ISSN-1224-3264

DIFFERENT HEAT SUM CALCULATION METHODS IN MAIZE PRODUCTION

Dénes Áron, Dorka
PhD, senior college lecturer
College of Nyíregyháza, H-4400 Nyíregyháza, Kótaji St. 9-11.

Maize production is of primary importance in the world, especially considering that its cultivation takes up one of the greatest ratios of land used for agricultural production. As a result, the number of farms where maize is not cultivated for either food production or foraging purposes is insignificant. For this reason, establishing economic production is of decisive importance when it comes to determining the efficiency of farms. Profitable maize production depends on a number of conditions, including the professional suitability of farmers, while some aspects of production are independent from these. Heat-sum calculations form a transition from this aspect, since temperatures ocuring during the growing season cannot be influenced by man. However, the method of calculation and evaluation and thus the tool to improve production is in the hands of the farmer. This scientific paper aims to give a special description of heat-sum calculation methods.

Keywords: *heat unit, photoperiod, solar radiation, base temperature.*

1. INTRODUCTION

The significance of maize is due to the fact that it is utilised for *direct human consumption*, as raw material in the food industry as a result of its high energy content and good digestibility. On the other hand, its utilisation as *animal forage* also has great significance. The whole plant is utilised as silo or green forage worldwide. Its significance is further increased by its *widespread industrial processing* and utilisation.

As a result of the above mentioned facts, making production efficient is of decisive importance to farms. The precise knowledge of climatic requirements for maize essential for profitable maize production. When considering *climatic conditions*, we have take into account that various climatic elements have different effects on the yield of maize *(Gilmore et al., 1958)*.

Regarding weather it can be concluded that maize can be mainly characterised by the following requirements: high amount of winter precipitation, which requires large water storages in the soil. Relatively high average temperature in April is required, which is a condition of early sowing and even, rapid germination. In May, high precipitation and relatively low temperatures and sunlight is favourable. In June, high sunlight length and temperature and relative low precipitation requirement is favourable. The optimal conditions of July and august are high precipitation, temperature and sunlight requirement. Warm, humid and wet weather favourably influences fertility and seed fixation. Optimal September is dry, and can be characterised by warm and sunny weather which promotes processes of assimilation, grain filling and ripening. Considering the above mentioned, it is clear that heat sum calculation plays an important role in maize production *(Mederski et al., 1973).*

2. APPLICATION AREA

During the 20. century, heat sum calculations were widely used for determining plant development rate and yield quantity *(Bonhomme, 2000).* However, calculations and actual yield quantities often differed from each other thus, the methods required continous development. Differences were due to both inaccurate calculations and both to different environmental conditions *(Wang, 1960).* Attention was mainly focused on making basis temperatures more accurate, which can be regarded as approximately zero for plant development or the upper threshold limit where development does not continue due to heat stress or where decaying starts. The global climate change that began during the 20-21. century, due to antropogen effects, has become more significant from the aspect of basis temperature and upper threshold temperatures as well as the formation of daily average temperature *(Ritchie et al., 1994).*

As a result, it is quite likely that climate borders will change in the future. The modeling of these processes will be of special significance from the aspect of future life conditions, opportunities and food provision of mankind since the cognition of harmful processes, extent and expected consequences can bring closer the solution and the possibility to live a more acceptable life on our planet.

Examinations and evaluations regarding these issues can be of great importance for Hungary as well since the Carpathian basin is located on the borders of wet oceanic, dry continental and meditarrenean, which is dry in the summer and wet in the winter, regions and this border zone can be especially sensitive to any small degree of climate change, since the change of climate zones can lead to the dominancy of one of the above mentioned climatic region.

The current nature of the topic and the outstanding influence on the Debrecen region is further emphasised by the fact that one out of the two specially sensitive regions of the country is the Great Plain while the other is the area of central and South Transdanubia.

3. RESEARCH COURSE AND METHOD USED

Nowadays, calculation methods can be grouped into three large sets:

- formulas using temperature data
- formulas using temperature and photoperiodic data
- formulas using temperature, photoperiodic and solar radiation

In our study we did not analyse formulas using temperature, photoperiodic and solar radiation data as well, with regards to the inconsistent database (significant data deficiencies) or the difficult comparison. Another problem was the data density, considering the difficulties caused by data deficiency. By choosing a month, we have selected the most appropriate and easiest to handle data density for evaluating heat sum calculation methods during a multiple step comparison. In the first step, we have calculated mathematical average from the data provided using the data of the above mentioned month, considering that average temperatures have outstanding significance in heat sum calculation methods. Evaluation was carried out at 3 levels, based on 1 soil temperature and 2 air temperature data sets. Altogether, we concluded that the values of the total 15 minute average, the 15 minute daily average and the normal daily average are the most reliable. In the second step we have examined the above mentioned results with cluster analysis as well. The SPSS has distinguished two groups. We compared the results with the calculations based on averages and found that the methods closer to the average of the average of the whole sample can be found in the second group. The hourly data density was the most outstanding from all the others. Based on these, we chose the hourly data density. We carried out the cluster analysis with different cluster element numbers and based on these we chose 15 minute daily average data density. This data density brought the most balanced results at all measurement levels. This data density has many advantages. It provides an ideal mean for suitable data separation and handling as well as for preventing possible errors, since it sets out minimum and maximum temperatures from each hour out of a separately calculated hourly average.

Then we selected the nine methods out of the 27 that we used to carry out calculations for the entire growing season. Firstly, we carried out the comparisons of the total daily heat sums calculation method and the special hourly calculation method for June and October months of 1997 at 0.5 m level. The selection of these two months was justified by the extreme values since these are the two months where the coldest and warmest days occur. Though July is hotter than June, the provided data are more unreliable since data deficiency for July of 1997 was greater than in June. Since there are no significant differences between the 2 months, we chose June.

Then, we carried out comparisons with both variance and cluster analysis. We selected identical ones from the clusters of June and October. Therefore, the following formulas were selected:

- Conventional average temperature, adjusted with basis temperature [1]
- Ontario heat sum calculation method [3]
- Stewart-type heat sum calculation method [4]
- Ritchie-type heat sum calculation method [5]
- Average temperature calculation method based on daily heat stress [9]
- Newman-type heat sum calculation method [16]
- Daytime average temperature hourly heat sum [25]
- Nighttime average temperature hourly heat sum [26]
- Daytime-nighttime average hourly heat sum [27]

The was followed by the weighting of the 9 selected formulas by using the Solver programme package.

During the solver optimisation, tha basic concept was to find out to what extent do heat sum values, calculated in the growing seasons, fluctuate according to the specific methods. The main objective during optimalisation was to minimise fluctuation values.

As the first step, we took all the heat sum values received with the 9 selected formulas in the growing season for 0.5 m level. We grouped them separately according to calculation methods.

Then we took the deviation and average of these values. Next we got their relative deviation by dividing the previously calculated deviation with the average. We carried this out with all 9 methods, then we received the 9 relative deviation values.

Subsequently calculating the average of the 9 relative deviations and we set this as an objective cell in the case of Solver. As a limiting factor we set $0<X<1$ interval and as a basic weighting we assigned 1 for each formula. Then, we divided each separately with the sums of values obtained during solver minimalisation, so their sums would be 1 which then provides the solution for weighing the 9 formulas when using them collectively.

After we calculated with each of the 9 algorithms, selected with the cluster analysis of June and October, the heat sums for all three levels of the growing period in all three years.

4. RESULTS AND CONCLUSIONS

We developed the weighting formula combination based on the weighting factors calculated for the entire growing season:

[1] * 0,12 + [3] * 0,06 + [4] * 0,13 + [5] * 0,12 + [9] * 0,07 + [16] * 0,12 + [25] * 0,06+ +[26] * 0,09 + [27] * 0,22

Based on the calculated values we concluded, that our assumption according to which the new formula combination is more accurate than any other algorithm from the 9 previously selected and analysed formulas proved to be right. We have received more precise values 11 times out of 81 measured and calculated heat sum values at 3 levels of 3 growing periods. Then we carried out a degree day analysis as well, which also provided more accurate results as well. Then based on the phenophase observations of 1997, we carried out a heat sum analysis and a leaf index evaluation as well.

The precise leaf number evaluation of examined maize hybrids was carried out 37 times in 1997. Thus we analysed the average leaf number changes of maize hybrids in the examined year of 1997, based on temperature values measured at 0.5 m. By using the 9 heat sum calculation methods, selected previously with cluster analysis, we calculated the heat sums up to the sample taking days and by dividing it with the average leaf number produced up to that day we received the temperature values required for the total development of a leaf. Then dividing their averages with the calculated heat sum values we calculated the accuracy of leaf number measurements according to calculation methods.

If we examine the results of formula combinations, optimised with the Solver programme, based on the differences between actual and calculated leaf number, it becomes clear that the weighted formula combination allows for a more precise prognosis than any other formula. It is also clear from the figure that the accuracy of the formula gradually decreases as the growing season progresses and deviations increase.

During the average 3 daily sample takings on all maize hybrids, the correlation between the observed average leaf numbers and the optimised formula combination can be regarded as high, at the same time it gradually decreases with the progress of physiological ripening (Fig.1.).

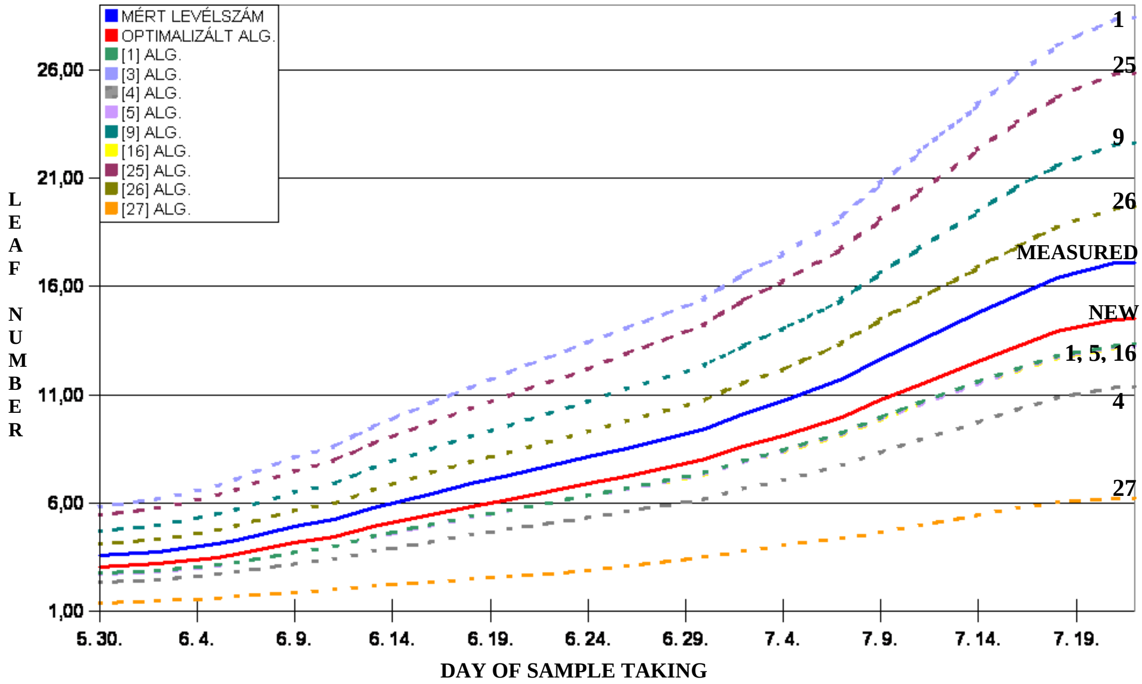

Fig. 1. **Comparison of measured and calculated leaf degree values (1997)**

5. FURTHER RESEARCH

The majority of prospects regarding climate change focus on the consequences inflicted by the warming atmosphere on the conditions of plant culture production. With the modification of general atmospheric circulation and the change in climate zones temperature and precipitation conditions also change. In specific areas we can expect increasing drought, and in other places wetter and more moderate climate. Therefore, the evaluation and analysis of future climate samples for example with General Circulation Models (GCM) are becoming more and more significant.

6. REFERENCES

Bonhomme, R. (2000) Bases and limits to using ‘degree.day units. European Journal of Agronomy, 13. 1-10.

Gilmore, E. C.-Jr., Rogers, J. S. (1958): Heat Units as a method of measuring maturity in corn. Agron. J., 50. 611-615.

Mederski, H. J. – Miller, M. E. – Weaver, C. R. (1973): Accumulated Heat Units for Classifying Corn Hybrid Maturity. 25. 182-197.

Ritchie, J. T.-NeSmith, D. S. (1994) Modelling Plant and Soil Systems. Agronomy, 31. 5-29.

Wang, J. Y. (1960): A critique of the heat unit approach to plant response studies. Ecology, 41. 785-790.