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Agroecological Analysis of Cucumber (*Cucumis sativus L.*) Crops in Orchards in a Mediterranean Environment

Jiménez-Ballesta R.*
Department of Geology and Geochemistry, Autónoma University of Madrid, 28049 Madrid, Spain

García-Navarro F. J.
Department of Science and Technology Agroforestry and Genetics, Castilla-La Mancha University, 13071 Ciudad Real, Spain

García-Giménez R.
Department of Geology and Geochemistry, Autónoma University of Madrid, 28049 Madrid, Spain

Trujillo-González J. M.
University of the Llanos, Campus Barcelona Villavicencio, 50001 Villavicencio, Colombia

Iñigo V.
Education Faculty. International University of La Rioja. Avda de La Paz 137, 26006 Logroño, Spain

Asensio C.
Department of Agronomy, Almeria University, 04120, La Cañada, Almeria, Sapin

Abstract

If adaptability is defined as the ability of a crop (or variety) to respond positively to changes in agricultural conditions, the purpose of this study was to explore the adaptability and relative influence of environmental factors on Cucumber Sativus L. to a specific Mediterranean environmental and agroecological site: Huete (Cuenca, Central Spain). Cucumber requires high temperatures and soil moisture for a satisfactory yield and maintaining an optimum level of humidity is very favorable, which is easy to achieve for farmers in Huete. Abundant sunshine is needed and this is another reason to cultivate during the summer period; it is estimated that there were between 2700 and 2800 hours of sunshine in the Huete area. The study described here revealed that the soils are poorly developed and evolved, with a simple Ap-C or Ap-Bw-C morphology. The soils are friable, slightly adherent and somewhat dry and hard. A significant feature is the presence of good drainage and appreciable effective depth. Like other crops, cucumber plants are preferably grown on loose, well-drained soils, such as the soils studied here. Huete cucumber seems able to tolerate certain levels of soil salinity when compared to other species. The cucumbers are irrigated with water with moderate electrical conductivity without an appreciable decrease in yield. Small doses of salinity may be one of the factors that leads to the characteristics associated with Huete cucumber, an aspect that would need to be investigated more deeply. Substrate nutrients and moisture management are two major concerns regarding Cucumber Sativus L. crops in Huete. Elemental chemical analysis revealed that strontium abounds and this is attributed to the presence of this element in the gypsums. The results of this study open a new horizon in the study of the aptitude of the land and represent a useful step towards the specific site and, consequently, the sustainable management of land under cucumber cultivation. Further research into a wider range of soils, fertilizer compositions and release rates is required.

Keywords: *Cucumber Sativus L.*; adaptation; agroecological; Huete; Mediterranean environment.

1. Introduction

While soil quality assessment is an new tool for monitoring the sustainability of production systems, the term 'agro-ecological zones methodology' (AEZ) has become widely used over the past 60 years. However, it should be noted that this term is associated with a wide range of different activities that are often related but are quite different in scope and objectives. AEZ provides a standardized framework for the characterization of climate, soil, and terrain conditions relevant to agricultural production [1]. Agroecosystem Analysis (AFA) is a research method to evaluate farming systems.

The Cucurbitaceae family is reasonably large and has around 130 genera and 900 species [2]; of these, around 30 species out of 9 genera are cultivated. In a similar way to the melon, watermelon and squash, cucumber (its botanical name is *Cucumis Sativus L.*) belongs to the family Cucurbitaceae [3]. The cucumber is a native vegetable to the tropical regions of South Asia, from where it spread to Europe and America. All Cucurbitaceae are frost-sensitive and the family is confined to the warmer parts of the globe. Around 7 million hectares of cucumber are cultivated worldwide, with more than half produced in Asia, 26% in Europe and the rest in Africa and America [4]. Spain was one of the first countries to produce cucumber in the European Union, with an estimated volume of

*Corresponding Author

between 700,000 and 800,000 tonnes of production per annum (740,000 in 2014, https://es.statista.com/estadisticas/510969/produccion-de-pepinos-en-espana-por-comunidad-autonoma/).

According to Jelaska [3], cucurbetaceae are harvested in the the tropics, subtropics and milder regions of both hemispheres. Nevertheless, cucumber can adapt to a wide variety of regions and is cultivated in zones close to sea level up to the region of 1,500 msnm. Cucumber can adapt to temperatures between 18 and 25 ºC, with a maximum temperature of 32 ºC, and it requires between 70 and 90% relative humidity.

Castilla La Mancha (Central Spain) is one of the Spanish regions with a large number of orchards and different cucurbetacea (melon, watermelon, cucumber) are produced in many farms in this region. These areas are traditionally dedicated to irrigated farming. In the agroecological management of soils, ancestral knowledge and traditional cultural practices must also be considered in terms of social and historical aspects linked to the land and its care. In this sense, the orchards should be included amongst the landscapes of great significance on a European scale along with terms such as the Atlantic ‘bocages’ or the ‘open fields’ of the interior of the continent. Indeed, the orchards "are the basis for the creation of local cultures and constitute a fundamental component in the cultural and natural heritage of Europe" and their disappearance would mean "a scarce reparable decline for the European historical heritage", which gives it a high level of protection. The agroecological and historical value of traditional orchards is important, although the traditional flood system must be compatible with drip irrigation. The contrast lies in ‘saving water’ but in turn it is necessary to avoid ‘significant environmental effects and losses in the historical and natural heritage that affect the landscape of the floodplain of numerous Spanish rivers’.

The cucumber of Huete (Castilla La Mancha, Spain) is highly valued gastronomically and it is used in salads and entrees. Regardless of the gastronomic character of Huete cucumber (it is called ‘crystal cucumber’), it should be noted that cucumber generally contains a high content of potassium but it is low in sodium and therefore it has favorable characteristics to treat hypertension or uric acid. Furthermore, cucumber also provides fiber and beta-carotene.

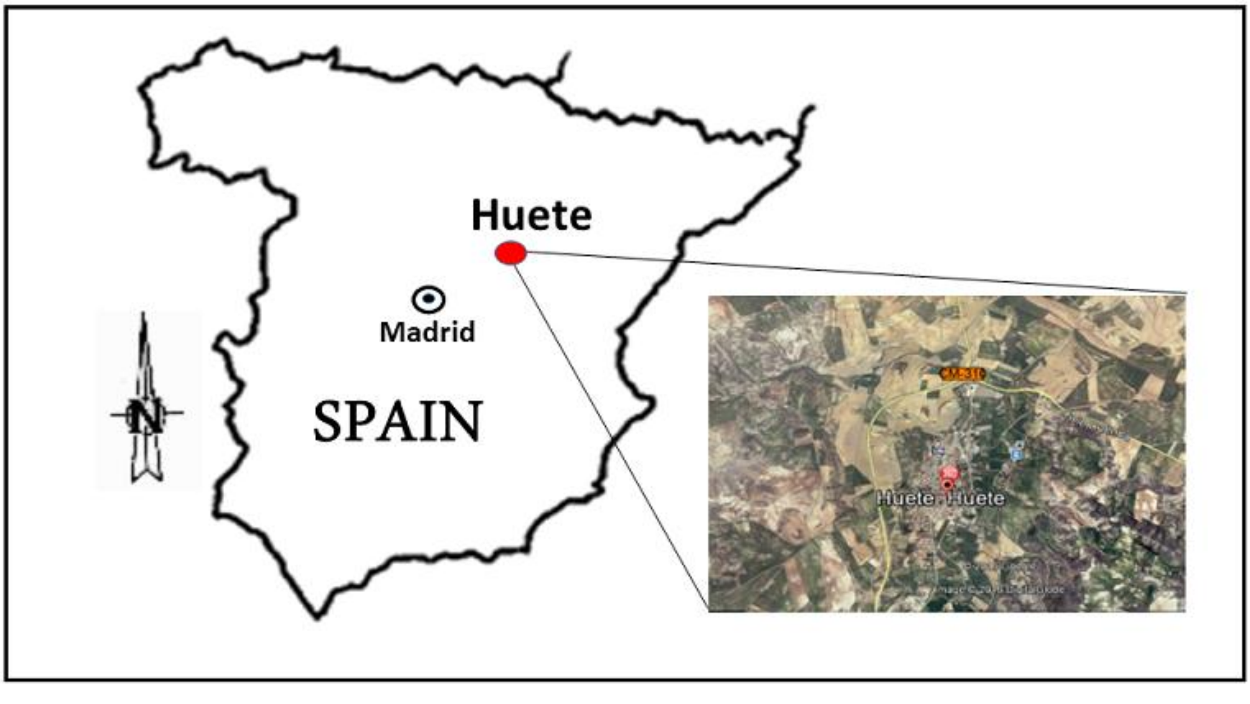
Huete cucumber is a strategic agricultural product and, as such, a study regarding the recognition and identification of its agroecological requirements can define the characteristics that make it unique, and in this way other areas can be identified in which cucumbers can be planted for production. The study described here does not attempt to address the different types of practices or management improvements aimed at achieving sustainable production. Since cucumber is an important crop in the Mediterranean environment, and very few studies have examined the agroecosystem factors in relation to its cultivation, the present work attempts to review the agroecological requirements (climate, soil and site) and adaptability in the case of Huete cucumber. The role and limitations of the climatic and edaphic properties that have an influence are identified in terms of the yield and quality of the cucumbers in the zone in question. As a consequence, the objectives of this work were to investigate the agroecological characteristics, with emphasis on the qualities and characteristics of the most effective soils for growth and yield of the cucumbers, while identifying the climatic adaptability and requirements for sun and water.

2. Material and Methods

2.1. The site

The study area surrounds the village of Huete, a municipality in the Cuenca region of the Alcarria (Castilla-La Mancha, Spain), located on the eastern and southern slopes of the Castillo hill (Figure 1) between the courses of the rivers Borbotón and Major. The altitude of Huete is 809 msnm.

Figure-1. Location of study area

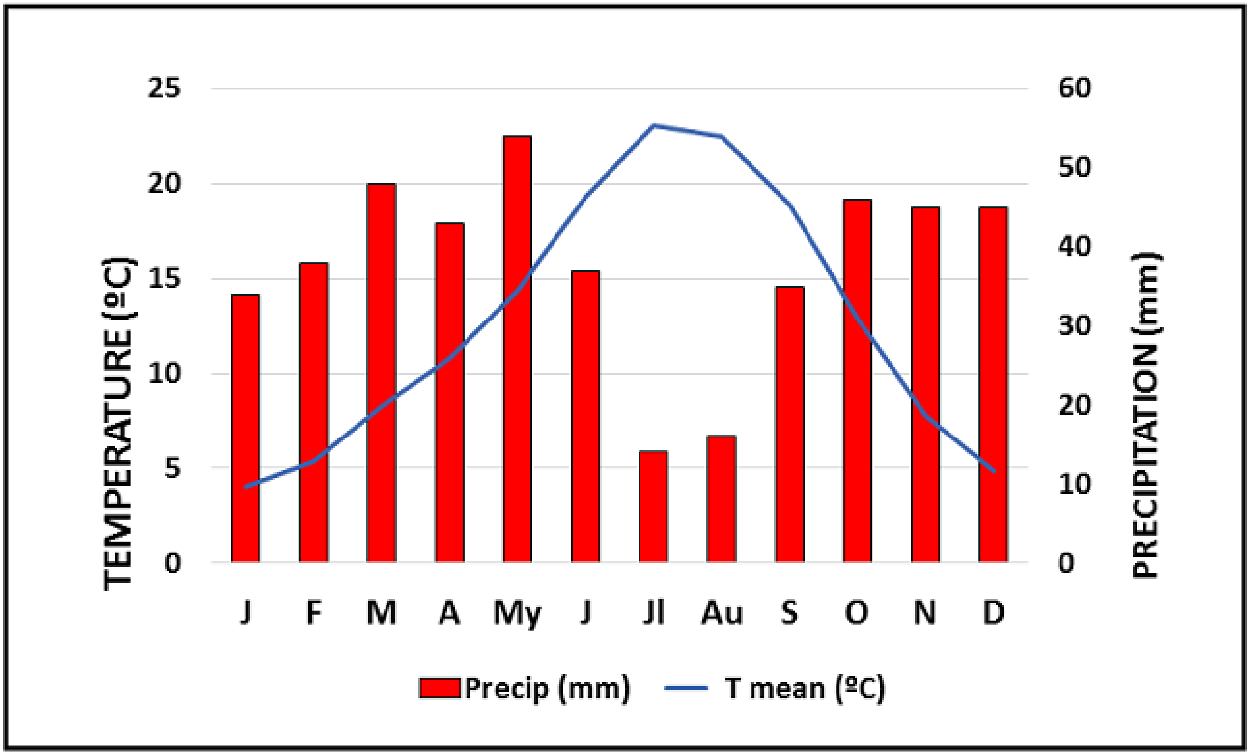


Geologically the study area is situated on the eastern edge of the Sierra de Altomira. The tertiary that borders the soils of the 'vega' where the Huete cucumber is planted is represented by materials of the Paleogene and Neogene continental environments and varied lithology (mainly conglomerates, sandstones, clays, gypsum, limestone). The quaternary (where the crop is located) is formed by deposits of erosion and filling (basically alluvial deposits from the valley, although sometimes in connection with coluvions and hillside deposits). Steep slopes and weak sedimentary rock make the area highly susceptible to erosion and mass movement (Figure 2).

The average annual temperature in Huete is 12.4 ºC and the precipitation has an average annual value of 451 mm. The climatic diagram shows that there is a period of water deficit (Figure 3) that normally coincides with the period of cultivation of the cucumber.

Figure-2. View of the landscape for the area of study. The typical relief showing the alternations in lithological materials is in the background. The alluvial material is in the first plane; to the bottom (background) disposition of the reliefs and lithologies that border the vega where the cucumber is cultivated.

Figure-3. Climatic diagram for Huete meteorological station. The dry period can be observed.



The area in which the cucumber is grown corresponds to the so-called vegetable garden. In addition to this agricultural use, the territory surrounding it, which is formed by gypsiferous outcrops, margoyesiferous or limestone, produces the installation of gypsophilic tomillars that are typical of gypsum hills. The high concentration of calcium sulfate in the soil determines an extreme ecological medium for the development of plant life, which together with the xeric character of the predominant climate accentuates the influence of the substrates on the vegetation. This richness of endemic flora, together with a very limited geographic distribution, leads to steppe-like formations such as that in the study area, which are a highly unique habitat with high ecological value. Directive 1992/43 / EEC ('the Habitats Directive') lists gaseous continental steppes as one of the natural habitat types of Community interest and for the conservation of such zones it is necessary to designate special areas of conservation (SAC) as a matter of priority.

2.2. Soil Sampling

The samples were taken from profiles opened with a caterpillar machine (approximately 1 × 1.5 meters in area and 2 meters in depth). In all cases manual tools were employed to condition the soil profile. The profiles (Table 1) were described and samples were collected from each horizon. All samples were air dried and sieved (<2 mm) prior to analysis.

2.3. Analytical Methods

Soil pH was measured in a 1:1 soil:water suspension; electrical conductivity was determined in a 1:5 soil:water suspension. The soil organic matter was determined using the dichromate method; the total $CaCO_3$ content was determined by the Bernard calcimeter method using 4 M HCl; total nitrogen was measured by Kjeldahl’s method; cation exchange capacity was measured my means of ammonium acetate, and finally available phosphorus was measured by extraction using alkaline sodium bicarbonate.

Table-1. General description and macromorphological characteristics of two soils investigated. In upper horizons of both soil profiles there is strong biological activity. The granule-like accumulations that appear within the soil mass, especially in the subsurface horizons, are not identifiable secondary carbonates, but practically pure gypsum – as evidenced by X-ray diffraction analysis. It is a autigenic gypsum that has arrived at the profile without translocation, probably accumulated with the same mass that makes up the horizons. It is therefore a material inherited from the parent material of the soil. Secondary carbonates or secondary gypsum were not detected, for example coating the faces of the aggregates; These appear as if in a pulverulent form but are compacted masses that appear as nodes, concretions or spheroidal aggregates, without coating pores or structural faces.

PROFILE 1							
Soil Type FAO/Soil Taxonomy	**Location/ Coordinates**	**Parent Material**	**Vegetation/ use**	**Topography**	**Slope**	**Drainage**	**Stoniness (class)**
Haplic Regosol (Calcaric, Siltic)/	Huete (Cuenca)				C-0	C-4	C-0
Typic Xerorthent	X: 527.062,44 Y: 4.445.097,8	Fluvial material/Marls	Irrigated farming	Botton valley	Flat	Well drained	No stoniness
Sample/ Horizons	**Colour**	**Estructure**	**Consistence**	**Roots**	**Pores**	**Límit**	**Stoniness (%)**
1 Ap 0-36 cm	10YR 4/5	Moderate, subagular blocky, medium	Slightly sticky, slightly plastic, friable and slightly hard	Frequent, fine and medium	Common, fine and medium	Gradual, wavy	2%
2 C1 36-83 cm	10YR 6/6	Massive to subagular blocky, coarse	Slightly sticky, slightly plastic, very firm and hard	Very few, fine	Common	Diffuse, wavy	2%
3 C2 83-142 cm	7,5YR 8/3	Massive to subagular blocky, coarse	Sticky, plastic, firm and hard	Very few, fine	Common	Diffuse,	2%
PROFILE 2							
Soil Type FAO/Soil Taxonomy	**Location/ Coordinates**	**Parent Material**	**Vegetation/ use**	**Topography**	**Slope**	**Drainage**	**Stoniness (class)**

Haplic Regosol (Calcaric, Siltic)	Huete (Cuenca)				C-0	C-4	C-0
Typic Xerorthent	X: 527.057,81 Y: 4.446.008	Fluvial material/Marls	Irrigated farming	Botton valley	Flat	Well drained	No stoniness
Sample/ Horizons	**Colour**	**Estructure**	**Consistence**	**Roots**	**Pores**	**Límit**	**Stoniness (%)**
4 Ap 0-35 cm	10YR 6/3	Strong, granular, medium	Sticky, plastic, firm and hard	Frequent fine and medium	Common, micro and macro	Diffuse, wavy	2%
5 C1 35-68 cm	10YR 6/6	Massive to subagular blocky, coarse	Slightly sticky, slightly plastic, very firm and hard	Few fine and medium	Common, micro	Diffuse,plane Diffuse	1%
6 C2 68-144 cm	7,5YR 8/3	Massive	Slightly sticky, slightly plastic, very firm and hard	None	Common		1%

3. Results and Discussion

The results of the analyses carried out on the soil samples are summarized in Table 2. The organic matter content is moderate, tending to low (<3%). Since cucumber, like other crops, has favorable growth if the soil is rich in organic matter, the farmer usually adds nutrient-enhancing elements such as fertilizers or manure. The organic carbon content of the soil is usually a good intrinsic criterion for soil fertility along with the cation exchange capacity. The same authors also suggested that it is not necessary to assess soil characteristics such as carbon content in arid regions, while the rate of clay activity usually exceeds the nutrient requirement of the plant. However, soil pH assessment alone would not be sufficient to evaluate soil fertility.

Table-2. Selected properties measured in soil samples: pH, EC electrical conductivity (dS/m), OC organic carbon (%), OM organic matter (%), calcium carbonate (%), active limestone (%), texture (%), N total nitrogen, P total phosphorus, CEC cation exchange capacity (cmol/kg), exchangeable cations (Ca, Mg, K, Na) cmol/kg and V saturation degree (%).

Sample	**pH (H_2O)**	**pH (KCl)**	**EC (dS/m)**	**OC (%)**	**OM (%)**	**$CaCO_3$ (%)**	**Active limestone (%)**	
1	7,55	7,53	2,23	1,0	1,70	21,5	16,5	
2	7,96	7,87	2,15	0,6	1,03	26,3	12,1	
3	7,97	7,85	2,10	0,4	0,69	22,6	16,2	
4	7,61	7,46	1,71	1,6	2,75	30,1	12,7	
5	7,67	7,52	1,83	1,5	2,72	52,3	9,8	
6	7,87	7,71	1,93	1,4	2,41	63,6	14,9	
Sample	**N (%)**	**P (mg/kg)**	**CEC (cmol/kg)**	**Ca^{2+} (cmol/kg)**	**Mg^{2+} (cmol/kg)**	**K^+ (cmol/kg)**	**Na^+ (cmol/kg)**	**V (%)**
1	0,07	12,3	43,6	26,4	16,2	0,3	0,7	100
2	0,06	9,8	34,4	14,6	18,3	0,4	1,1	100
3	0,05	5,4						
4	0,09	14,6	29,3	26,8	1,2	0,4	0,9	100
5	0,08	9,7	29,4	95,6	2,3	0,3	1,2	100
6	0,08	5,8						

In determining the suitability of soils for practically all types of crops, one of the most important characteristics is soil texture [5]. The reason for this is that this property fundamentally influences the availability of water and nutrients in the soil, as well as in land management practices. Thus, fine-textured soils are given a positive value, since they favor cation exchange capacity and water retention capacity. The texture of the studied soils is relatively uniform, predominantly loam-loamy with a low percentage of gravel, although within the study area deep pockets of clay-loam are also frequent.

The fine texture can cause problems with the infiltration of water into the soil. As a consequence, under severe conditions the water can cause sequestering, which affects the roots and causes aeration problems for the plants. Additionally, if the water retention capacity is high, there is an increase in the likelihood of diseases being manifested by invasion of cucumber roots. On the other hand, soils with a heavy texture cause volatilization of nitrogen fertilizers. The low cation exchange capacity and water retention of coarse textured soils are the main problems in such soils due to leaching of essential nutrients and the occurrence of drought stress. Given the above information, the texture of the soils of Huete gives them favorable characteristics for the growth of the cucumber.

The cation exchange capacity ranges from 29.3 to 43.6 cmol / kg and this is dominated by Ca^{2+}. There are no high concentrations in the soil of toxic ions for plants such as Na^{+}, so such ions cannot cause water deficits or deficiencies in certain elements such as K^{+}. The soils are deficient in phosphorus (varies between 5.4 and 14.6 ppm) and the N content is also low.

The carbonate content (which is lower in profile 1 than in profile 2) is in the range between 21.5 and 63.6%. The effect of calcium carbonate on the yield of cucumber, as with other constituents, depends on the carbonate content and, in particular, the active limestone content present in the soil. In this case the active limestone reaches almost 17% and this is relatively high. In general, the presence of carbonates in soils of semi-arid regions, especially in particles smaller than 20 micrometers, develops the structural consistency of these soils, which is very useful for the movement of air and water in the soil. However, high concentrations of calcium in the soil, particularly in very fine fractions increase the possibility of nutrient deficiency. In addition, high carbonate contents in soils when irrigated tend to become impermeable to roots.

The results of elemental chemical analysis reveal that, in general, the elements are in proportions within the common ranges of the soils of the Community of Castilla La Mancha (Table 3). However, strontium is present at relatively high levels and this is attributed to its presence in the gypsums. Other elements are also present in higher proportions than in the average of Castilla La Mancha, but these levels are only moderately higher.

Table-3. Minor and trace element contents (all elements in $mg \cdot kg^{-1}$)

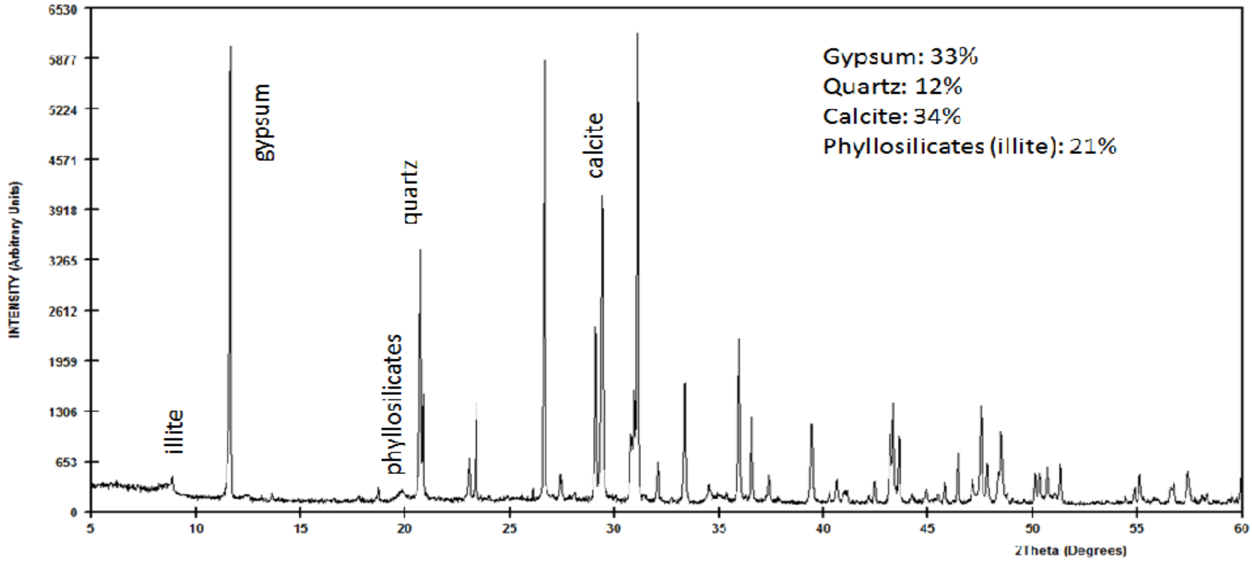
Element	Sample 1 P 1, Hor Ap	Sample 4 P 2, Hor Ap	Reference values CLM (*)
Li	28	60	n.d.
Be	1	2	n.d.
B	275	233	n.d.
P	526	266	n.d.
Sc	21	7	23
V	29	62	55
Cr	21	46	67
Co	4	8	8
Ni	15	26	24
Cu	32	28	12
Zn	48	46	40
Ga	7	11	12
Ge	1	2	1
As	6	10	8
Rb	29	72	86
Sr	4126	2868	369
Y	5	8	86
Zr	27	46	178
Nb	n.d.	2	10
Mo	1	1	1
Sn	3	4	5
Sb	n.d.	3	3
Cs	1	4	8
Ba	138	10	409
La	6	21	25
Ce	12	3	60
Pr	1	2	n.d.
Nd	5	10	23
Sm	1	2	7
Gd	1	2	n.d.
Dy	1	1	n.d.
Yb	n.d.	1	3
Hf	1	1	5
W	1	2	3
Pb	19	14	21
Th	2	5	10
U	n.d.	1	4

The X-ray diffractograms of different soil sample horizons (Figure 4) show that in profile 1 calcite and gypsum are the major components at 34 and 33%, respectively. These are followed by phyllosilicates (mainly illite) with

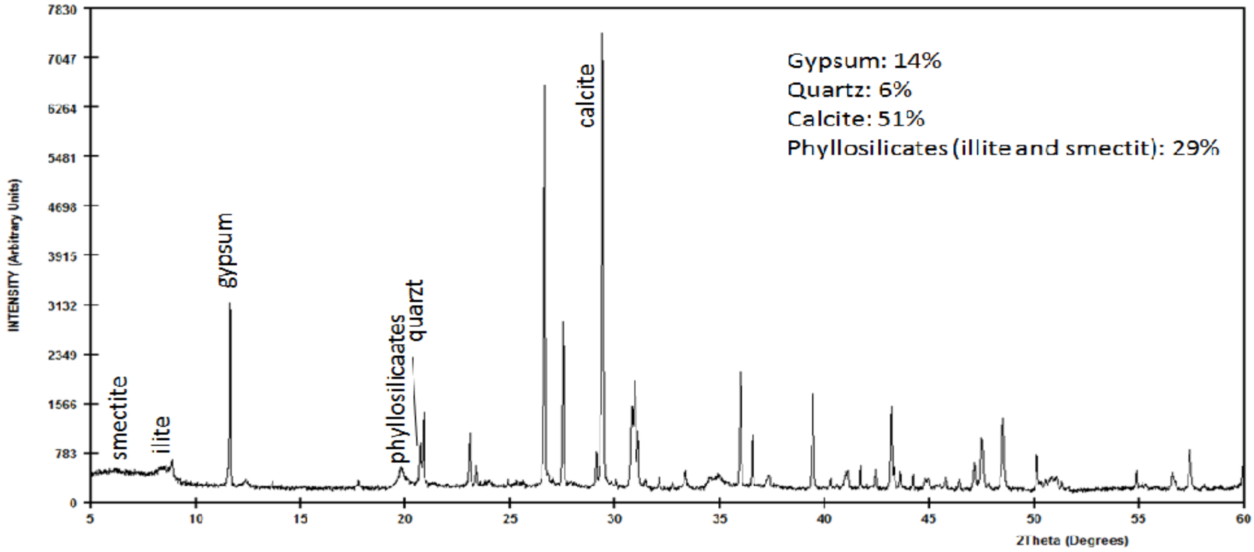
21% and finally quartz with 12%. In the case of profile 2, sample 4 corresponding to the Ap horizon has a similar composition, although the calcite is present with a greater content, as is the case with the phyllosilicates, while the gypsum and quartz are at lower levels. The sample of the powdery ridge in profile 1 consists exclusively of gypsum.

Figure-4. A) X-ray diffraction diagram. Sample 1, horizon Ap profile 1. B) X-ray diffraction diagram. Sample 4, horizon Ap profile 2. C) Detail of the gypsum accumulation; X-ray diffraction diagram of said accumulation, horizon C1 of profile 1.

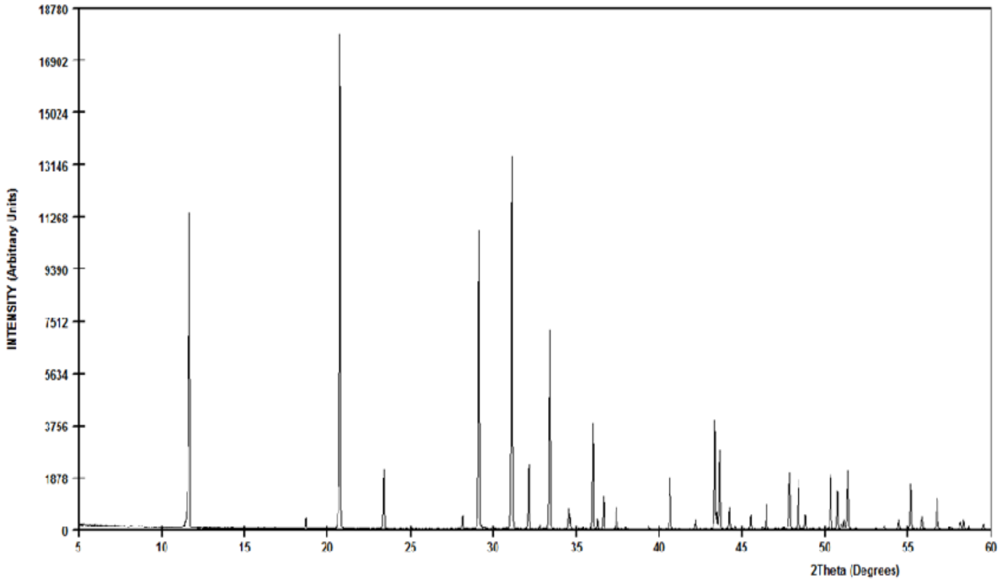
A



B



C)



When concentrations of gypsum in the soil exceed more than 25%, it is considered as a waterproof layer for roots. Low gypsum contents may be one of the limiting factors in some cucumber orchards. Gypsum is more soluble than lime (more than 100 times) and it therefore has greater effects on soil properties at lower concentrations than calcium carbonate. It is clear that calcium ions released from soil gypsum concentrations below 2% could improve soil structure and provide calcium, which are the requirements of many common plants such as pistachio and probably cucumber.

However, one of the most significant features of the soils of the area dedicated to cucumber cultivation is the presence of a certain level of salinity. It is generally known that plants have a poor tolerance to salinity, since if there is a significant salt concentration then water absorption is difficult, resulting in slow growth and stem weakening. In the case of the cucumber the leaves also become smaller and the fruit can even appear more rickety and deformed with a dark color.

Cucumber is known to be a moderately salinity tolerant plant (somewhat less than melon); this means that if the electrical conductivity of the soil is very high, the plants tend to absorb the irrigation water with difficulty and growth would be slower, while the stem would weaken and the leaves would be smaller. On the other hand, if the electrical conductivity is too low, the opposite will happen, and the plants will acquire a more luxuriant character but will have a greater sensitivity to possible diseases.

Salinity is a characteristic that is common to many soils of the Alcarria Conquense (Castilla La Mancha region) where the study area is located. Salinity is a factor that affects almost every aspect of the physiology and biochemistry of plants, thereby significantly reducing crop yields. Since saline soils and saline waters are common in many regions of the world, especially in arid or semi-arid zones, studies have been carried out to identify the physiological aspects of tolerance to salinity in plants, with the idea that plant breeders.

The Huete cucumber appears to be able to tolerate higher amounts of soil salinity than many other species. The cucumbers are irrigated with water with moderate electrical conductivity without an appreciable decrease in yield. In addition, Sanden, *et al.* [6] pointed out that the electrical conductivities in the soil up to 6 dS / m do not place any limitation to the growth of the pistachio, as could occur in the case in question; in the case of pistachio only when the electrical conductivity of the soil exceeds 8 dS / m does the yield decrease by approximately 50 percent. In the studied soils the electrical conductivity values are in the range between 1.7 and 2.2 dS / m and these are slightly higher in profile 1 than profile 2.

In addition to the soil salinity, there may be high amounts of sodium ions in the soil, namely exchangeable sodium (ESP). Soil structure destruction was not observed [7, 8]. In the literature [5] it is considered that 15% is a key value in the structural deterioration of the soil and the occurrence of sodium toxicity that damages the plants. Ferguson, *et al.* [7] reported that an ESP of 25% was a non-limiting level for pistachios and it is feasible that this level is similar for the cucumber. It will be necessary to decide whether the ESP can be even greater than 45% or whether this level is too high. High amounts of SAR in the soil have been reported as the main limiting factor for pistachio.

Salinity is considered primarily as an important limitation for the soil due to its detrimental effects on the growth and yield of the plant. The problem stems from soil osmotic pressure and the consequent pressure-induced water stress, but also due to specific ionic toxicity that may jeopardize the development of plants.

Cucumber is a common crop in arid and semi-arid regions and these possibly have saline soils. As a consequence, it is possible to consider salt stress, which has an inhibitory effect on the growth and development of the plant due to the reduction of photosynthesis, respiration, protein synthesis and, consequently, the production of biomass – especially in susceptible species [9]. Salinity and water deficit have the same effects in that they hinder the absorption of water and nutrients by the root, which is equivalent to water stress in the plant.

When crops are irrigated with salt water, as in the case of Huete, there is the risk of precipitation of Ca and Mg from carbonates or sulfates occurring during evaporation, which would cause sodium to become the dominant ion in the soil solution. If this situation occurs, this cation would be absorbed by the minerals of the clay, which in turn would cause the loss of the structural development or a degradation of the clay. This phenomenon was not observed given the abundance of Ca and Mg. In this way, the germination of the seeds is not difficult and nor is the absorption of water and nutrients by plants.

The topographic characteristics of the soils dedicated to the cultivation of cucumber are gypsiferous or margoyesiferous soils from which abundant Ca emanates due to its dissolution and drag down slope and this affects the composition of the soils. The doctoral thesis by Baragé [10] addresses the identification of sources of tolerance to water stress and salinity in accessions of wild species of the cucurbit family. Comparison of the cultivated species of melon, watermelon and cucumber was achieved by carrying out tests under controlled environmental conditions. It was concluded that cucumber – like melon and watermelon – is sensitive to water stress and salinity, although there are wild accessions that are more tolerant. There are also wild species that are tolerant to salinity but not to water stress. In particular, accessions of wild species *Cucumis africanus* L4 and *Cucumis zeyheri* L2 exhibit a remarkable degree of tolerance to water stress.

It is also known that there are some beneficial effects in crops such as spinach, cabbage, lettuce and tomato when grown in moderately saline soils. Constant irrigation with saline water ultimately gives the soil a concentration that constantly increases and this will have an impact. In this respect, several studies on salinity tolerance have been carried out and an unfavorable effect was highlighted [11]. However, a certain level of tolerance has also been reported [11].

In spite of the salinity data outlined above, we believe that this small dose of salinity may be one of the factors that leads to the unique characteristics of Huete cucumber, an aspect that would need to be investigated more deeply.

For example, it would be necessary to evaluate whether, as a consequence of a low to zero salinity, the plants would appear more or less leafy, or more or less sensitive to the acquisition of certain diseases. It is acceptable for farmers to use cultivation techniques that allow them to grow crops under saline conditions while preserving the yield and quality of the varieties. This is probably the case in Huete, where farmers in the area have strategically solved the complex problem of the profitable use of salt water in irrigated agriculture. For this purpose they have used cucumber, a relatively salinity-tolerant crop, in conjunction with a series of cultural techniques in order to help the plants to withstand the deleterious effects of salt. Among the strategies used, it is worth noting the application of fertilizers at levels somewhat above the optimum for freshwater irrigation. The use of seed priming and seedling conditioning are also worth highlighting. Above all, however, the increase in the relative humidity in a semi-arid climate causes harsh working conditions, which, together with other factors such as sociological factors, have led to the abandonment of soils in relatively recent times. Awareness in the sense of favoring crops as valued as the cucumber of Huete should radically change the nature of the aid received by the field.

The growth of cucumber plants is very rapid and, with proper management, high production levels can be achieved. Therefore, the intensive use of the productive capacity of the land should be encouraged in the floodplain area by supporting the development of irrigation infrastructure to maximize the productivity of land in intensive agricultural and livestock use. In principle, given the plant's enormous capacity for climbing to form true vines, most varieties grow over any space, even when it is small in area. In this sense, the growth of the cucumber in Huete is appropriate. From the point of view of underwatering, this possibility does not exist since the irrigation is controlled and the soils are well drained (Table 1) while having a light texture and being relatively poor in organic matter. In addition, salinity tolerance must be noted although the soils are not excessively saline. In the following sections the results are analyzed in greater detail.

3.1. Climate Requirements

Although the cucumber is a product with a generic form throughout the year, its consumption intensifies in the summer period and, for this reason, the climatic conditions of culture must be related to this period. The sowing of the crop takes place approximately 2–3 weeks after the last known spring frost date.

Cucumber requires high temperatures and soil moisture to achieve a satisfactory yield, and under unfavorable climatic conditions several problems may occur, such as the reduction of female flowers [12], a delay in fruit growth [13, 14] and mineral disorders. Therefore, planting is usually carried out in the spring-summer season when the weather conditions are favorable for plant growth and high yields can be achieved.

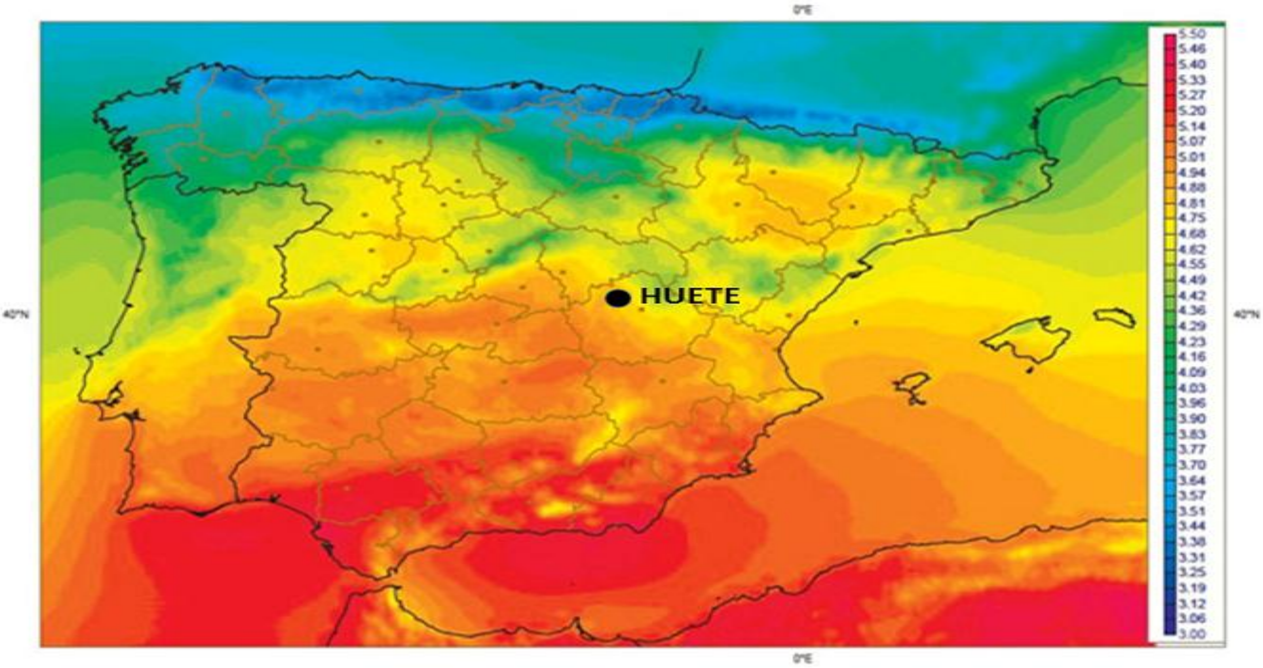
Consistent optimal temperatures are essential for the proper functioning of the crop and frost has a marked detrimental effect. Low night-time temperatures are also detrimental to the crop. At temperatures below 16 ºC the plant begins to suffer and shows symptoms such as malformed fruits. During the day the temperatures can range between 20 and 30 ºC. Lower temperatures (1–10 °C) are known to disturb cellular physiology, cause oxidative stress by creating an imbalance between the generation and metabolism of reactive oxygen species (ROS) and this ultimately leads to cell and / or plant death [15].

Sub-optimal (low non-freezing/chilling) temperatures are amongst the major environmental factors that are known to impact crop productivity by affecting growth, development and metabolism – especially in the tropics and subtropics [16]. The climate in Huete covers all of these requirements perfectly.

3.2. Light Requirements

Abundant sunlight is needed for cucumber cultivation to develop well and this is one more reason to cultivate during the summer period. It is estimated that there are between 2700 and 2800 hours of sunshine in the area of Cuenca (State Agency of Meteorology, Figure 5) and, for this reason, Huete is considered to be a suitable area.

Figure-5. Average global irradiation in the period 1983–2005 around Huete. http://www.aemet.es/es/idi/clima/productos_climaticos (date 25 july 2017)



3.3. Water Requirements

Irrigation is an important factor that limits crop yield, because it is associated with numerous other factors related to the plant environment that influence growth and development. The availability of sufficient moisture at critical stages of plant growth not only optimizes the metabolic process in plant cells but also increases the effectiveness of the mineral nutrients applied to the crop. As a consequence, any degree of water stress may have adverse effects on the growth and yield of the crop.

Cucumber requires water for growth and although they have some tolerance for periods of 'dry' soil, it is not desirable that such a process occurs so it is best to maintain moist soil while taking care not to soak the soil and saturate it. Given this low tolerance to water stress, the traditional solution has been to irrigate frequently but not abundantly, as with drip irrigation. This latter method does not wet the leaves during irrigation, in contrast to to sprinkler irrigation, for example. Finally, localized irrigation minimizes the risk of diseases such as powdery mildew.

In Huete cucumber is generally grown under the conventional surface irrigation method. In this method the majority of the irrigation water is lost by surface evaporation, deep percolation and other losses, all of which result in lower irrigation efficiency. Moreover, there is a tendency for farmers to apply excess water when it is available. Under limited water supply conditions farmers tend to increase the time between irrigations and this creates water stress and results in low yields and poor quality.

Irrigation in the production area of Huete is assured for two reasons: firstly, the location in which the cucumber is grown is a river floodplain, which transmits edible moisture and has easily extracted water. Secondly, there are numerous wells that are connected to the underground levels of the quaternary aquifer. The main question is to identify the best type of irrigation for this area. In other areas irrigation has commonly been blanket, superficial or gully irrigation [17].

Drip irrigation is able to provide small and frequent water applications directly in the vicinity of the plant root zone and this method has attracted interest because of the lower water requirement and possible increase in production. As the world increasingly becomes dependent on the production of irrigated lands, irrigated agriculture faces serious challenges that threaten its suitability. It is prudent to make efficient use of water and irrigate larger areas using available water resources. This can be achieved by introducing advanced methods of irrigation and improved water management practices [18].

3.4. Discussion

According to Azcon and Talon [19], among the stress factors that affect the abiotic cucumber type, it is worth highlighting low temperatures, excessive or insufficient lumninous radiation, anaerobiosis, water deficit, salinity, atmospheric pollutants such as ozone, SO_2, herbicides, and various elements. The wind is also a detrimental factor.

In terms of climate, Huete and its surrounding environment is part of a continental Mediterranean context. The annual rainfall is around 451 mm and the rainfall period occurs mainly in spring and winter. The average temperatures are around 12.4 °C, with the minimum temperature in January (–0.4 °C) and the maximum in July (30.7 °C). Under these conditions the summer period is most conducive to cucumber cultivation (it is accepted that cucumber grows best at temperatures ranging from about 20 °C to 30 °C during the day). If the temperature exceeds 30 °C certain imbalances related fundamentally to the photosynthesis and respiration processes can occur. If the temperatures at night fall below 15–17 °C, certain malformations can occur that affect the fruit. Temperatures in the environment of around 0 ºC are clearly unfavorable, since the plant freezes. As consequence, cucumbers are often grown in greenhouses with the aim of increasing the temperature and therefore the production.

Irrespective of rainfall, the remarkable leaf surface of the cucumber means that it requires the soil to be moist, with moisture values in the daytime of around 70%, while at night this requirement can reach up to 90%. This level of moisture is achieved by irrigation with adequate doses of water.

It appears that excess moisture during the day can reduce production as it would decrease transpiration and consequently photosynthesis. Cucumber is not considered to be very tolerant to water stress, hence the need to keep the soil moist without causing asphyxiation, which could occur if saturation is reached. Regarding solar radiation, it should be noted that this is very intense and prolonged in Huete (Figure 3), which strongly favors the cucumber crop. Temperature stress (both heat and cold) can cause changes in membrane fluidity and denaturation of proteins and enzymes [19]. This effect is not usually observed in Huete cucumber, since these humidity and temperature conditions are maintained in a balanced manner.

The response of plants to water stress is growth inhibition due to excessive dehydration, which affects photosynthetic and respiratory processes, reduces intercellular spaces, causes the closure of stomates and degradation of proteins and nucleic acids [20] and increases the concentration of growth retardants. For these reasons, maintaining an optimum level of humidity is very favorable and this is easy for farmers in Huete to achieve given the ease with which they can control the channels of the rivers that surround this municipality.

The results of the macromorphological study revealed that the soils are poorly developed and evolved, with a simple A-C or A-Bw-C morphology and horizons that have loose or moderately developed structures (in subangular blocks). The soils are friable, slightly adherent and somewhat dry and hard. A significant feature is the presence of good drainage and appreciable effective depth. Like other crops, cucumber plants are preferably grown on loose, well-drained soils, such as those studied here (Tables 1 and 2).

The ideal pH range for this plant is relatively wide. In Huete the soils dedicated to cucumber cultivation have a slightly basic pH (between 7.55 and 7.96 in water, whereas in KCl it ranges between 7.46 and 7.87). Soil pH is one of the most important factors for soil fertility in arid and semi-arid regions. The pH influences the solubility of soil elements and soil microbial organisms. Therefore, soil pH has a significant effect on nutrient availability. In cases where the pH of the soil is alkaline the solubility of the micronutrients (such as Zn, Cu, Mn, Fe) is severely limited, whereas an acidic soil pH can lead to deficiencies in P or Ca or the toxicity of Al, Fe or Mn [21]. It has been widely reported that a pH between 6.5 and 7.5 is the best soil pH for almost all plants, including cucumbers.

3.5. Agroecological Characteristics of Huete cucumber

As in any region, starting from a characteristic geomorphological landscape, an agro-ecological zone is nothing more than a sub-landscape that presents a certain degree of homogeneity for the growth and development of vegetal species adapted to its conditions and with economic benefits. Agroecological zoning is a process involving the biophysical definition of the conditions that determine the behavior of related agroecosystems, where an agroecosystem is understood to be the scenario where ecological and agricultural processes are dynamically manifested through the interaction of biological, cultural, and social factors. Economic and environmental factors determine both the range of variability of biotic-productive conditions and the diversity of production systems. In this sense, the orchard is a subzone or land system derived from the interaction of its biotic and geographic factors, and it thus constitutes a traditional environmental unit for the exploitation and management of natural resources. The variables that determine the productive behavior of the orchard are as follows: a local landscape, defined by a fluvial local plain, a Mediterranean climate (average temperature 12.4 ºC), average precipitation 451 mm, soil types Entisol (Soil Taxonomy) or Regosol (FAO-ISSS-ISRIC) with moderate salinity. These soils have been developed from materials deposited by river currents, i.e., soils that, because of their relatively low genetic development, do not have clearly defined diagnostic horizons but are characterized by being moderately deep, with medium and moderately thick textures, on sandy subsoils or sandy loam and that are moderately permeable and susceptible to saturation during periods of prolonged rainfall. The soils are generally fertile, are susceptible to mechanized tillage and they only rarely have a stony phase.

The unique biophysical characteristics derive from the influence of the periodic floods caused by torrential discharges and the interaction with the river system. The overall effect has been the natural emergence of a certain degree of homogeneity in the behavior of the variables that determine the productivity of the reigning ecosystem(s). In general terms, this area is characterized by its flat relief and regular or slightly inclined topography, with slopes not greater than 3%.

Depending on the variation in the effective depth of the soils, their texture, natural drainage conditions, degree of interference by thick fragments, erosive susceptibility and magnitude of the slope, the land use capacity that dominates the surface area is suitable for intensive cultivation in conjunction with appropriate technology. The cultivation of cucumber in the area under investigation is carried out with a good level of technology, since it uses traditional seeds from the zone, fertilization of the ground and foliar, and control of plagues and diseases. Most of the area is irrigated due to its proximity to the river beds of the Borboton and Mayor rivers, which ensures the presence of abundant groundwater and provides great potential for the development of irrigated crops.

As far as the risk factors are concerned, it is necessary to point out the possibility of damage due to threats and vulnerabilities. There is risk of flooding and historically the area has been prone to flooding in the summer season. Flood problems are mainly caused by river overflows. There is also a risk of drought, although this is counteracted by artificial irrigation.

5. Conclusions

If adaptability is defined as the ability of a crop (or variety) to respond positively to changes in agricultural conditions, the purpose of this study was to explore the adaptability and relative influence of environmental factors for *Cucumber Sativus L.* in a unique Mediterranean environmental and agroecological site, namely Huete (Cuenca, Central Spain).

Given the lack of knowledge on the requirements for the agroecological and, in paticular, edaphic systems for cucumber, which in turn provides a basis for assigning the best sites and management practices to support production, the main aim of this work was to define the characteristics of an area used to produce a high quality cucumber such as Huete cucumber.

Cucumber requires high temperatures and soil moisture for satisfactory yields and an optimum level of humidity is very favorable, which is easy to achieve for farmers in Huete. Abundant sunshine is also required and cultivation during summer is therefore advantageous, with an estimated between 2700 and 2800 hours of sunshine in the Huete area.

The results of the macromorphological study described here indicate that the soils are poorly developed and evolved, with a simple A-C or A-Bw-C morphology and horizons that have loose or moderately developed structures (in subangular blocks). The soils are friable, slightly adherent and somewhat dry and hard. A significant feature is the presence of good drainage and appreciable effective depth. Like other crops, cucumber plants are preferably grown on loose, well-drained soils such as those studied here.

Huete cucumber appears to be able to tolerate higher levels of soil salinity than other species. The cucumbers are irrigated with water that has a moderate electrical conductivity and an appreciable decrease in yield is not observed. Low levels of salinity may be one of the factors that provides the characteristic properties of Huete cucumber, an aspect that would need to be investigated more deeply. The results of the elemental chemical analysis revealed that strontium is present at relatively high levels and this is attributed to its presence in the gypsums.

Substrate nutrient and moisture management are two major factors to consider for the *Cucumber Sativus L.* crops in Huete. This study opens up a new horizon for studies into the aptitude of the land and also represents a useful contribution to the specific site and, consequently, the sustainable management of land under cucumber cultivation. Further research into other types of soils, fertilizer compositions and release rates is required.

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