrence with desert plants. For example, whenever in the Tucson region the arid seasons are uncommonly long, or there has been a relatively small rain, as 25 per cent less than usual, much of the vegetation may remain dormant. Under such conditions an evergreen like *Covillea tridentata* drops all save the youngest and smallest leaves and maintains this nearly defoliate condition for long periods, with little other change. The plant behavior noted is always connected with insufficient moisture.

The soil in the oueds and probably also in the reg, as well as that of the dayas, is of considerable depth. The soil depth, or rather the depth before solid rock is encountered in the valley of the Oued M'Zab at Ghardaia, is from 20 to 30 meters, or even more; at the Daya Tilrempt the depth to water in one of the wells is about 95 meters. Although there is much gravel and sand in the fill of these depressions, it is likely that they afford the most favorable soil conditions in the desert for the development of a large root-system. Be that as it may, it is certain that large plants, such as *Tamarix* and *Pistacia*, occur only in such places.

Where there is most soil on the hamada, as in certain pockets near the old hill town of Ghardaia, abandoned several centuries since, one finds also the most and largest plants of this, the hamada, formation. Moreover, at the time in November when growth was noticed in the oued plants, it was also taking place in these favoring situations, about 50 meters above the level of the valley of the M'Zab and much above any possible permanent water-supply such as is afforded by a water-table.

The various habitats, therefore, not including the oases, are naturally closely associated with soil differences. These are few and, in nearly each case, to name is sufficient definition. There are dunes (areg), hamada or stony desert, reg or alluvial desert, the daya, and the flood-plain of the oueds (reg?). Modification of the hamada, reg, and oued flood-plain occurs whenever white hard-pan (caliche) is present. The soil of the reg, often that of the oued flood-plain and that of the daya, is fine alluvial and is relatively or actually deep. The hamada has the poorest soil condition, being underlaid by rock, and often or always by hard-pan as well. Large stones and boulders are embedded in the soil or lie on the surface. A modification of the hamada occurs whenever sand is strewn over its surface, even

if the sand is only a few centimeters in thickness. This acts as an effectual mulch, increasing the retentive capacity of the soil, and very strikingly changes the character of the vegetation. The final habitat to be mentioned is the salt spot, or chott, where gypsum constitutes an important salt.

As regards their relative importance the habitats in southern Algeria can probably be grouped in the following sequence, a relation which very possibly holds good for the Sahara taken as a whole: Hamada, dune, oued, flood-plain, reg, daya.*

The habitats are unlike as regards the relation to the rainfall and its effects. This is in part due to the differences in soils, or their depth, and in part to topographical differences. By the latter the low-lying areas receive a relatively large amount of water; and since their soil is relatively deep the water is retained longer than on the hamada, for instance, where the soil is shallow.

The habitat preferences of the plants of southern Algeria are marked, as would be expected from the striking differences in the habitats. On the dunes, for example, we find drinn (*Aristida pungens*) as possibly the most commonly occurring and the most widely distributed sand-plant. One finds on sandy areas also *Tamarix* sp., *Euphorbia guyoniana*, *Ephedra* sp., *Retama retam*, *Limoniastrum guyonianum* (zaita), and other forms in smaller numbers. On the oued banks there are *Tamarix*, *Nerium oleander* (Laghouat), and, near the oases, date palm and other introduced plants. On the flood-plains will be found a large number of species, among the most typical of which are *Peganum harmala*, *Retama retam*, *Ephedra*, *Genista* sp., and *Haloxylon* sp. The typical plants of the dayas are *Pistacia atlantica* and *Zizyphus lotus*, the latter occurring on flood-plains and the reg as well. On the chotts we find mainly such halophytes as *Anabasis articulata*, *Halocnemon strobilaceum*, *Salsola* sp., *Limoniastrum guyonianum*, and others. The flora of the reg, so far as my observations show the conditions obtaining, is essentially like that of the flood-plains, which would be expected from the relation of the two habitats. South of Biskra, however, where the reg is probably not of fluvial origin, one finds a forest of *Zizyphus lotus*, and much *Ephedra* sp. among the most striking forms. Finally, the flora of the hamada, which has a peculiar stamp, can be briefly characterized.

On the hamada are to be found the fewest species and the smallest individuals. Probably most perennials of the hamada are under 30 cm. in height. Among the species characteristic of the hamada are *Artemisia*, *Teucrium*, *Deverra*, *Centaurea*, *Acanthyllis*, *Thymelæa*, *Echinops*, *Henophyton*, and *Haloxylon*. The last named is possibly the most widely distributed, occurring in other habitats as well.

* The mountains have been disregarded, since in southern Algeria they are nearly barren. The only exception to this that I saw was that of the crustaceous lichens in small numbers at Ghardaia. In the central Sahara, however, where the mountains are of great elevation, the mountain climate brings about favorable conditions for plant life.

ROOT-CHARACTERS AND SPECIES DISTRIBUTION IN SOUTHERN ALGERIA.

The general principles bearing upon the relation between the type of root-system and the distribution of the species, as observed in southern Algeria, can be briefly stated. Often the relation is close and apparent, but not always. For example, large perennials, such as *Tamarix* and *Zizyphus*, have an obligate specialized root-system, with a long tap-root. These plants naturally occur where there is considerable depth of soil, and hence are not to be found on the hamada, for instance, where it is shallow. On the other hand, such species as have a generalized root-system, like *Acanthyllis* and *Haloxylon*, are to be found on the hamada, but they occur also in other habitats where the soil is deep. The last type of root-system is flexible, accommodating the species to a wide range of soil conditions. In doing this the change in form is almost a change in type; for example, the roots of *Haloxylon* on the hamada at Ghardaia develop both laterals and a main root, but in deeper soil, as at Biskra and Ghardaia also, the laterals are nearly suppressed and the tap-root is the striking feature. A marked exception to the rule that plants with a generalized type of root-system have also the widest local distribution lies in *Peganum harmala*, which, having roots of this character, is nevertheless restricted to habitats where the soil is deep. The species is a half-shrub, having a perennial subterranean portion and a short-lived subaerial portion, the life of which appears to depend on the character of the water-supply. As learned by Fitting, the species can develop in its leaves a very dense sap, enabling it to extract water from a very dry soil.* In spite of this fact it appears to act like an annual in certain regards, requiring at all times, particularly during the most arid season, a relatively good water-supply.

Thus, in brief, a study of the relation of the root-type of the Algerian plants to the plant's distribution leads to the same general conclusion already obtained by similar but more extended study in the Arizona desert, namely, that the connection is often a very close one and often of definitive importance. Where the root-type is an obligate type the distribution of the species is much restricted, but where it undergoes modification with changed environment the distribution of the species is much less confined. It is of interest to note especially that as a rule it is the latter kind of root-system that is developed by such plants as occur where the soil conditions are most arid, that is, on the hamada or its equivalent, and not the former, from which it follows that the generalized type of root-system is really the xerophytic type *par excellence*, and not the type with the most deeply penetrating tap-root, as might be supposed.

* Die Wasserversorgung und die osmotischen Druckverhältnisse der Wüstenpflanzen. Zeitschr. f. Botanik, 4, 1911.

THE BIOTIC FACTOR.

It will be well to summarize some of the main facts regarding another and important environmental feature of the Saharan plants, namely, the relation to herbivorous animals. In the western Sahara, wherever there is any forage, animals which subsist on it are to be found. Of the wild animals the gazelle is probably the most numerous and the most destructive. All travelers across the desert have noted the presence of this animal. In the northern Sahara Tristram remarked its abundance fifty or more years ago, and it may be frequently seen by the traveler at the present time. In addition to the native animals, the domestic animals, especially the sheep, goats, and camels, are very numerous, very destructive of plants, and range great distances for food. As a result, an area around every well or oasis, extending as far as 40 kilometers or even much more than this,* is repeatedly grazed over and has been utilized in this manner for centuries. As a result only the poisonous or the distasteful species, or the plants especially well armed, are left undisturbed to grow and reproduce, while the balance are more or less consumed, frequently so much so as to be quite unrecognizable. From the large number of camels, sheep, and goats which range the desert pastures it might be concluded that the leading types of plants to be found would be such as are not eaten by them, but this is not the case. On the other hand, possibly the most generally consumed form is *Haloxylon*, which grows on the oued flood-plain, the reg, and the hamada. Thus, so far as this type is concerned, there is probably little or no diminution in numbers because of the attacks of animals.

A similar conclusion would doubtless be drawn after study of other forms, but there lies at least one notable exception, namely, the influence of animal grazing on the distribution of the betoum (*Pistacia atlantica*). The betoum, which is the largest arboreal species in the Sahara, is confined to the region of the Dayas; that is, to the country immediately south of Laghouat. The tree is unarmed and is eagerly sought after by all herbivorous animals for its foliage and tender twigs. Owing to the presence of such animals, wild and domesticated, the young tree would have no chance to survive were it not that, growing in association with it, is the jujube (*Zizyphus lotus*), which is armed and is not eaten by any animals. The jujube affords safe protection for the seedling betoum, and in its capacity as nurse prevents predatory attacks by animals during the critical period. The survival (and probably the distribution as well) of the betoum is mainly conditioned on the presence of its protector.

When I first visited southern Algeria it seemed improbable that any portion of it, or at least any portion that I should be likely to see, would exhibit the possibilities of plant growth as unaffected by herbivorous animals.

* Hayward, *loc. cit.*, p. 320, says that at In Salah camels are driven 200 kilometers before finding suitable grazing-grounds.

But finally there were found two classes of plant formations in which animals either had not intruded at all, or not to a harmful degree. One of these is the wide flood-plain of the Oued M'Zab, or one of its tributaries, lying about 50 kilometers east of Ghardaia. Despite the fact that the flocks are very numerous in the vicinity, and that the flood-plain is on the regular caravan route between Ghardaia and Ouargla, there are few signs of grazing. The entire plain is so well covered by shrubs that the vegetation gives the tone to the landscape—a rare thing in the desert. Here one finds *Retama retam*, *Genista saharæ*, and *Ephedra* sp., as well as other species in fair abundance. Thus the plants are not only numerous, but are of a good size. It should be observed that on either side of the flood-plain, on the hamada, scarcely any vegetation may be found.

The second formation referred to is that of protected areas, especially at Ghardaia, which have been little disturbed at any time, and portions of them not at all disturbed for centuries. These are the cemeteries. Such areas are situated not only in the floor of the M'Zab Valley, where the plant conditions are relatively favorable, but also on the hamada, where they are relatively very unfavorable. Both in the valley and on the hamada, as well as on the valley wall between the two wherever there chances to be soil, the plants are relatively numerous and of fair size. This fact has been detailed under the section on Ghardaia and need not be more than mentioned here.

From these two general observations (exceptions to the usual conditions), that on the flood-plain of the Oued M'Zab and the cemeteries at Ghardaia, it is concluded that the grazing of animals has had a very marked influence in modifying the flora of southern Algeria. So far as could be told from the limited opportunity to observe, the modification has gone along on at least two lines, which are, of course, closely related. The size of the plants eaten is much under normal for the particular locality, and at the same time the capacity of the plant for reproduction has been greatly lessened. That such species as are not touched by animals have not spread more rapidly, or even have not become the dominant forms, is an interesting problem, and one that would have to be worked out for each species. It can be suggested, however, that the restricted distribution probably lies in the fact that the struggle of desert plants is mainly with an adverse physical environment rather than with one another, and that such conditions would not be affected by grazing animals. For example, large shrubs do not occur on the hamada, hence *Tamarix*, *Zizyphus*, and *Rhus*, as well as *Peganum harmala*, are limited to situations where the soil is fairly deep and the water relatively favorable. *Euphorbia guyoniana* also occurs only in sandy soil, and the number of plants limited in their distribution to soil characters is necessarily a large one.

COMPARISON OF SOME GENERAL FEATURES OF THE VEGETATION OF SOUTHERN ALGERIA AND OF SOUTHERN ARIZONA.

When we compare the most striking characteristics of the vegetation of the Algerian Sahara with that of the Tucson region where the Desert Laboratory is situated, we find some interesting differences, which may be summed up in the terms "desert" and "semi-desert," as applied to the two widely separated regions. What is meant by these terms will be apparent from the following short characterization:

Passing into the Sahara from the Saharan Atlas, over the route which I followed, one encounters a great variety of topography, of which the most extensive may for the moment be classed as plains. The plains are divided into three well-marked regions, that of the dayas, the Chebka, and the Gantara (hamada). The topography is further diversified by oueds and their flood-plains and by low, flat-topped mountains. On the northern portion of the plains one encounters a sparse population of low perennials, and as Ghardaia is approached the plains vegetation becomes continuously poorer until at Ghardaia there appears to be none. On the hamada between Ghardaia and Ouargla areas are to be crossed, several kilometers in width, where perennials are wholly lacking. The decreasing plant population of the plains, until it entirely disappears, is entirely due to the increase in aridity as one goes from the mountains to and across the Ghardaia-Ouargla country. The low mountains are almost entirely barren. The flood-plains of the oueds, however, support a surprisingly luxuriant population of perennials.

Should we contrast the topography and vegetation of the Algerian Sahara with that of southern Arizona we would find little that is similar and much that is different. The wide-stretching plains (bajada) of southern Arizona are well covered with perennials of good size. The water-courses are fringed with trees, and often an open forest is to be found on the flood-plains. The low mountains have a fairly dense plant population, partly of trees, and the lower mountain slopes are often covered with a mixed flora of shrubs and trees. It may be said that there is probably no large area in southern Arizona, where the soil conditions are favorable for plants, where the water conditions are too meager to support a perennial flora of some sort. The greater aridity of the northern portion of the Sahara is evident, therefore, from the great contrast in its flora.

In crossing the plains of southern Algeria one is likely to call a region barren when close inspection will show that this is not the condition. In fact, it was found that areas on the plain, 16 by 16 meters in extent, carried as many as 330 or more perennials, although a casual glance did not reveal the presence of any conspicuous vegetation.* Both of these condi-

*It should be understood that such densely populated areas are separated by wide stretches where are few or no plants.

tions are the immediate result of the small rainfall. The reason for the large number of plants in certain areas, as above noted, lies in their small size, since it would probably be difficult to find an equal number on this area were the plants as large, for example, as in southern Arizona. The fact that the perennials are inconspicuous is in part because they are small and in part because the leaves are either absent or greatly reduced.

When viewed somewhat more closely, one finds other features in which the flora of southern Arizona and of southern Algeria are unlike. Travelers, botanical as well as non-botanical, have described the armed condition of the Saharan plants until the impression is general that such plants as persist from season to season are usually well provided with spines. What may be the proportion of armed to unarmed plants in the northern Sahara I do not know, but to a person familiar with the plants of southern Arizona, where spinose forms are very numerous, the Algerian plants do not appear especially well protected. As this appears to be a general condition, it is scarcely an accident that the spines of the American species of the genus *Zizyphus*, for example, are much better developed than are those of the Algerian representative of the same genus. From the circumstance that grazing by wild as well as by domestic animals is very destructive in Algeria, apparently more so than in Arizona, where the results of grazing are scarcely to be noted, the general facts regarding spininess in plants, as given above, suggest the really small influence such animals play in shaping such a character in desert plants.

Finally, it need only be remarked that plants with a water-balance are wanting in southern Algeria, and that they constitute one of the striking features of the flora of the southwestern United States.

Fig. 4. Shoot-habit of Acanthyllis tragacanthoides. Laghouat.

Fig. 5. Shoot-habit of Zollikoferia spinosa. Laghouat.

Fig. 6. Acanthyllis tragacanthoides on sandy plain. Laghouat.

Fig. 7. Zollikoferia spinosa in habitat, plain (hamada). Laghouat.

Fig. 8. Detail of north slope of Nomad Mountains where Zollikoferia spinosa is the dominant species. Laghouat.

Fig. 9. Vegetation of plain (hamada) at Tilrempt. The conspicuous shrub is Haloxylon articulatum.

Fig. 10. The Daya of Tilrempt from the plain, showing the character of the depression.

Fig. 11. Near view of the Daya of Tilrempt. The fortified stage station, bordj, and a nomad camp are to be seen. The flattened, level, lower surface of the trees is the effect of grazing, mainly by camels.

Fig. 12. Jujube (Zizyphus) shrubs and betoum (Pistacia) at the Daya of Tilrempt.

Fig. 13. A young specimen of betoum in the midst of a protecting jujube, at the Daya of Tilrempt.

Fig. 14. Leaf and shoot habit of the jujube (Zizyphus lotus). Daya of Tilrempt.

Fig. 15. Leaves of the betoum (Pistacia atlantica), from the Daya of Tilrempt.

Fig. 16. South wall of the valley of the Oued M'Zab at Ghardaia.

Fig. 17. Detail of an eroded bank of the Oued M'Zab at Ghardaia. The overhanging stratum is hardpan similar to the "caliche" of southwestern United States.

Fig. 18. Shoot-habit of Haloxylon articulatum, from the plain near the Daya of Tilrempt.

Fig. 19. Agriculture at Ghardaia. The fields are divided into plots about 3 by 4 feet in size, for the more economical use of water. Young barley is shown growing (November).

Fig. 20. Vegetation in upper part of a "draw" on plain north of the M'Zab Valley' Ghardaia.

Fig. 21. Situation of square No. 2. on plain north of valley at Ghardaia.

Fig. 22. Capparis spinosa at base of valley wall at Ghardaia.

Fig. 23. Leaves of Capparis spinosa, from Ghardaia.

Fig. 24. Leaf-habit of Dæmia cordata. Ghardaia.

Fig. 25. Shoot-habit of Salvia ægyptica. Ghardaia.

Fig. 26. Upper surface of rocks, showing small incrusting lichens, on a low mountain about 5km. north of the M'Zab Valley, Ghardaia.

Fig. 27. Habitat of Peganum harmala, at Melika, Ghardaia.

Fig. 28. Shoot and leaf habit of Peganum harmala, from Ghardaia.

Fig. 29. Habit of Henophyton deserti at Ghardaia when growing in a protected situation (cemetery).

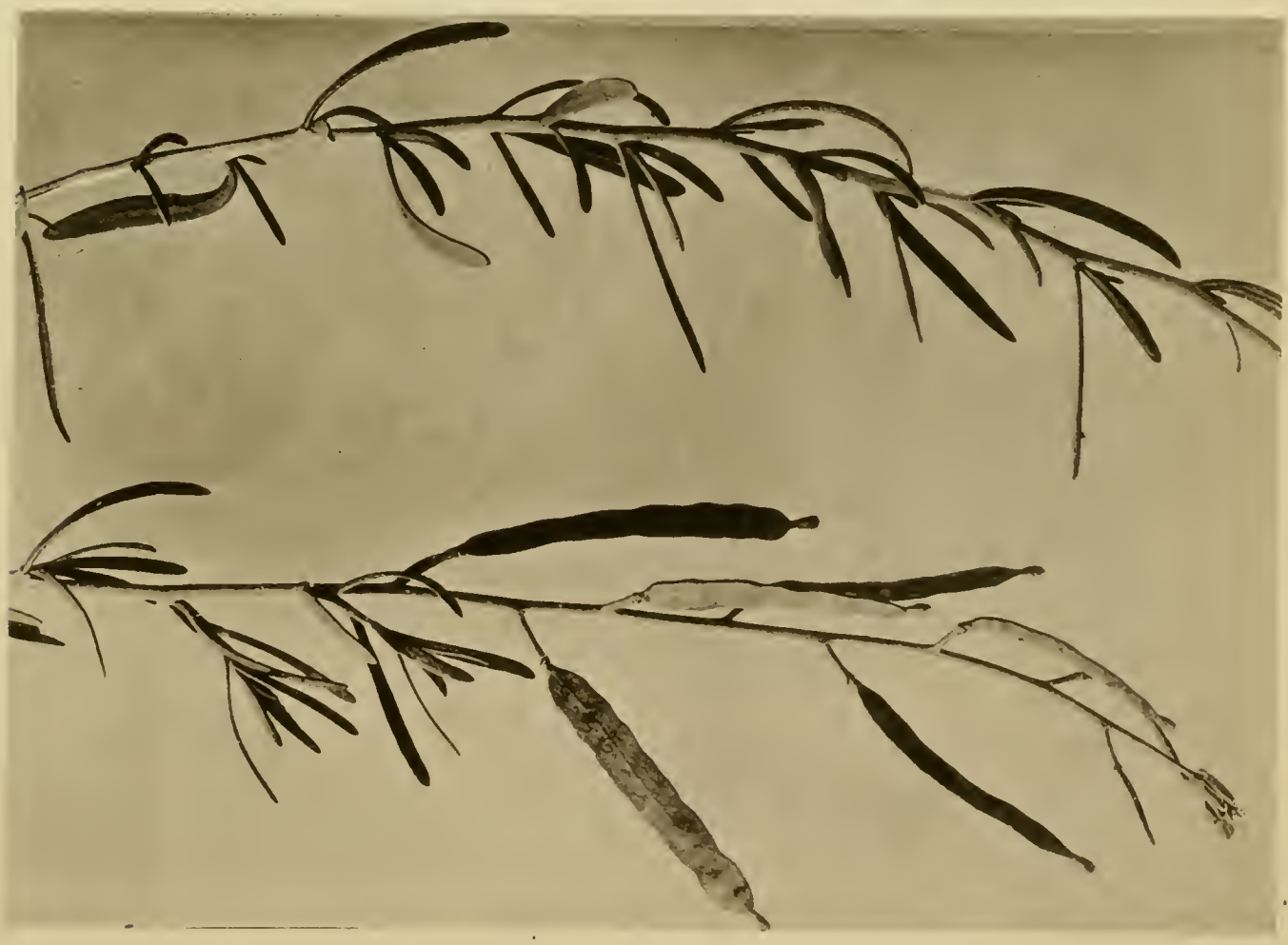

Fig. 30. Leaf-habit of Henophyton deserti. Ghardaia.

Fig. 31. View in a cemetery at Ghardaia, to show the relatively abundant vegetation.

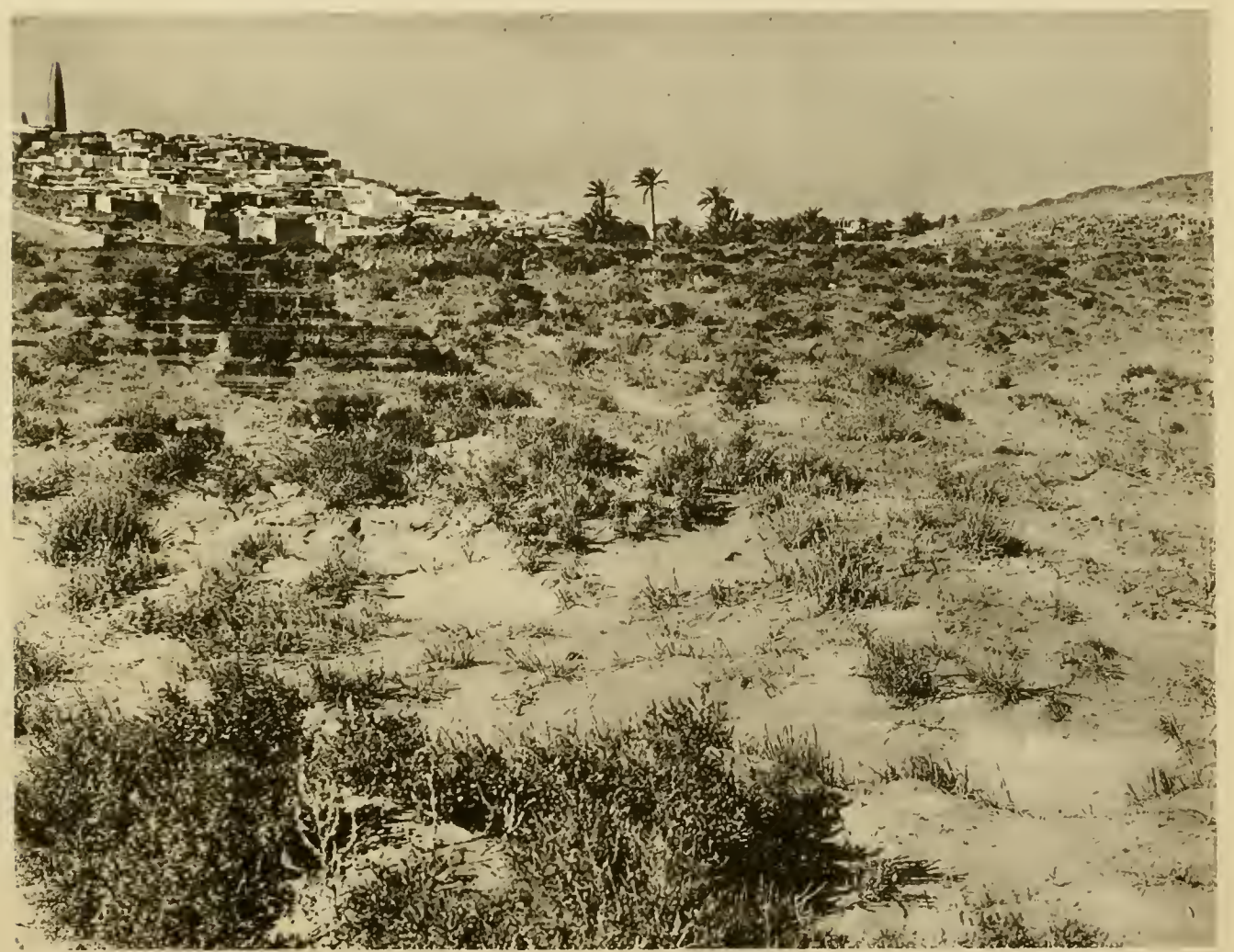

Fig. 32. View in an M'Zabite cemetery, Ghardaia. Haloxylon articulatum is the leading species shown.

Fig. 33. Habit of Deverra scoparia, from plain about 3km. north of M'Zab Valley, Ghardaia.

Fig. 34. Root-habit of Gymnocarpos fruticosum, from plain about 3km. north of M'Zab Valley at Ghardaia.

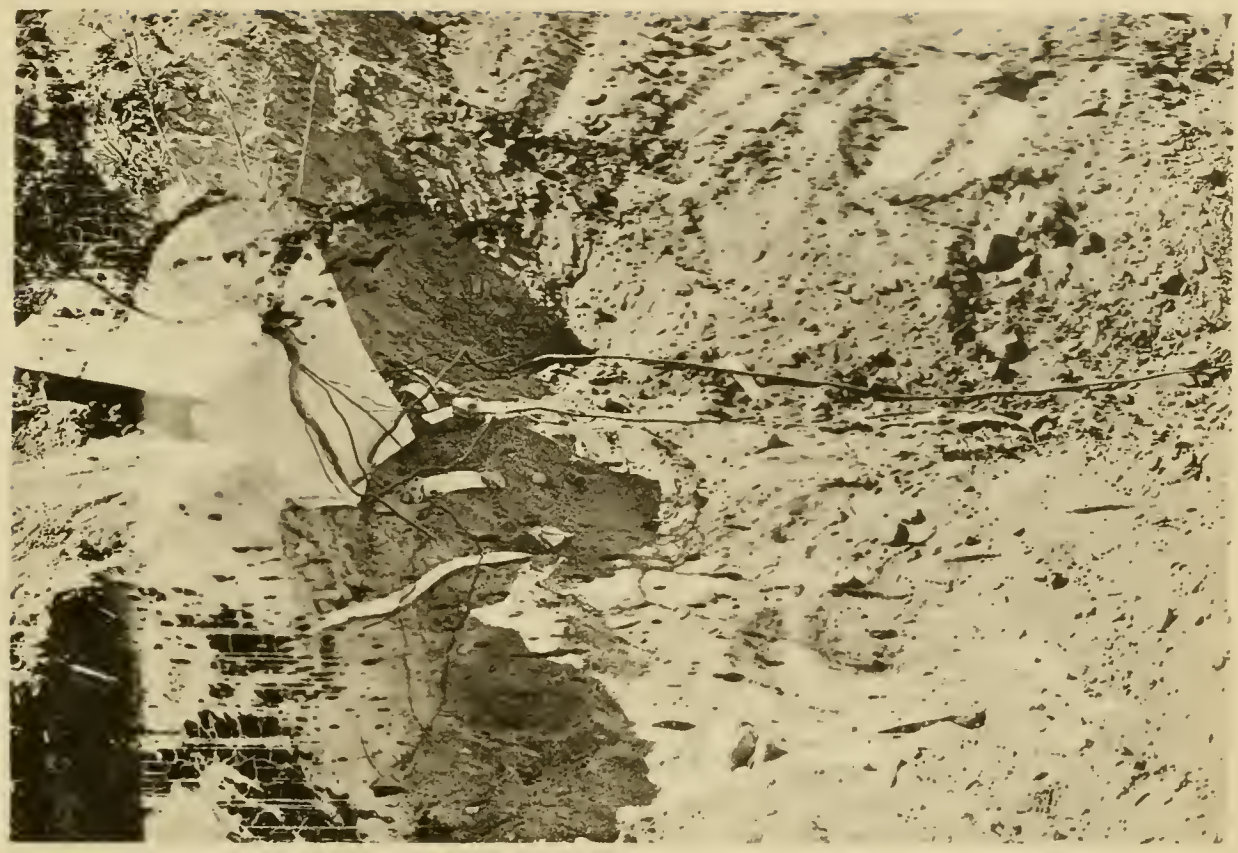

Fig. 35. Root-habit of a mature specimen of Peganum harmala, from the floor of the M'Zab Valley near Ghardaia. The soil at the place is comparatively deep. (See text for further explanation.)

Fig. 36. Root-systems of Helianthemum sessiliflorum (right), Haloxylon articulatum, and Nolletia chrysocomoides (left), from the flood-plain of the Oued M'Zab, Ghardaia.

Fig. 37. Shoot and root habit of Citrullus colocynthis. Oued M'Zab, Ghardaia.

Fig. 38. Euphorbia guyoniana, in the valley of the Oued M'Zab at Ghardaia.

Fig. 39. Habit of Euphorbia guyoniana. Ghardaia.

Fig. 40. To the left, shoot of Centaurea sp., showing effects of grazing; to the right, shoots of Teucrium pseudo-chamæpitys. From Ghardaia.

Fig. 41. Habit of Salsola sp. (below), and Echinopsilon muricatus, from the M'Zab Valley, Ghardaia.

Fig. 42. Ghardaia to Ouargla. View overlooking the hamada about 28km. from Ghardaia. The relatively abundant vegetation is associated with a light cover of sand over the area shown. The leading species are Aristida, Deverra, and Haloxylon.

Fig. 43. Retama retam, in dunes about 58km. from Ghardaia.

Fig. 44. Dates at the bordj Zolfana, about 58km. from Ghardaia. One of two wells encountered between Ghardaia and Ouargla.

Fig. 45. Ghardaia to Ouargla. View overlooking flood-plain of the Oued M'Zab, or a tributary of this oued. The adjacent upland is apparently without plant life.

Fig. 46. Vegetation on edge of the Oued M'Zab, about 63km. east of Ghardaia, showing habitat of Rhantherium adpressum in foreground.

Fig. 47. Sandy flood-plain of the Oued M'Zab, about 63 km. from Ghardaia. Retama, Genista and Ephedra are the leading plants in this place.

Fig. 48. Habit of Ephedra alata in habitat shown in figure 47. This specimen was 1.5m. high.

Fig. 49. View of habitat of Ephedra alenda, 138km. from Ghardaia.

Fig. 50. Detail of suckering habit of Ephedra alenda, from habitat shown in figure 49.

Fig. 51. Vegetation, mainly Ephedra and Retama, of the western edge of the Chott Mellala.

Fig. 52. Approach to western edge of the Chott Mellala, showing characteristic rounded hills, or mamelons.

Fig. 53. View between the Ouargla plain and the Chott Mellala, showing characteristic appearance of eroded hills.

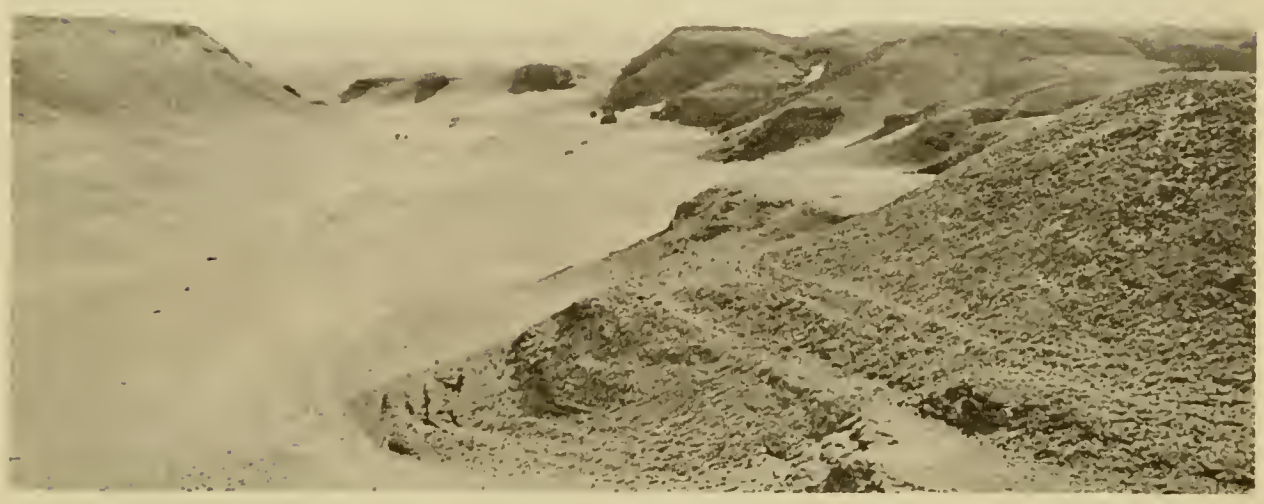

Fig. 54. Looking toward the Ouargla plain (reg).

Fig. 55. Shallow well about 25km. north of Ouargla.

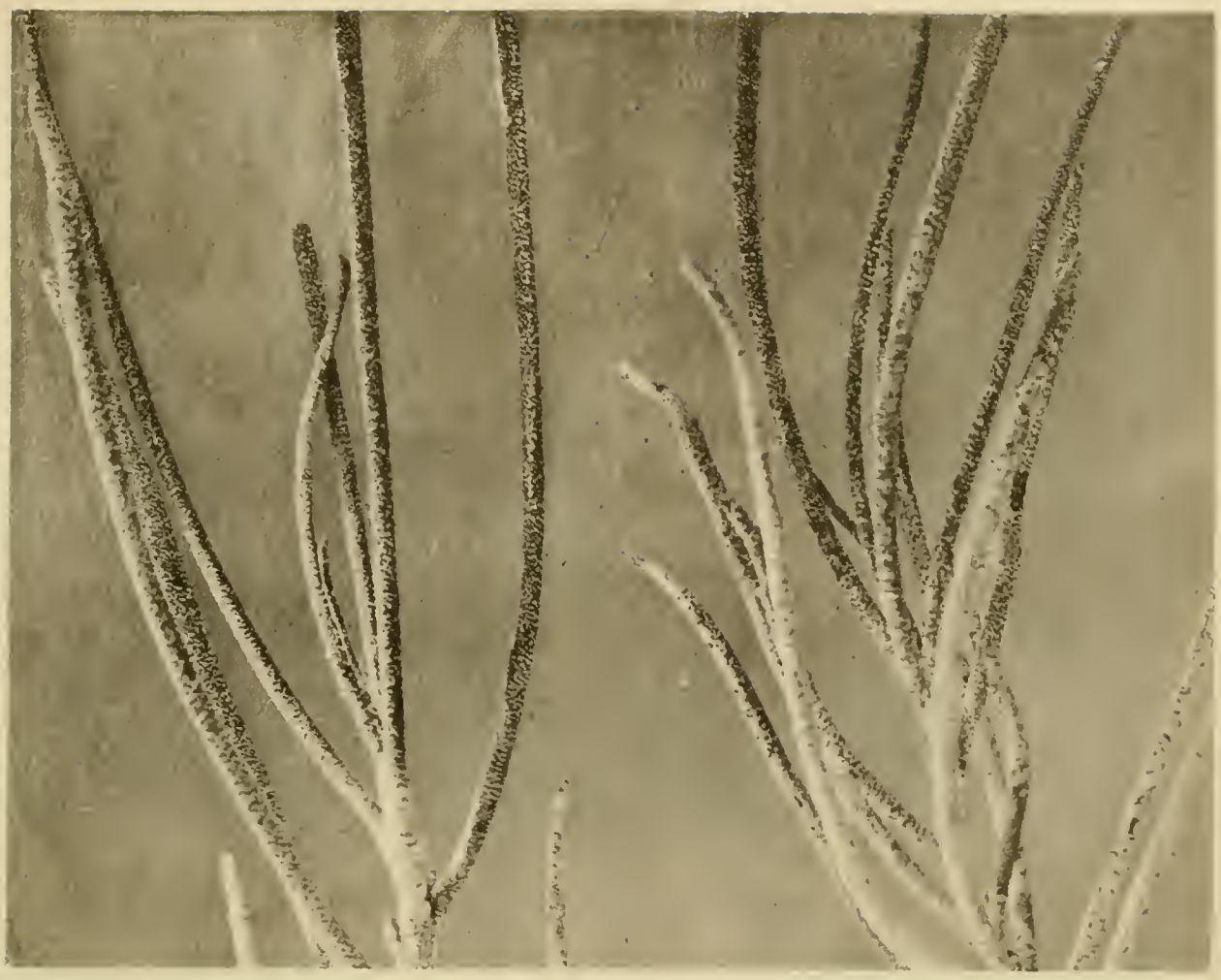

Fig. 56. Ouargla to Touggourt. Leaf habit of Limoniastrum guyonianum. The surface of the leaves is covered with an incrustation of salts.

Fig. 57. Habit of Limoniastrum guyonianum. About 25km. north of Ouargla.

Fig. 58. Vegetation of the reg. desert, about 25km. north of Ouargla. Ephedra and Retama are the leading species of the area a spreading dune.

Fig. 59. Shoot-habit of Halocnemon strobilaceum, about 28km. north of Ouargla.

Fig. 60. Habit of Halocnemon strobilaceum, on the edge of a chott, about 28km. north of Ouargla.

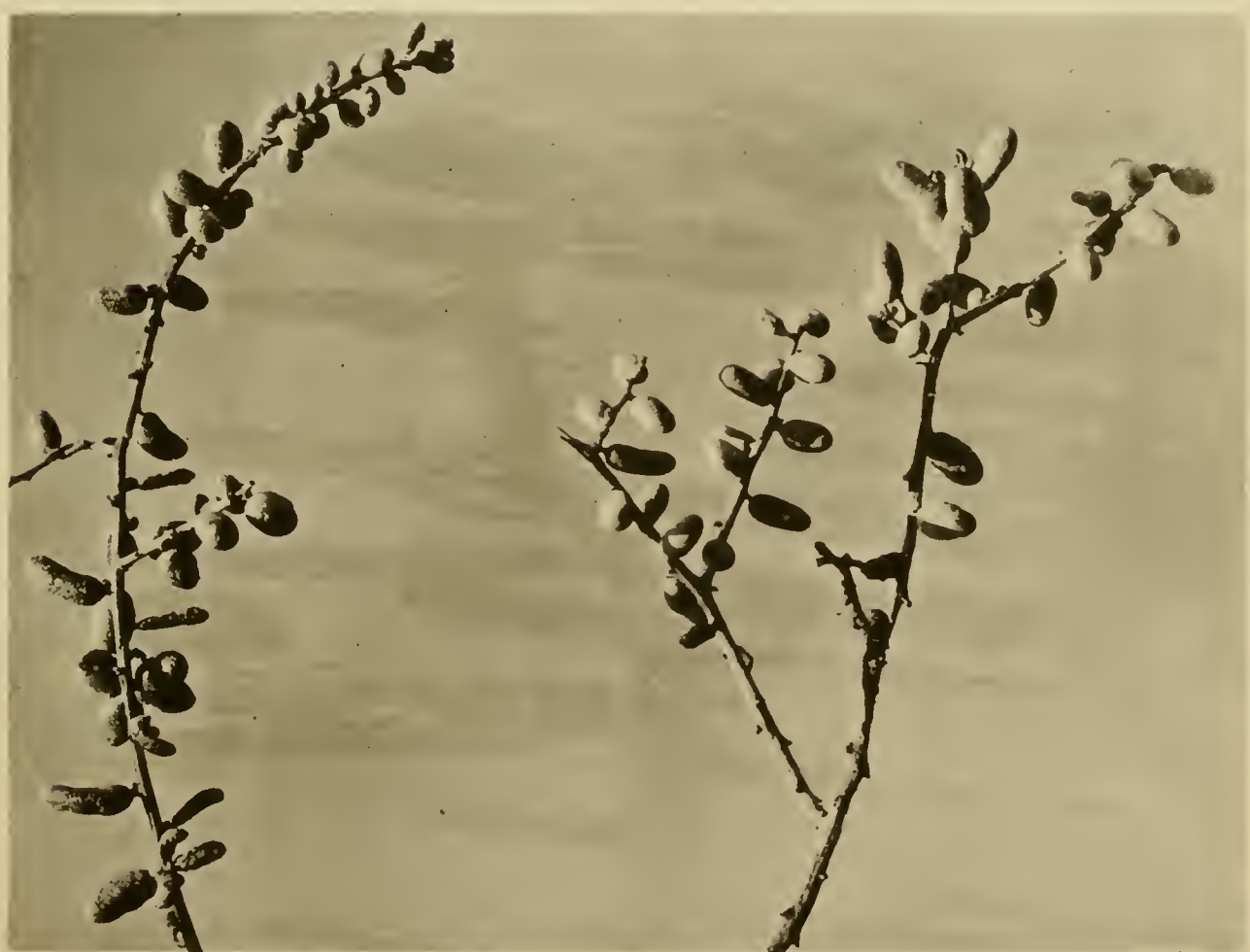

Fig. 61. Shoot and leaf habit of Anabasis articulata, about 32km. north of Ouargla.

Fig. 62. Detail of the shoot-habit of Salsola tetragona?, about 25km. north of Ouargla.

Fig. 63. Habit of Nolletia chrysocomoides near the edge of a chott, about 80km. north of Ouargla.

Fig. 64. Tamarix sp. as a sand-binder near Bled-el-Amar, south of Touggourt.

Fig. 65. Biskra Habitat of Euphorbia guyoniana, looking toward the Djebel Maouya, with the Chaine de Sfa in the background.

Fig. 66. Characteristic vegetation on the north slope of the Djebel Bou Rhezal, Biskra. Haloxylon scoparium is a prominent species.

Fig. 67. North base of Ed Delouatt hills, west of Biskra, showing the low-facing dunes. To the right is a glimpse of an oued which pierces the hills in the middle distance.

Fig. 68. Flood-plain of the Oued Hamman es Salahin, Biskra. Halophytes of various species occupy the foreground.

Fig. 69. Habitat of Phelypæa violacea shown in figure 70.

Fig. 70. Young shoots of Phelypæa violacea, at north base of Ed Delouatt hills, Biskra.

Fig. 71. Habit of young specimens of Phelypæa. Except for about 15 cm., plants were buried by sand. Biskra.

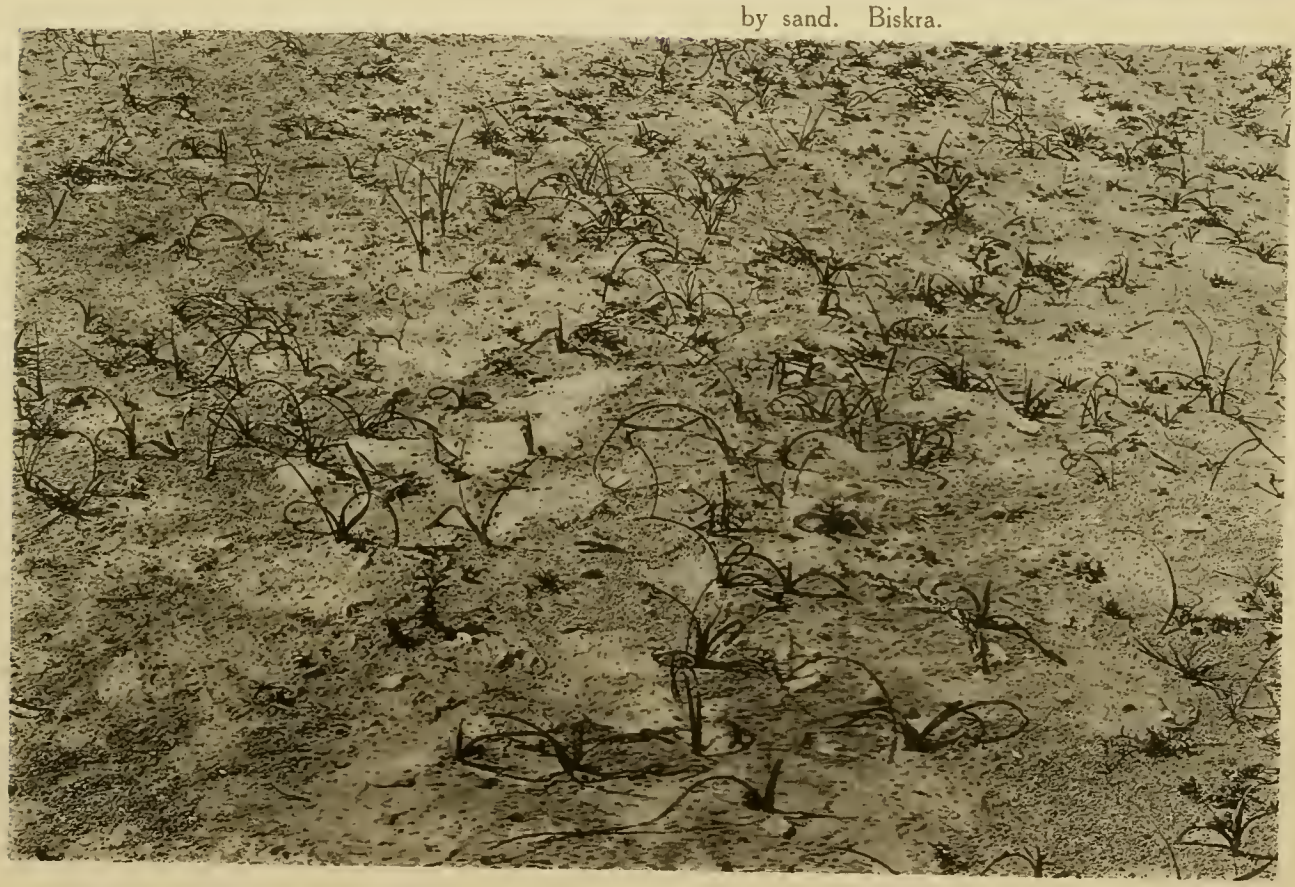

Fig. 72. Asphodelus sp. at north base of Ed Delouatt hills, Biskra. Photographed in March.

Fig. 73. Detail of square No. 1, on low hills north of Biskra.

Fig. 74. Vegetation of north slope of the low hills which are north of Biskra. Ferula vesceritensis is the perennial appearing in the figure.

Fig. 75. Detail of square No. 2, near area shown in fig. 74. Ferula and Haloxylon are the leading species.

Fig. 76. Root-habit of Haloxylon scoparium, from a wash near Biskra.

Fig. 77. Young shoots and mature roots of Ferula vesceritensis. North of Biskra.

Fig 78. Root-habit of Fagonia growing on edge of a wash. Biskra.

Fig. 79. Large lateral root of Haloxylon, with numerous deciduous rootlets, no longer functional.

Fig. 80. Shoot-habit, taken from above, of Fagonia from the flood-plain of a small oued near Biskra

Fig. 81. Spring annuals, March 17th, on north slope of the Djebel Bou Rhezal, Biskra.

Fig. 82. Root and shoot habit of Peganum harmala, Biskra. The main root is especially well developed although the species has a generalized root-system. (See text.)

Fig. 83. Annuals growing with Peganum, near Biskra.

Fig. 84. General view of the north face of the Djebel Bou Rhezal, Biskra. Apparently barren, plants are rather numerous in the rock crevices and small washes of the mountains.