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ESTIMATING THE DURATION OF DAYLIGHT IN A GIVEN TIME OF THE YEAR DEPENDING ON THE LATITUDE OF THE LOCATION

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Abstract: *Photoperiodicity is the physiological reaction of organisms to the length of day or night. The total amount of energy is unimportant as long as it exceeds some low minimum level required to trigger changes in phytochrome. Response to photoperiodic stimuli include flowering, tuber and bulb formation, bud dormancy, seed germination etc. Since the relationship between the daily succession of light and dark periods frequently influences flowering and fructification of plant species, photoperiod appears as a major contributing factor in limiting areal plant species and associations. Knowing the variation of the daily light period duration and requirements of various plants in different growing phases according to the day light is useful in agricultural practice in order to determine the period of plant cultivation, crop rotation and duration of lighting in protected areas (greenhouses, solariums) in the case of using additional sources of illumination. Establishing successive vegetable cultivation and instalments will be both depending on their requirements according to day length and on the purpose for which plants (leaves, underground organs, inflorescences, etc.) are being cultivated. Since the change in the duration of daily light depends on the location this paper presents a calculation method in order to determine the period of the year with a certain minimum amount of daylight duration depending on the latitude value of the location expressed in degrees and minutes. The apparent motion of the Sun on the sky has the following consequences: the seasons – astronomically defined as the period of time the Sun takes to describe the arc between two fundamental consecutive points of the elliptic -, the inequality of days and nights – by day understating, as opposed to night, the duration of the Sun's visibility, meaning the period of time when the Sun can be found above the horizon of the spot - and the heat areas of the Earth – meaning the splitting of the terrestrial surface into several areas of heat, warm area, two cold and two temperate areas.*

Key words: *photoperiodicity, duration of daily light, location in degrees.*

INTRODUCTION

Astronomy is one of the oldest sciences born out of practical needs – the science that studies the motions, structure and evolution of the celestial bodies and of the systems they form.

The applications of astronomy in the agricultural field are:

- it offers information about the beginning of seasons and data concerning agricultural works;
- it helps establishing the sort of plants that can be cultivated in certain areas according to the amount of time in which the duration of daylight varies within certain value limits;
- it helps establishing the calendar period for cultivating plants according to the purpose of the agricultural period.

The reaction of an organism to modifications of the duration of day is called photoperiodism. Several physiological processes (flowering, tuber and bulb formation, bud dormancy, seed germination etc.) are depending on the photoperiodism (MOHAN, 2004). The research performed by Garner and Allard (quoted by ZAMFIRESCU et al., 1956) prove that flowering and fruit harvesting can take place only when daylight is within certain limits. According to the way of reacting to the light, the vegetables can be classified in:

- long day plants (14-16 hours): spinach, onion, radish, cabbage, chicory, dill, carrot, , potato, lettuce, beets, peas;
- short day plants (8-12 hours): beans, cucumber, pepper, tomatoes, egg plant, etc.;
- intermediate plants: some tomato varieties, lettuce, spinach (ZAMFIRESCU et. al., 1956; VOICAN, 1998; INDREA, 2007).

If we watch the sky, it seems that the Sun is executing a daily motion from East to West (in a retrogressive sense), when, in fact, the Earth is the one executing the rotation motion from West to East (direct sense). The large circle described by the Sun in its apparent motion on the sky is called the ecliptic and has an inclination of $23^0 27'$ to the Equator. On the ecliptic (the εε' plane) we find the 4 most important points to people: the vernal point (γ), the autumnal point (ω), the summer solstice point (ε) and the winter solstice point (ε') (CHIS, 1968).

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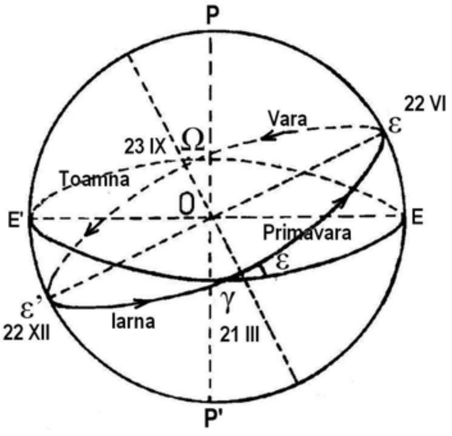

Figure 1: The ecliptic

The trajectory of the Sun on the ecliptic is not uniform hence the equal arcs formed in between points *γ, ω, ε* and *ε'* are being covered in different periods of time, ranging from 92 days and 20 hours in spring, 93 days and 15 hours in summer, 89 days and 19 hours in autumn and 89 days in winter (CHIS, 1968).

MATERIAL AND METHODS

The sunrise and sunset represent crossroads of their trajectory in the apparent daily motion with the plane of the place's horizon. We will try to establish the moments corresponding to these events. We can also find out the exact place in the horizon plane where the Sun rises and sets.

This problem is reduced to solving the Sun position triangle. In the case of the sunrise and sunset, the zenith distance is 90, thus we have a rectilater triangle (it is a spherical triangle with at least 1 rectangle and one side measuring 90).

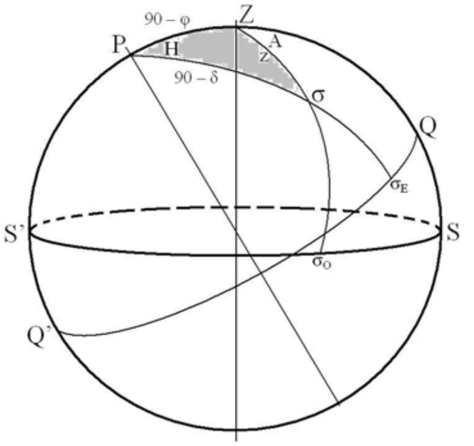

Figure 2: Equatorial coordinates

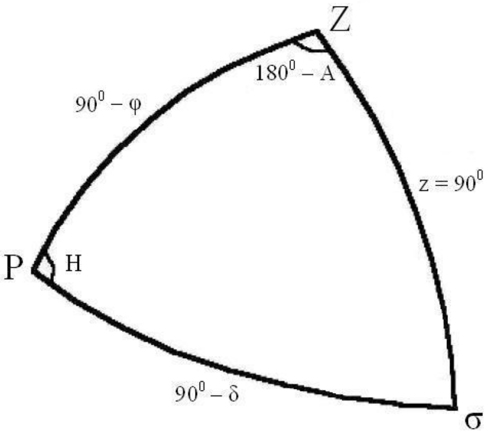

Figure 3: Spherical triangle position

The notations used are the following: σ the relative position of the Sun on the celestial sphere, Z the zenith of the observatory, P the North Pole, δ the Sun's declination (the angle formed by the vector radius of the Sun with the plane of the celestial equator), φ the latitude of the place of observation, PZ, the zenith distance of the celestial pole (equal to the complement of the latitude), SS' the horizon of the place, QQ' the celestial equator.

In order to determine the angle in P we will apply the theorem of the cosines in the position triangle: with the following notations (PAL. et. al., 1999): P → A, Z → B, σ → C, and we get: a → $z = 90^0$; b → $90^0 - \delta$; c → $90^0 - \varphi$; A → H:

$$\cos a = \cos b \cos c + \sin b \sin c \cos A . \quad (1)$$

from which

$$\cos 90^0 = \cos\left(90^0 - \delta\right)\cos\left(90^0 - \varphi\right) + \sin\left(90^0 - \delta\right)\sin\left(90^0 - \varphi\right)\cos H . \quad (2)$$

After trigonometry transformation we get:

$$\cos 90^0 = \sin\delta \sin\varphi + \cos\delta \cos\varphi \cos H , \quad (3)$$

which leads to the relation:

$$\cos H = -tg\delta \; tg\varphi , \quad (4)$$

from which $H = \pm H_0 = ar\cos(-tg\delta \; tg\varphi)$.

The condition for the trigonometrical equation (4) to have solutions (that is for the Sun to rise and set) is obtained by rewriting this equation under the form:

$$\cos H = -\frac{tg\delta}{tg\left(90^0 - \varphi\right)} . \quad (5)$$

This equation has solutions if and only if

$$\left|\cos H\right| \le 1 . \quad (6)$$

that is by analyzing the signs of the expressions: $\left|\delta\right| \le 90^0 - \left|\varphi\right|$.

Remark 1. If this condition is not fulfilled the sun does not rise or set for the northern hemisphere.

Remark 2. In order to determine the exact moment o the sunrise or sunset we need to consider first its apparent disk as well as the phenomena modifying the position of the star

(UReCHE, 1982, 1987): the refraction and the paralaxis. Thus the condition z = 90^0 must be replaced in rigorous calculations by:

$$z = 90^0 + \rho_{ap} + \rho_{r\,oriz} - p_0 \qquad (7)$$

where ρ_{ap} = the apparent radius, $\rho_{r\,oriz}$ = the horizon refraction, p_0 = he daily horizontal paralaxis of the star. In the case of the present research these phenomena are being neglected.

We can estimate the number of hours in a day by placing the calendar data on the abscissa and the number of hours of the day for the specified area on the ordinate axis: at the Equator (figure 4), in the area $0 < \varphi < 66^05'$ (figure 5); in the area $66^05' < \varphi < 90^0$ (figure 6) and the poles area $\varphi = 90^0$ (figure 7).

If the latitude of the place is $\varphi = 0^0$ that is if we are at the Equator we will have equal days and nights, the Sun being at the zenith of the observatory during the equinoxes.

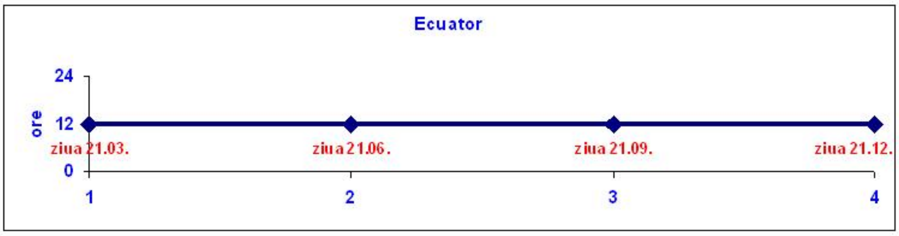

Figure 4: At the Equator

If we are in an area in which $0 < \varphi < 66^05'$ and nights with a variable number of hours (estimation still to be done).

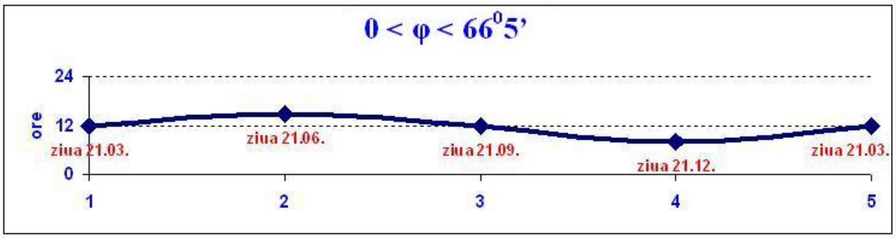

Figure 5: The zone $0 < \varphi < 66^05'$

If we search the zone in which $66^05' < \varphi < 90^0$ we will have polar day and night while the Sun doesn't set or, respectively, rises, whose length measured in hours decreases from pole to polar circle, apart from normal days. On the 22nd of June, the Sun is on the Tropic of Cancer, situated completely above the horizon that means that this particular day the Sun doesn't set.

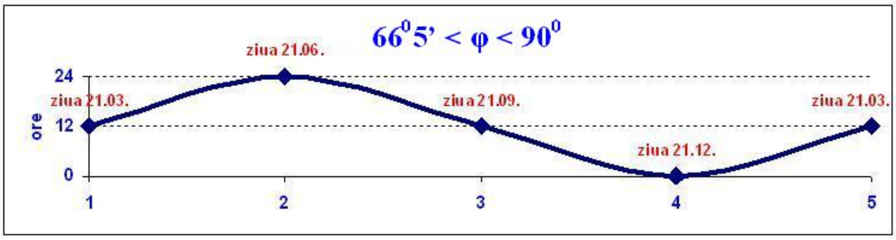

Figure 6: The zone $66^05' < \varphi < 90^0$

If the latitude of the place is $\varphi = 90^0$ that is if we are at the North Pole we will have a polar day and a polar night of 6 months.

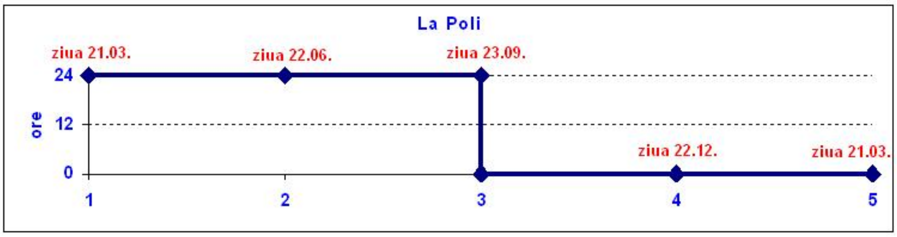

Figure 7: At the North Pole

RESULTS AND DISCUSSIONS

In our country we only have normal days and nights (CHRIS, 1968) in between 15 hours and 32 minutes and 8 hours and 50 minutes. Due the astronomical refraction, the crepuscule ads to the results found above and lengthen the day by several minutes.

Long day plants blossom earlier and richer if the duration of daily light during the vegetation period crosses the limit of a certain period called critical hemeroperiod, whose value is higher than the trophic minimum (CEAUŞESCU I., 1979). Short day plants blossom if the photoperiod value is lower than a certain critical value and at least equal to the trophic minimum of 8 hours. Intermediate plants blossom in specific photoperiodic conditions where the duration of daylight varies between 2 limit values which are different from the trophic minimum.

The needs of the cultivars regarding the photoperiod can be different even if they belong to the same species. For the majority of the cultivated vegetables there are cultivars obtained by means of selection having a lower sensibility to the photoperiod. The obtaining of such cultivars has allowed the extension of both the cultivated areas of various vegetable species and the periods of the year in which they can be cultivated.

As the modification of the rapport between the duration of daily light and dark periods frequently influences the blossoming and harvesting of plant species photoperiodism appears to be an important factor contributing to the limitation of the areas of vegetal species and associations. In this case we can talk about geobotanics and the existence of a photic climate in which the vegetal carpet is born and evolves. The existence of synusies is conditioned by the photic microclimate (BORZA, 1965).

In the case where the duration of the photoperiod is consistent with the needs of the vegetables, their growth and development takes place in a more intense rhythm, the duration of the vegetation period is smaller if the needs for water, air, carbon dioxide and heat are met.

CONCLUSIONS

The graphics allow a discussion on the duration of the time in which we have a smaller or larger period of the day than certain important critical values for the growth and development of plants. By delimitating graphic areas we notice the calendar periods in which the duration of the day fits the interval of certain values.

The practical application for this estimation is the establishing of the time of the year when certain varieties and plant hybrids can be cultivated according to their needs from the photoperiod and the category of the intended production.

Knowing the variation of the daily light period duration and requirements of various plants in different growing phases according to the daylight is useful in agricultural practice in order to determine the period of plant cultivation, crop rotation and duration of lighting in protected areas (greenhouses, solariums) in the case of using additional sources of illumination.

BIBLIOGRAPHY

1. CHIS GH., 1968: Astronomie, Ed. Didactica si Pedagogica, Bucureşti.
2. PAL A., POP V., URECHE V., 1999: Astronomie. Culegere de probleme, Ed. Presa Universitara Clujeana, Cluj-Napoca
3. URECHE, V., 1982: „Universul Vol. I, Astronomie”, Ed. Dacia, Cluj-Napoca
4. URECHE, V., 1987: „Universul Vol. II, Astrofizică”, Ed. Dacia, Cluj-Napoca
5. BORZA A., BOŞCANU N., 1965 – Introducere în studiul covorului vegetal. Ed. Academiei R. P.R., Bucureşti. P. 159
6. IDREA, 2007
7. VOICAN V., LĂCĂTUŞ V., 1998 – Cultura protejată a legumelor în sere şi solarii. Editura Ceres, Bucureşti.
8. MĂNESCU B., 1972 - Culturi forțate de legume. Ed. Didactică şi Pedagogică, Bucureşti.
9. MOHAN GHE., ARDELEAN A., 2004 – Dicționar enciclopedic de Biologie. Ed. ALL Educational, Timişoara.
10. ZAMFIRESCU N., VELICAN V., VALUȚA GH. 1956 – Fitotehnie. Vol. I, Ed. Agro-sivică de stat, Bucureşti.