Analele Universităţii din Craiova, seria Agricultură – Montanologie – Cadastru (Annals of the University of Craiova - Agriculture, Montanology, Cadastre Series) Vol. 53/1/2023

THE MAIN LIMITING FACTORS THAT INFLUENCE SUGAR BEET CULTURE

Bianca-Anamaria Popa[1]

University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Mărăști Blvd, District 1, Bucharest, Romania

Author email: popa.bianca22@yahoo.com

Corresponding author email: popa.bianca22@yahoo.com

Abstract

The biological requirements of sugar beet define it as one of the most difficult crops to grow. Achieving large and stable productions requires a precision technology that ensures the optimal presence of growth and development factors.

Sugar beet requires a high consumption of water (600-650 mm/year), a fact that influences the choice of a culture area, especially in irrigated areas or with groundwater supply. Areas with abundant rainfall during the growing season are also recommended. The location of the culture will take into account the sensitivity to soil acidity and its settling, determining the choice of flat, medium-textured, deep, rich in organic matter and with a neutral reaction (pH = 6.5-8).

***Key words**: sugar beet, water consumption, soil, texture, compaction*

INTRODUCTION

Beta vulgaris is a member of the Chenopodiaceae family and, like the other members of the family, is a halophytic plant.

The storage organ of the sugar beet plant is called the root, although only about 90% is actually derived from the root, the remaining 10% representing the upper part (crown) being derived from the hypocotyl.

Sugar beet is also used in the alcohol industry, where from 100 kg of roots with a 17% sugar content, approximately 10-11 liters of alcohol can be obtained. The leaves and chops, which represent 40-45% of the total sugar beet harvest, are used as green, pickled or dry fodder in cattle nutrition, having a nutritional value close to that of corn for green mass.

Industrial residues are also of particular importance: molasses, noodles and sludge from the press filters resulting from the extraction of sugar from beets. These residues are successfully used in animal feed for fattening.

Sugar beet is a biennial plant that was developed in Europe in the 18th century from white fodder beet. Sugar reserves are stored in the root of the sugar beet during the first growing season for an energy source during the winter. The roots are harvested for sugar at the end of the first growing season, but plants that overwinter in a mild climate will produce stems and seeds that will flower the following summer and fall.

The sugar content of sugar beet can vary from 12% to 20%. It is the sugar that gives value to the sugar beet crop. Sugar beet by-products such as pulp and molasses add up to 10% of the sugar value. The speed of sugar extraction depends on the sugar content of the sugar beet when it arrives at the processing point. European rules define sugar beet as marketable if it contains 14% sugar or more (in Ukraine, for example, the average sugar content is only 11.2%). Standard sugar beet should have a sugar content of 16%, which would produce 130 kg of sugar per 1 tonne of standard sugar beet processed at a sugar

factory - the ideal efficiency is 82.5% (Cooke, D. A., & Scott, J. E., 2012).
The technology and the increased attention that the plant needs during the vegetation period, transform the sugar beet culture into a "niche" culture. Fewer and fewer farmers choose to integrate beet in the farm's crop palette, which is why the area cultivated with sugar beet at the national level is in continuous decline, from 2015 until now.

MATERIALS AND METHODS

In order to characterize the main limiting factors of sugar beet cultivation, data were collected regarding: climatic conditions (temperature, humidity, light), soil properties (physical - texture, structure, density, apparent density, porosity, degree of compaction; chemical - the colloidal complex of the soil, the soil solution, acidity, oxido-reduction (redox) potential salinity, alkalinity), macroelements and microelements).
The paper presents bibliographic data, collected from different sources or studies published by Romanian or international authors.

RESULTS AND DISCUSSIONS

Climate conditions

Sugar beet is a mesothermal plant, which requires during the first year of vegetation a sum of temperature degrees of 2400-2900 ° C, and in the second year around 1800 ° C. In the first year of vegetation, normal growth and development is achieved in areas with a daily thermal average of 10.7 ° C, between April 15 and June 15; 18.8 °C from 15 June to 15 August and 16.5 °C from 15 August to 15 October.
In the period from sowing to emergence, sugar beet is less demanding on heat.
The minimum temperature for germination is 3-4 ° C, but the duration of germination at this temperature is 20-30 days. At temperatures of 9-10 ° C the seeds germinate in about 9 days, and at 15-16 ° C in 4-7 days. Temperatures lower than 4 °C in the cotyledon phase cause the appearance of flowering shoots in some plants since the first year of vegetation.
The thermal requirement per vegetation phase is structured as follows:
- 650 ° C in the interval from emergence to the beginning of root thickening;
- 1150 ° C from the beginning of the thickening of the stem until the beginning of the accumulation of sugar;
- 1000 ° C until harvesting.

In the phase of maximum sugar accumulation, the most suitable average temperature is around 16-16.5 degrees Celsius. Sugar accumulation stops at temperatures of 5-6 ° C. Roots harvested and frozen at -1 ° C negatively influence the sugar yield, producing the phenomenon of "sugar inversion" (Petkeviciene, B.,2009).
A precise correlation between temperature and production could not be established. However, it has been established that the ripening of beets is directly related to the temperature during the month of July. The warmer this month is, the faster the beet development, sugar accumulation and technological maturity. Beet ripening is little influenced by the fact that the following months are much colder. Temperatures lower than 4 degrees during the emergence and in the cotyledon phase disturb the vegetation of the plant, and temperatures of minus 2 degrees Celsius to minus 4 degrees Celsius cause the frosting of the cotyledons. However, plants with 6-10 pairs of leaves can withstand frosts down to minus 8 degrees Celsius. Beets obtained from late sowing or hit by hail or attacked by diseases show a weaker resistance to low temperatures.
The low temperature at planting and after planting contributes to the vernalization of

plants and, consequently, to a higher degree of sprouting. Temperatures of 15-20 degrees Celsius during the flowering period provide suitable conditions for fertilization. Cold weather in the phase of embryo formation and development favors the appearance of flower shoots in plants.

Sugar beet is a demanding plant regarding to humidity. High and stable productions are obtained in areas where 500-600 mm/year of annual precipitation are registered.

The water consumption of sugar beet is between 350 and 400 mm. At a production of 50 tons/hectare of roots (about 12.5 tons/hectare of dry substance), sugar beet consumes about 500 mm of water. Sugar beet has the highest water requirements in the months of June, July and August. In those three months of vegetation (June-August), the plants form their leaf apparatus and develop their roots strongly, and consumes 78-80% of the total water consumption (Hoffmann, C., & Jungk, A., 1995).

Taking into account the humidity requirements of the plants, it is considered that for a harvest of 50 tons/hectare, 250 mm of water must accumulate in the soil until sowing, and during the growing season, another 200 mm, from precipitation, of which the most mostly during peak consumption period.

In the spring months, precipitation should fall in moderate amounts, due to the reserves accumulated during the winter, the lower consumption of the plants and the fact that with a suitable amount of water, the soil is better prepared for sowing, and the seeds have optimal conditions for germination. In the months of July and August, a greater amount of precipitation is required, because in these two months accumulates the greatest amount of organic matter.

High soil moisture ensures a significant increase in the weight of sugar beet roots. At the same time, however, this also causes the sugar content to decrease. It was highlighted that the rainfall in September-October, in large amounts, has a negative influence on the percentage of sugar in the roots. The higher the amount of precipitation in these months, the lower the sugar percentage. Optimum soil moisture for sugar beet is achieved when the soil contains 50-75% of the active moisture range during the periods of leaf growth, root thickening and sugar accumulation.

The plant is a long-day plant, with rich foliage, which makes good use of light energy. The duration of sunshine during the entire vegetation period must be about 850 hours, with a daily average of at least 5 hours.

Sugar beet is a plant that has an intense process of photosynthesis, so light plays a very important role in production. In the absence of direct sunlight, the percentage of sugar decreases, and the amount of non-sugar substances and the content of mineral substances increase. A high yield in the deposition of organic substances is ensured when, during the day, intense light alternates with weaker light due to cloud cover.

Light intensity and insolation are very important in the months of August-September, when large quantities of sugar accumulate. Sugar synthesis occurs only during the day, and migration and accumulation in the root takes place both during the day and at night.

For the best utilization of light, is necessary an optimal distribution of plants in space and an adequate care of the culture in order to keep it clean of weeds and to prevent shading (Pidgeon, J. D., Werker, A.

R., Jaggard, K. W., Richter, G. M., Lister, D. H., & Jones, P. D., 2001).

The physical properties of the soil

Texture. The degree of fragmentation of the mineral part into components of different sizes and the proportion with which they participate in the composition of the soil represent that physical property known as soil texture.

Sand consists of rock fragments, which strongly resist disaggregation (quartz or other minerals such as pyroxenes, magnetite, etc.) it is very permeable, does not exhibit adhesion, swelling, contraction, plasticity, cohesion, has a low capacity to retention for water and nutrients. The sizes of elementary particles are comparatively larger, the number of particles per unit volume of the soil is small, the specific surface area is small (Pavel, Ş., Pascu, I. B., Ţăranu, B. O., Grad, O. A., & Negrea, R., 2019).

Clay is the granulometric fraction with the most important role in determining the physical and chemical properties of the soil. It has high cohesion, plasticity and adhesion, increased capacity to retain water and nutrients, extremely high specific surface, which favors a multitude of physico-chemical, biological processes and regulates soil fertility itself. Dust is an intermediate component between sand and clay, consisting of rock fragments in an advanced degree of disaggregation, with properties close to those of clay. Dust or silt contributes to the plasticity and cohesion of the soil, increases the water-holding capacity available to plants. A high proportion of dust is not favorable because it gives the soil some unfavorable properties such as pronounced settlement, poor structuring, because it does not coagulate and cannot form structural microaggregates by itself (table 1).

Table 1. Class groups and textural classes

Symbol	Name	Clay (< 0,002 mm)	Dust (0,002 – 0,02 mm)	Sand (0,02 – 2mm)
G	Coarse texture	≤12	≤32	≥56
N	Sand	≤5	≤32	≥63
U	Loamy sand	6 – 12	≤32	56 – 94
M	Medium textures	13 – 32 ≤32	≤32 ≥33	35 – 87 ≤67
S	Sandy loam	13 – 20 ≤20	≤32 ≥33	48 – 87 ≤67
L	Loam	21 – 32	≤79	≤79
F	Fine textures	≥33	≤67	≤67
T	Clay loam	33 – 45	≤67	≤67
A	Clay	≥46	≤54	≤54
O				

Soil structure. By soil structure we define the grouping of elementary particles into aggregates of different shapes and sizes. The new conception of structure refers to two components:

- the way of spatial arrangement of elementary soil particles;
- the nature and intensity of the links that exist between them.

In the present system, the structural state of a soil is defined based on the following criteria:

- type of structure;
- the size of the structural elements;
- the degree of development of the structure

According to the shape and arrangement of the structural aggregates in the soil mass, the following types of structure are distinguished:

Structured soils are more resistant to erosion processes and are easier to work with than unstructured ones. Loose lands on a deep layer provide the best conditions for the development of sugar beet roots.

Soils without structure in the superficial layer form a crust, which causes great damage at emergence, especially for monogerm seeds (Mihalache, M., & Ilie, L., 2009).

Density. Soil density (D) defines the mass per unit volume of the solid phase, or mathematically it is understood as the ratio between the mass of a completely dry soil sample (M) and the actual volume occupied by solid mineral and organic particles.

Density values are used to calculate porosity and assess soil composition, as they reflect the proportion between the mineral and organic parts.

Bulk density. The bulk density of soil is the mass per unit volume of a completely dry, naturally settled soil and is used in calculating the total porosity of the soil. Its values are used to calculate important components of the soil: the reserve of humus, phosphorus, potassium, etc. (Horn, R., Taubner, H., Wuttke, M., & Baumgartl, T.,1994).

Total porosity. The loose settlement of particles and aggregates as well as the intense biological activity create in the soil a network of spaces or pores of very different sizes, shapes and orientations.

The totality of the spaces or pores forms the total porosity of the soil and is expressed as a percentage of the volume of the soil in natural settlement (%). Sugar beet prefers soils with optimal aeration.

Compaction. Soil compaction is an important soil degradation process that affects the agricultural role of the soil, and determines its vulnerability to erosion, reduces the availability of soil water and nutrients, and minimizes the natural biological activity of the soil. From an agricultural point of view, compacted soil has low porosity, low permeability to water and air, and an increased need for traction power in the tillage process. Soil compaction can limit root and shoot growth of sugar beet plants. The roots are the organs of the sugar beet plants directly exposed to soil compaction and are therefore affected by this phenomenon in the first place (Figure 1) (Hebblethwaite, P. D., & McGowan, M.,1980).The main factor that prevents the growth of roots in compacted soil is the resistance to penetration of the soil and its poor aeration. In compact soils, the sugar beet root is prevented from developing normally, on the one hand, due to the physical resistance of the soil and, on the other hand, due to inadequate aeration and moisture regime (Badalíková, B.,2010).

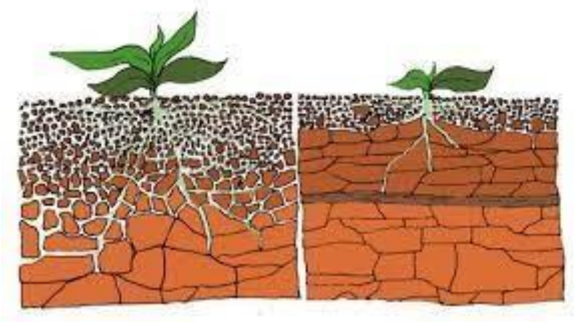

Figure 1. Soil compaction

The chemical properties of the soil

The colloidal complex of the soil has many functions, among which we mention: the mechanical retention capacity of particles in suspension in water; the physical retention capacity or surface adsorption of mineral or organic soil particles, molecules of some substances from the air or soil solution; the physico-chemical or ion exchange retention capacity refers to the adsorption of ions (either cations or anions) on which the colloidal complex.

The soil solution. It has a very complex composition, varied from one type of soil to another, it shows variations on the same soil profile, as well as variations in time, both seasonal and diurnal.

The composition is determined by a multitude of factors, such as: climatic ones (precipitation, temperature, evapotranspiration), the depth and mineralization of groundwater, the type of vegetation, the type of humus, the microbiological activity in the soil, the nature and degree of solubility of mineral substances and organic compounds, the properties of the colloidal complex of the soil.

Acidity. The concentration of free hydrogen ions existing in the soil solution represents what is called current acidity and is expressed in pH units.

Sugar beet prefers a slightly alkaline reaction in the soil, a pH of 7.2 being very favorable. The species is considered as a plant tolerant to moderate soil salinity. However, on lighter soils and richer in humus, satisfactory results are also obtained at a pH of 6.5.

Oxido-reduction (redox) potential. The oxidation represents any process that takes place with the loss of electrons, so the number of free positive charges will increase.

The reduction reaction is an opposite process to oxidation, it being defined as a loss of oxygen or a gain of hydrogen or electrons, so an increase of free negative charges.

To characterize the redox potential of soils, it is usually used to determine the pressure (P) of molecular hydrogen (H2), defined by the rH index.

Salinity. The main source of soil salts is the rocks and minerals in the earth's crust. The most common salts are carbonates, chlorides, sulfates, silicates or nitrates.

Alkalinity. The alkaline reaction of the soils is given either by the presence of alkaline salts (carbonates and bicarbonates of alkaline and alkaline-earth metals), or by the enrichment of the adsorptive complex in exchangeable Na+. A high alkalinity is not favorable for sugar beet, because it hinders the germination of the seeds. A higher alkalinity can also cause boron to be fixed in the soil and creating favorable conditions for diseases.

The macroelements

Within the plant, nitrogen has the same role as in other organisms, as a component of amino acids and nucleic acids. Nitrogen also plays a critical role in the structure of chlorophyll, thus also playing a role in photosynthesis. This, together with its structural role in amino acids, explains why plants require large amounts of nitrogen and therefore why it is often the limiting nutrient for plant growth.

Phosphorus has many important functions in plants, the first being the storage and transfer of energy through the plant. Adenosine diphosphate (ADP) and adenosine triphosphate (ATP) are phosphate compounds that control most processes in plants, including photosynthesis, respiration, protein and nucleic acid synthesis, and nutrient transport through plant cells.

Potassium is the primary ion involved in plant cell membrane dynamics, including stomatal regulation and maintenance of turgor and osmotic balance. It also plays an important role in the activation and regulation of enzyme activity.

The microelements

Trace elements (B, Mn, Cu, Zn, Fe and Mo) are essential nutrients for plants, and the absence of any of these elements in the soil will lead to serious regressions in growth and production. The role of trace elements in biochemical and physiological processes in plants and animals shows a great similarity between the behavior of these elements in organisms and in enzyme systems, and the idea that micronutrients play a catalytic role in biological reactions has received general agreement.

Boron is an indispensable element for bud development, increases pollen germination and floral fertility, guaranteeing better flowering and fruit setting. It contributes to increasing the sugar content in products.

Copper participates in the synthesis of chlorophyll, in the respiration and growth processes of plants.

Plant iron, under normal conditions, should be present in analyzes with levels between 300 and 1,300 ppm, and in severe deficiency conditions there may be values of 60-90 ppm. It participates, combining in certain fundamental growth substances (cytochromes and ferroporphyrins), in the formation of the chlorophyll molecule, in the synthesis of amino acids and proteins.

Manganese increases the production of carbohydrates and dry matter.

Molybdenum is a catalyst included in many vital processes, such as those responsible for the formation of nitrogen-fixing "tubercles" of leguminous roots and those responsible for the reduction of nitrates in leaves.

Zinc is a catalyst for the synthesis of tryptophan, amino acid precursor of the synthesis of indole-acetic acid which is an important auxin-like growth regulator of the plant. It positively influences the growth of plants and the development of the root system (Ronen, E., 2016).

CONCLUSIONS

The specific characteristics of the plant in terms of temperature and rainfall allow the territory of Romania to be a proper area for sugar beet.

The importance of fertilizing with mineral fertilizers lies in the fact that they intensify physiological processes such as: breathing, transpiration, opening of stomata and photosynthesis.

As for the soil, loose soils on a deep layer provide the best conditions for the development of sugar beet roots. Soils without structure in the surface layer form a crust, which greatly damages the emergence of sugar beet seeds. Sandy soils, poor in nutrients and too permeable to water, are also less suitable.

Sugar beet is very picky about the soil, thanks to its deep root system, with a high breathing capacity and a high consumption of nutrients and water. The culture prefers a slightly alkaline reaction in the soil, a pH of 7.2 being very favorable.

In conclusion, sugar beet is an intensive, very profitable crop, which efficiently capitalizes on fertilization, soil or irrigation water, and is also a good precursor plant for most agricultural crops.

ACKNOWLEDGEMENTS

The author collected information from all the works stated in the bibliography, for which reason he thanks all the authors of the stated sources.

REFERENCES

Badalíková, B. (2010). Influence of soil tillage on soil compaction. *Soil engineering*, 19-30.

Cooke, D. A., & Scott, J. E. (2012). *The sugar beet crop*. Springer Science & Business Media.

Hebblethwaite, P. D., & McGowan, M. (1980). The effects of soil compaction on the emergence, growth and yield of sugar beet and peas. *Journal of the Science of Food and Agriculture*, *31*(11), 1131-1142.

Hoffmann, C., & Jungk, A. (1995). Growth and phosphorus supply of sugar beet as affected by soil compaction and water tension. *Plant and Soil*, *176*, 15-25.

Horn, R., Taubner, H., Wuttke, M., & Baumgartl, T. (1994). Soil physical properties related to soil structure. *Soil and Tillage Research*, *30*(2-4), 187-216.

Mihalache, M., & Ilie, L. (2009). Bonitarea terenurilor agricole. *Editura Dominor, Bucureşti*.

Pavel, Ş., Pascu, I. B., Ţăranu, B. O., Grad, O. A., & Negrea, R. (2019). Aspecte privind predicţia coroziunii electrozilor de pământare în solul municipiului Timişoara Partea I. Măsurători. *Romanian Journal of Civil Engineering/Revista Romana de Inginerie Civila*, *10*(2).

Petkeviciene, B. (2009). The effects of climate factors on sugar beet early sowing timing. *Agron. Res*, *7*, 436-443.Pidgeon, J. D., Werker, A. R., Jaggard, K. W., Richter, G. M., Lister, D. H., & Jones, P. D. (2001). Climatic impact on the productivity of sugar beet in Europe, 1961–1995. *Agricultural and forest meteorology*, *109*(1), 27-37.

Ronen, E. (2016). Micro-elements in agriculture. *Practical Hydroponics and Greenhouses*, (164), 35-44.