SOIL TEMPERATURE, MOISTURE MONITORING AND GROWIND DEGREE DAYS IN THE TRANSYLVANIAN PLAIN, IN ROMANIA

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ABSTRACT: The Transylvanian Plain, Romania is an important region for agronomic productivity. However, limited soils data and adoption of best management practices hinder land productivity. Soil temperatures of the Transylvanian Plain were evaluated using a set of twenty datalogging stations positioned throughout the plain. Soil temperatures were monitored at the surface and at 10, 30, and 50 cm depths, and soil moisture was monitored at 10 cm. Preliminary results indicate that most soils of the Transylvanian Plain will have a mesic temperature regime. However, differences in seasonal warming and cooling trends across the plain were noted. These have important implications for planting recommendations.

Growing degree days (GDDs) are preferred over maturity ratings, because they can account for temperature anomalies. The crop being considered for this study was corn. The base temperature (BT) was set at 10^{O}C, and the upper threshold was 30^{O}C. Two methods were used to calculate GDDs; 1) minimum and maximum daily temperatures, and 2) 24 h of averaged temperature data. Growing degree days were run from 110-199 day of year (DOY) to represent approximate planting date to tasseling. The DOY that 694 accumulated growing degree days (AGDDs) was reached at each site was then analyzed to identify differences across the TP. Three sites failed to reach 694 AGDDs by DOY 199, and were excluded from comparisons to other results. Averaged values were used to create spline interpolation maps with ArcMap 9.2 (ESRI, Redlands, CA, USA). The southeastern portion of the TP was found to tassel a month earlier assuming a planting date of 109 DOY. Four DeKalb® corn hybrids were then selected based on GDDs to tasseling, drydown, drought tolerance, and insect resistance. With a better understanding of the GDD trends across the TP, more effective planting and harvesting could be accomplished by Romanian farmers to maximize agronomic production.

Keywords: Soil temperature, Soil moisture, GDD, Transylvanian Plain

1. INTRODUCTION

Transylvanian Plain (TP), with an area of approx. 395,000 ha, has a predominantly agricultural character, and in the past, because of the large areas of agricultural land, with fertile soil, produced large quantities of grain, for economic and social needs of the country. Cereal and steppe character (or anthropogenic steppe) of the area, led to widespread of the popular term "plain", as over 30 villages, located in mid-southern region, wears, along with their name, the addition "plain". In time, however, because of rugged terrain, deforestation, fixation of the public lakes on quick slopes and irrational agrotehnics for the crops, large areas of productive agricultural land were turned into degraded land, with reduced productivy or unproductive. After Ministry of Agriculture and Rural Development of Romania data, about 1954 hectares of the Transylvanian Plain area, are aside agricultural production and tens of thousands of hectares are with productivity greatly reduced under the normal. Another feature of the TP is that, although it is lower than the surrounding region, no major river valleys, no major roads, do not converge to its center, but it surrounds it on the periphery. So it is a poor area in water resources, avoid by the heavy traffic, and so it partly explains its rural character and layout of cities around the edges (Rusu et al., 2009). The last research upon the evolution of the climate inside the Carpathian basin, pointed out an increase of the air temperature in the last one hundred years with about 0.7°C. This fact is also shown by the fact that, six of the warmest years of the 20th century were registered in 1990's. Contrary to its name, the TP is not a geographically flat plain, but rather a collection of rolling hills approximately 300 to 450 m above sea level in the south and 550 to 600 m above sea level in the north. Climate of the TP is highly dynamic, ranging from hot summers with high temperatures of >25°C to very cold winters with lows ~-5°C (Climate charts, 2007). The southern TP generally has a xeric moisture regime with steppe vegetation while moisture increases somewhat in the northern TP as an udic moisture regime.

However, near-surface temperatures have often been estimated from air temperatures, with little long term study and virtually no soil temperature data. The goals of this study are to: 1) characterize the soil resources and establish a network of datalogging stations to measure soil temperatures and moisture monitoring across the TP, 2) develop interpolated soil temperature regimes from collected data, 3) evaluate variables such as slope inclination and aspect which impact soil temperatures, and 4) make recommendations to farmers on optimal planting dates for seed germination of local crops.

2. MATERIALS AND METHODS

Twenty datalogging stations have been deployed across the TP on divergent soil types, slopes, and aspects. The location of each site was recorded using Garmin eTrex Vista (Olathe, KS, USA) handheld GPS units. Ten datalogging stations were installed in March of 2008, with an additional ten stations installed in March of 2009. HOBO Smart Temp (S-TMB-M002) temperature sensors and EC-5 (S-SMC-M005) moisture sensors were connected to HOBO Micro Stations (H21-002) at each site (On-set Computer Corp., Bourne, MA, USA). Additionally, at 10 of the 20 sites, tipping bucket rain gauges (RG3-M) were deployed (On-set Computer Corp., Bourne, MA, USA).

At sites with a tipping bucket rain gauge, the following data were recorded: soil temperature at 10, 30, and 50 cm; soil moisture at 10 cm; surface air temperature; and precipitation. At sites without a tipping bucket rain gauge, the following data were recorded: soil temperature at 10 and 50 cm; soil moisture at 10 cm; and surface air temperature. Data is downloaded from the Micro Stations every two months via laptop computer using HOBOware Pro Software Version 2.3.0 (On-set Computer Corp., Bourne, MA, USA). Table 1 shows the station configuration.

For this study, GDDs were run from approximately day of year (DOY) 110 to 199 to use available data from twenty datalogging stations to evaluate the mid-pollination GDDs of corn cultivars available from DeKalb®. The Baskerville-Emin (BE) and averaging method (AM) were calculated using 24 h temperature values collected at each station (BE-Full and AM-Full) and then recalculated using only the minimum and maximum values for each day (BE-M/M and AM-M/M), giving four different values; (1) BE-Full, (2) BE-M/M, (3) AM-Full, (4) AM-M/M. Baskerville-Emin was calculated using Eq. [1a] for 24 h data and Eq. [1b] for the minimum and maximum of each day. To calculate BE, Eqs. [1c1], [1c2], and[1c3] must be evaluated and the values placed in Eqs. [1a] and [1b] (Baskerville and Emin, 1969). The AM was calculated by Eq. [2] (Arnold, 1960).

$$\text{BE-Full} = \{[W * \text{Cos}(A1)] – [(BT – AVG_F) * ((3.14/2) – A1)]\}/3.14 \quad [1a]$$

$$\text{BE-M/M} = \{[W * \text{Cos}(A2)] – [(BT – AVG_{MM}) * ((3.14/2) – A2)]\}/3.14 \quad [1b]$$

$$A1 = \text{Arcsine } [(BT – AVG_F)/W] \quad [1c1]$$

$$A2=\text{Arcsine } [(BT – AVG_{MM})/W] \quad [1c2]$$

$$W = (MT – BT)/2 \quad [1d]$$

$$AMGDD = (MT – BT)/2 \quad [2]$$

Where AVG_F = the average temperature using the full days worth of temperature readings, AVG_{MM} = the average temperature using the minimum and maximum for the day, BT= base temperature, and MT= maximum temperature. The lower threshold was set at 10^oC, and the upper threshold was set at 30^oC, in case either the BT or MT was below or above, respectively. Outside of this temperature range, crop growth is limited.

Station number	Station name	Latitude	Elevation, m	Rain gauge
1	Balda (MS)	46.717002	360	No
2	Triteni (CJ)	46.59116	342	No
3	Ludus (MS)	46.497812	293	Yes
4	Band (MS)	46.584881	318	No
5	Jucu (CJ)	46.868676	325	Yes
6	Craiesti (MS)	46.758798	375	No
7	Sillivasu de Campie (BN)	46.781705	463	Yes
8	Dipsa (BN)	46.966299	356	Yes
9	Taga (CJ)	46.975769	316	No
10	Caianu (CJ)	46.790873	469	Yes
11	Cojocna (CJ)	46.748059	604	Yes
12	Unguras (CJ)	47.120853	318	Yes
13	Branistea (BN)	47.17046	291	Yes
14	Voiniceni (MS)	46.60518	377	Yes
15	Zau de Campie (MS)	46.61924	350	Yes
16	Sic (CJ)	46.92737	397	No
17	Nuseni (BN)	47.09947	324	No
18	Matei (BN)	46.984869	352	No
19	Zoreni (BN)	46.893457	487	No
20	Filpisu Mare (MS)	46.746178	410	No
MS = Mureş county; CJ = Cluj county; BN = Bistriţa-Năsăud county				

Table 1. Station configuration in the Transylvanian Plain, Romania

In 2009, temperature values were recorded at twenty datalogging stations by two different sensors. Ten stations without rain gauges (rain-) recorded air temperature using a 12-Bit Temperature Smart Sensor, while the other 10 (rain+) have a HOBO® Data Logging Rain Gauge (Onset Computer Corporation, Bourne, MA, USA). At the rain+ stations, temperature was recorded once every hour, while at the rain-stations, temperature was read every 2 min and a 10 min average was recorded. Both temperature sensors are within .5 m of the surface, which removes errors that could occur due to higher elevated air temperatures not accurately describing the vegetative microclimates (Roltsch et al., 1999). The temperature data was processed in Microsoft Access 2007 to produce the minimum, maximum, and average temperature for 110-199 DOY. The temperature values were then moved to Microsoft Excel 2007 to calculate the GDDs, using the above equations.

The accumulated growing degree days (AGDDs) of the four methods were analyzed to find the approximate day of tasseling based on a 694 AGDDs tassel date. The data was analyzed in SAS software (SAS Institute, 2008) using the LSD test to identify any differences between sites located across the TP. Finally, the data was georeferenced to station locations in

ArcMap 9.2 (ESRI, Redlands, CA, USA) to create spline interpolation maps showing the GDD trend across the TP.

3. RESULTS AND DISCUSSION

Calculation of soil temperature regime according to the Soil Survey Staff (2006) consists of averaging soil temperatures at 50 cm between summer (June, July, and August) and winter (December, January, and February). The Soil Survey Staff (2006) defines mesic soil temperature as a “mean annual soil temperature that is >8°C, but <15°C where the difference between mean summer and mean winter soil temperatures is more than 6°C at 50 cm or at a densic, lithic, or paralithic contact, whichever is shallower.” Year 1 data from sites 1-10 show that all sites have a mean annual soil temperature of ~10°C at 50 cm with more than 6°C variation between summer and winter. Thus, it appears as though mesic is the appropriate soil temperature regime for soils of the TP.

The TP has shown some growing season variability from initial GDDs data. Table 2 shows the LSD results for the DOY that 694 AGDDs were reached at 16 sites. Three sites failed to reach 694 AGDDs by 199 DOY; the last day of data currently available. Site 3 had no air temperature data due to datalogger error.

Site	Mean†
1	189.25
2	189.5
4	184.5
5	188.0
6	180.5
7	190.0
8	190.75
9	183.75
10	189.75
11	187.5
12	188.5
13	184.5
14	190.75
15	184.5
17	185.75
20	181
†LSD =	1.966

Table 2. Least significant difference test of the day of year each site reached 694 accumulated growing degree days, Transylvanian Plain, Romania (Haggard et al., 2010)

It was found that 694 AGGD were reached at 177 DOY while some sites had not reached the AGDD needed by 199 DOY. As such, sites 6 and 20 would tassel an entire month sooner than sites 8 and 14 on the plain, even with the same planting date. A slice was performed in ArcMap 9.2 (ESRI, 2006) with the same data that was evaluated in SAS using LSD, and split into 6 equal intervals (Fig. 1).

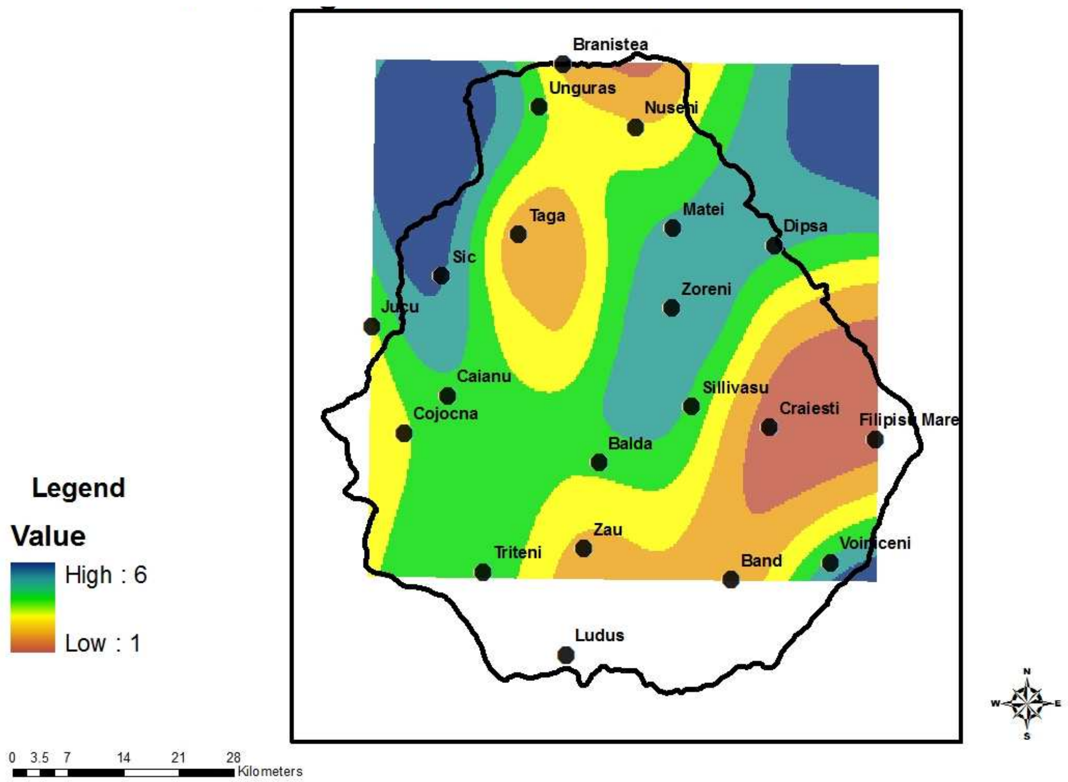

Figure 1. Sliced spline interpolation of AGDDs using 6 equal interval class breaks, Transylvanian Plain, Romania (Haggard et al., 2010)

The DOY when each site reached 694 AGDDs for BE-F and AM-F was interpolated using spline and then contours were made using the spline map outputs (Fig. 2 and 3).

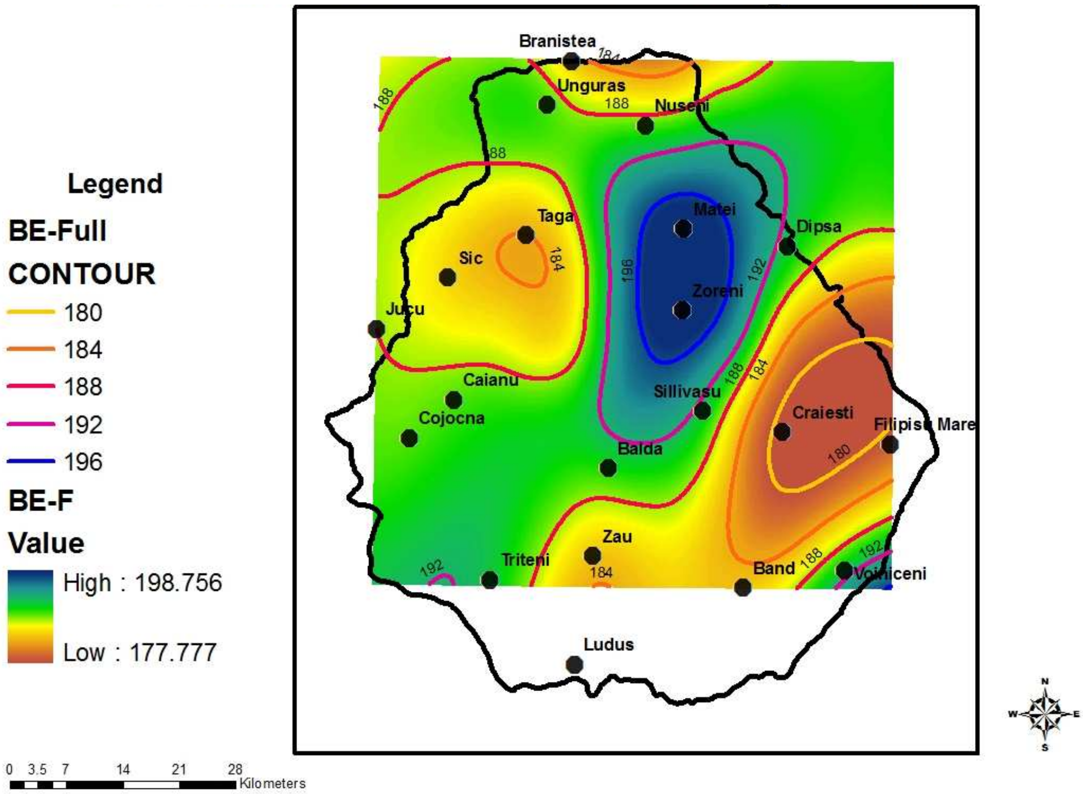

Figure 2. Spline interpolation of DOY that 694 AGDDs were reached using the BE-Full method, in the Transylvanian Plain, Romania (Haggard et al., 2010)

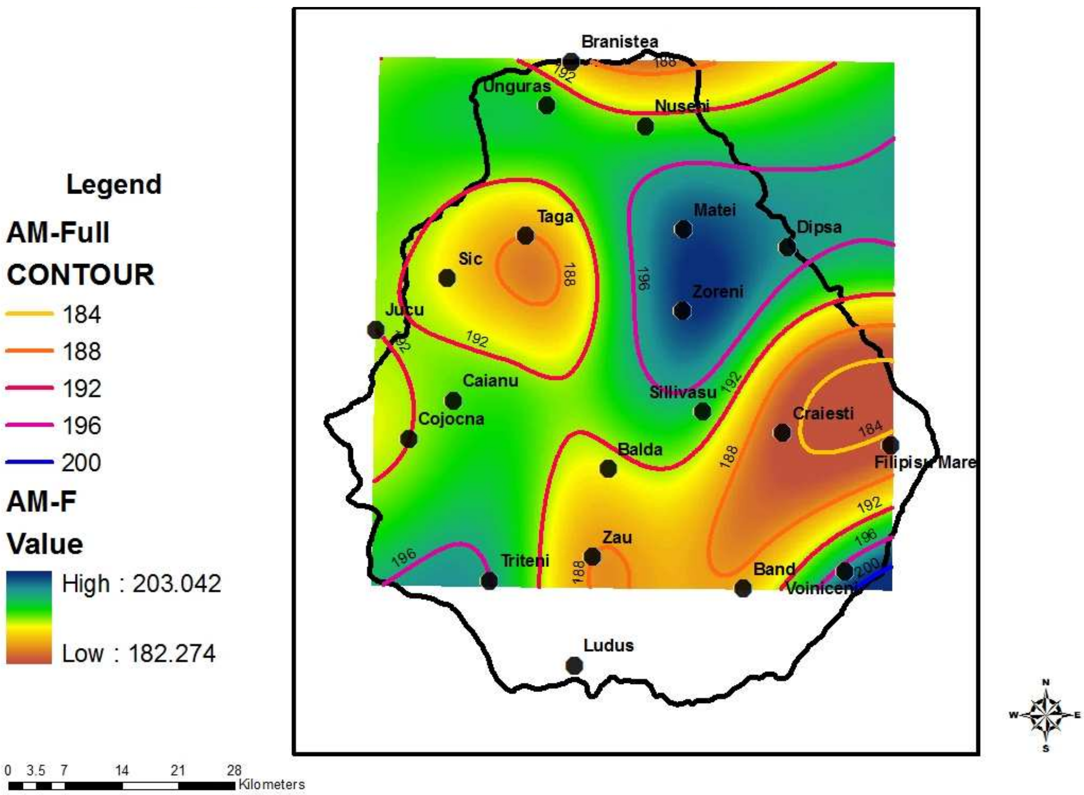

Figure 3. Spline interpolation of DOY that 694 AGDDs were reached using the AM-Full method, in the Transylvanian Plain, Romania (Haggard et al., 2010)

Table 3 shows some of the hybrids available from DeKalb® that would be suitable for the TP. The sites that accumulate GDDs faster were placed with hybrids that require more AGDDs to tassel.

DeKalb® Hybrid Brand	Site	Drydown†‡	AGDDs- till Tasseling‡	Relative Maturity‡	Drought Tolerance†‡
DKC52-45	6, 20, 4, 9, 13, 15	1	713	102	3
DKC52-59		1	711	102	2
DKC48-37	1, 2, 5, 7, 10, 11, 12, 17	2	679	98	3
DKC42-72	8, 14, 16, 18, 19	2	672	92	2

Table 3. Corn hybrid selection for sites based on drydown and drought tolerance (Haggard et al., 2010)

† Scale: 1-2 = Excellent, 3-4 = Very Good, 5-6 = Good, 7-8 = Fair, 9 = Poor

‡Obtained from 2010 Seed Resource Guide (Monsanto Co., 2009).

Growing degree days could be a very useful resource for farmers in the TP. This study was not intended to definitively determine the AGDDs within the plain, but to serve as a guideline for further research. The BE-Full and AM-Full are thought to be more accurate, since their average is making use of the full dataset of temperature. However, it is more common to see GDDs that have been calculated using minimum and maximum temperatures, due to the availability of data. The LSD test confirmed what the interpolated maps show: Craiesti and Filpisu Mare are the warmest areas based on 2009 summer data, allowing for an earlier planting date and harvest prior to the first killing frost. The ability to increase productivity throughout the plain, would not only be beneficial for the farmers, but also for Romania. By choosing the best hybrid for a certain area, yields could be increased by 620 to 3100 kg ha-1 (Roth, 1992). The corn hybrids that were selected (Table 3) were based on GDDs, drydown, drought tolerance, and insect resistance. Irrigation is practically nonexistent in the TP, making drought tolerance a key characteristic. Drydown is an important factor when evaluating corn hybrids in Romania because it becomes too expensive to use drying systems (Purcell, 2005). Roth (1992) suggested using a 10-day range in the relative maturity when comparing hybrids to account for any stress caused by weather events. Such stressful weather events are possible since August has a tendency to be very dry in Romania, limiting summer crop development before the harvest (Roth, 1992). In 2010, field truthing will be conducted in the TP to ascertain the most accurate method of calculating GDDs for the TP. Corn will be monitored at chosen stations to determine the most accurate GDD calculation based on tasseling and maturity. The fall temperatures will be used to determine the first killing frost across the TP.

4. CONCLUSIONS

Soil temperatures of the Transylvanian Plain, Romania were evaluated via twenty datalogging stations. Preliminary results from year 1 of the study indicate that the soil temperature regime will be mesic.

Growing degree days are a valuable resource in Romania with the ability to increase crop productivity. Significant differences in air temperatures exist across the TP. These differences need to be acknowledged when choosing the planting date to utilize the full growing season. DeKalb® hybrids were selected based on when 694 AGDDs were obtained at the stations and characteristics that are necessary for corn grown in the TP. Differences in air temperature across the TP are clearly evident in interpolation maps produced in ArcGIS 9.2 for 2009 data. Corn grown in the TP can be more productive with an increased knowledge of GDDs. Romania is known for many traditions, including the practice of farming the same way for generations. However, adoption of contemporary hybrids and agronomic practices holds the potential for increasing productivity on the TP.

REFERENCES

1. Ash, G.H.B., D.A. Blatta, B. Davies, B.A. Mitchell, R.L. Raddatz, C.F. Shaykewich, and J.L. Wilson. 1999. Agricultural climate of Manitoba [Online]. Available at http://www.gov.mb.ca/agriculture/climate/waa50s00.html (verified 25 Sept. 2009). Manitoba Agriculture-Food and Rural Initiatives, MB, Canada.
2. Arnold, C.Y. 1960. Maximum-minimum temperatures as a basis for computing heat units. Am. Soc. Hort. Sci. 76:682-692.
3. Baskerville, G.L., and P. Emin. 1969. Rapid estimation of heat accumulation from maximum and minimum temperatures. Ecology. 50:514-517.
4. Climate charts. 2007. Climate, global warming, and daylight charts and data for Cluj-Napoca, Romania [online]. Available at http://www.climate-charts.com/Locations/r/RO15120.php. Verified 26 May 2009.
5. Cox, W.J. 2006. Using the number of growing degree days from the tassel/silking date to predict corn silage harvest date. What's Cropping Up? [Online]. Available at www.css.cornell.edu/extension/WCU/Vol16No42006July-August.pdf (verified 2 Sept. 2009). Cornell University Cooperative Extension, Ithaca, NY.
6. ESRI. 2006. ArcGIS Desktop. Release 9.2. ESRI, Redlands, CA.
7. Haggard, B.J., D. Weindorf, H. Cacovean, T. Rusu, J. Lofton, 2010, Analysis of Growing Degree Days in the Transylvanian Plain, Romania. Studia Universitatis Babeş-Bolyai, Geographia, Anul LV, nr. 2/2010, pag. 13-20, Cluj-Napoca. ISSN: 1221-079x, ISSN v. online: 2065–9571, http://studia.ubbcluj.ro/serii/geographia/ index_en. html
8. Monsanto Co. 2009. 2010 Seed resource guide [Online]. Available at http://www.asgrowanddekalb.com/web/pdf/ products/2010_seed_resource_guide_north.pdf (verified 25 Sept. 2009). Monsanto Company, St. Louis, MO.
9. Purcell, B. 2005. Romania and Bulgaria: Crop travel confirms bumper winter and spring crops [Online]. Available at http://www.fas.usda.gov/pecad/highlights/ 2004/11/eu_travel_pt2/index.htm (verified 15 Sept. 2009). USDA-FAS-PECAD, Washington DC.

10. Roltsch, W.J., F.G. Zalom, A.J. Strawn, J.F. Strand, and M.J. Pitcairn. 1999. Evaluation of several degree-day estimation methods in California climates. Int. J. Biometeorol. 42:169-176.
11. Roth, G.W. 1992. Considerations for selecting corn hybrids in Pennsylvania [Online]. Available at http://cropsoil.psu.edu/extension/facts/agfact34.pdf (verified 24 Sept. 2009). Agronomy Facts 34, Penn State Cooperative Extension, Pennsylvania State University, University Park, PA.
12. Rusu, T., D. Weindorf, P.I. Moraru, H. Cacovean, V. Turcu, 2009. Soil and plant methods researches. Editure Risoprint Cluj-Napoca, Romania.
13. SAS Institute. 2008. The SAS system for Windows. Release 9.2. SAS Inst. Inc., Cary, NC.