EFECTUL EXTREMELOR TEMPERATURII AERULUI DIN ULTIMELE DOUĂ IERNI DIN ROMANIA, ASUPRA VIABILITĂȚII MUGURILOR DE ROD LA SPECIILE CAIS, PIERSIC ȘI CIREȘ

THE EFFECT OF THE EXTREME VALUES OF THE AIR TEMPERATURE FROM THE LAST TWO WINTERS IN ROMANIA ON THE VIABILITY OF THE APRICOT, PEACH AND SWEET CHERRY FLOWER BUDS

Chitu Emil[1], Paltineanu Cristian [2], Sumedrea Dorin [1], Butac Mădălina [1], Militaru Mădălina [1], Tănăsescu Nicolae [1], Sirbu Sorina [3], Jakab Zsolt [4], Petre Gheorghe [5], Caplan Ion [6], Iacobuta Gheorghe [7], Calinoiu Ion[8], Diaconu Aurelia [9]

[1] Research Institute for Fruit Growing Pitesti, Romania
[2] National Research Institute for Soil Science, Agrochemistry and Environmental Protection, Bucharest, Romania
[3] Research and Development Station for Fruit Growing Iasi, Romania
[4] Research and Development Station for Fruit Growing Bistrita, Romania
[5] Research and Development Station for Fruit Growing Voinesti, Romania
[6] Research and Development Station for Fruit Growing Constanta, Romania
[7] Research and Development Station for Fruit Growing Falticeni, Romania
[8] Research and Development Station for Fruit Growing Targu Jiu, Romania
[9] Research and Development Centre for Plant Growing on Sand Dabuleni, Romania

Abstract

From the climate factors, low temperature is one of the most important abiotic factor limiting growth, productivity and distribution of plants on Earth. The abilities of cold-hardy plants to resist de-acclimation during transient warm spells and to re-acclimate when cold temperatures return are significant for winter survival. The objective of this paper is to identify the episodes of frost stress during the dormancy period of fruit trees in recent years. Also, amid the general stagnation temperatures of winter, we want to draw an alarm signal on the negative impacts of climate change in Romanian orchards, manifested by the increased incidence of rapid succession of temperature extremes in the dormancy period, in the year winters 2014 -2015 and 2015 - 2016. To determine the flower bud's damages, the samples of annual braches from the upper and bottom third of the canopy were collected right after the climatic accident by the specialists of the Research Institute for Fruit Growing Pitesti, of the Research and Development Stations for Fruit Growing: Iasi, Bistrita, Voinesti, Constanta, Falticeni, Targu-Jiu and of the Research and Development Centre for Plant Growing on Sand in Dabuleni. The results showed that the apricot was the most affected species by climate accidents of the review period, especially in March, followed by peach and sweet cherry. Increased frequency of the extreme events, reported as a consequence of climate change, is a major risk factor for growing thermophilic species, or cultivars and rootstocks not adapted to the temperate - continental climate of Romania. To reduce the negative impact of these phenomena, it is necessary to rework the horticulture zoning based on models using Geographic Information Systems (GIS) by combining binary and suitability layers developed from the most important climatic and soil parameters, and with databases from the past 30 years or with forecasted data.

Cuvinte cheie: decălirea pomilor, rezistența la ger, cais, piersic, cireș
Keywords: fruit trees deacclimation, cold hardiness, apricot, peach, sweet cherry

1. Introduction

The international studies on the environmental impact on trees behavior are of great interest, because there are proofs about the climate change and CO_2 concentration level in air; there are, however, little information (Smith et al., 1996) on the future behavior of crops, specifically of perennials. Recent research of the Capstick et al. (2014), have identified several climatic influences which would increase the risks for Europe. Advancing trends in blooming dates of many tree species indicate that dormancy breaking processes are indeed changing, most likely in response to climate change (Guédon and Legave, 2008 and Legave et al., 2009).

Action to adapt to climate changes through an appropriate management of structure, rotation and technology of fruit crops require knowledge of regional and local characteristics of present and future climate and of assessment the associated risks. In the latest 50 years, according to the studies of the National Meteorology Administration (Bojariu, et al., 2015), the monthly average of air temperature exclusively presents growth trends, statistically significant over the whole Romania, during spring and summer. There are also rising trends of air temperature in the winter, for the central and north-eastern part of the country, but the percentage of stations showing significant trends is lower (Birsan and Dumitrescu, 2014). A gradual downward trend was also noted in the intensity of cold stress generated by minimum air temperatures below -15°C in the winter months, from 26 units of the "cold" in the 1961 to 1970 decade, to a range between 12 and 21 of "cold" units in the last four decades (1971-2010).

Chitu et al. (2015) found that in 1985-2014 period, the highest growth rate of both the maximum temperature and minimum one from all the months had been recorded in November, the trend (+1.3°C in ten years for maximum and 0.94°C for minimum) being statistically insured. It was also noted that if in the west and center part of the country, winters were becoming milder (temperature increase with more than 1.5°C per decade, even if the trend is not statistically assured). In the eastern and especially in the southern Romania in the last 30 years, lower temperatures by 0.1 to 0.8°C were recorded.

From the climate factors, the low temperature is one of the most important abiotic factors limiting growth, productivity and distribution of plants on Earth. Freezing temperature is a primary environmental stress, resulting in economic damage and limiting the distribution of horticultural crops (Parker, 1963). The abilities of cold-hardy plants to resist de-acclimation during transient warm spells and to re-acclimate when cold temperatures return are significant for winter survival (Kalberer et al., 2006). Yet compared to the volume of research on the biology of cold acclimation, relatively little is known about how plants maintain and/or reacquire cold hardiness in late winter and spring. De-acclimation and re-acclimation are highly dependent on exogenous and endogenous factors such as the ambient temperatures, water availability, photoperiod, energy budget and metabolism, growth and development, and the dormancy status of plants.

The ultimate survival of woody plants is dependent on not only the maximal capacity of cold hardening, but also on the timing and rate of both cold acclimation and de-acclimation, the stability of cold hardiness, and the ability to re-acclimate after unseasonably warm periods (Larcher 1968, Fuchigami et al. 1982). Hence, the successful performance of a woody species in a particular locality implies synchronization of the annual development of cold hardiness with the seasonal temperature changes.

Gusta and Wisniewskib (2013) shows that despite an exponential increase in our understanding of freezing tolerance, understanding cold hardiness in a manner that allows one to actually improve this trait in economically important crops has proved to be an elusive goal. This is partly because of the growing recognition of the complexity of cold adaptation. The ability of plants to adapt to and survive freezing temperatures has many facets, which are often species specific, and are the result of the response to many environmental cues, rather than just low temperature.

Pagter and Arora (2013) and Pagter et al. (2011), found that in association with the progressive increase in atmospheric CO_2, temperate and boreal winters are becoming progressively milder, and temperature patterns are becoming irregular with increasing risk of unseasonable warm spells during the colder periods of plants' annual cycle. Because de-acclimation is mainly driven by temperature, these changes pose a risk for untimely/premature de-acclimation, thereby rendering plant tissue vulnerable to freeze-injury by a subsequent frost. Thus, there is a greater need for cultivars that are adaptable to irregular changes in temperature, than for very hardy cultivars that tolerate extremely low temperatures. The authors concluded that relative to cold acclimation, de-acclimation is a little studied process.

According to Marini and Schupp (2016), from the Pennsylvania State Extension, “cold hardiness” is a vague and often misleading term because low temperature injury can vary depending on when the low temperatures occur (early vs. mid or late winter), how fast the temperature drops, what the temperatures were during the previous few days, and how long the low temperatures are sustained. For this reason, every cold event is fairly unique and a plant may be affected differently by different cold events.

Szymajda et al. (2014), found for peach in Poland that if during the winter there are spells of mild weather with the temperature rising above 4.4°C, the flower buds start accumulating growing degree hours. This means that the developmental processes in the flower buds have started and they are simultaneously losing their resistance to low sub-zero temperatures. Such a situation occurred in Central Poland during three winters 2010/2011 – 2012/2013). During the 2010/2011 winter the lowest air temperature (-22.3°C at a height of 2 m) was recorded on February 20, during the winter of 2011/2012 the maximum temperature drop (-23.3°C at a height of 2 m) was noted on February 3-4 and during the winter of 2012/2013 (-22.3°C at a height of 2 m) on 24 March.

Garcia (2001), from the Vermont University, has found that loss of hardiness can be very rapid if tissues are exposed to warm temperatures. For example, sweet cherry flower buds lost 5°C of hardiness when are exposed 4 hours at 24°C; 'Haralson' apple lost as much as 31°C of hardiness during one day, exposure to 21°C.

A summary of a survey of Pennsylvania apple orchards, published in the Proceedings for the American Society for Horticultural Science by Anthony, Sudds and Clarke (1936), described tree injury following a very rapid decline in temperatures in mid-January 1936. In general, trees that were most injured were those that lacked adequate vigor, those that were too vigorous, and those that had been pruned before the cold event. Trunk injury was greater than expected considering that the lowest temperature was only -24°C, but this was accompanied by a rapid drop of 25°C to 30°C.

The objective of this paper is to identify the episodes of frost stress during the dormancy period of some fruit tree species: apricot, peach and cherry in recent years. Also, amid the general stagnation temperatures of winter, we want to draw an alarm signal on the negative impacts of climate change in Romanian orchards, manifested by the increased incidence of rapid succession of temperature extremes in the dormancy period, in the years winters: 2014 -2015 and 2015 - 2016.

2. Material and methods

The experiment was carried out at Research Institute for Fruit Growing (RIFG) Pitesti, Maracineni, Arges County, in the winters between 2014-2015 and 2015-2016 years. We presented also, based on meteorological data National Meteorological Administration Bucharest, the thermal extremes emergence and rapid temperature oscillations country-wide. In the first case, thermal oscillation, which occurred between December 24, 2014 and December 31, 2014 - January 1, 2015 was analyzed. In the second case, the variation of air temperature was analyzed in two calendar periods: between 27 - 28 December 2015, and 1 January 2016 and from 11 January to 19 - 24 January 2016.

Climatic data used were collected for Maracineni, Arges County, by two automatic weather stations - WatchDog 2900ET (Spectrum Technologies, Inc.) and iMETOSag (Pessl Instruments), and for other localities from Romania by the National Meteorological Administration Bucharest (120 meteorological stations evenly distributed in the territory and representative of the entire area of Romania). The temperatures of air collected from the meteorological shelters, in the vicinity of experimental fields, at an interval of 10 minutes and a height of 2 m above the ground level, were used.

The daily mean values of temperature data of the three oscillations mentioned above were compared to a large database written in the Microsoft Office Excel program and consisting of 47 years (1969-2015) of daily weather data of Maracineni, southern Romanian station. Probabilities of the weather data mentioned above were computed using statistical function NORMDIST of Microsoft Office Excel.

To determine the flower bud's damages, the samples of annual braches from the upper and bottom third of the canopy were collected right after the climatic accident by the specialists of the Research Institute for Fruit Growing (RIFG) Pitesti, of the Research and Development Stations for Fruit Growing (RDSFG): Iasi, Bistrita, Voinesti, Constanta, Falticeni, Targu-Jiu and of the Research and Development Centre for Plant Growing on Sand (RDCPGS) Dabuleni. These were stored in the laboratory (18°C) for 1 week to activate the enzymatic processes and make evident the damaged tissues. The viability of the flower buds (50 buds for the upper third of canopy and 50 for the bottom) was determined by cross cutting according to the methodology presented by Larsen (2010).

3. Results and discussions

The dynamics of the air temperature of the two winters and the damage caused is presented separately for each calendar year in part.

3.1. The effect of the extreme values of air temperature from December 2014 to January 2015

As shown in Figures 1 and 2 for Maracineni, Arges county, the lowest air temperatures were recorded in a very short time after a prolonged period of very high temperatures occurred between 12 and 25 December 2014.

Thus, between 12 and 25 of December, the probability of the minimum air temperatures has exceeded 90 % in 10 days from a total of 14 days (Figure 1), and in 7 days was above 95% (higher values can be recorded only once in 20 years). Also in 6 days out of 14, the probability of the average temperature of the air has been over 80%, and in two days (23 and 24 December) 99 % (only once in 100 years may be recorded higher values). It should be observed in figure 2, that in only 7.7 days from the maximum of up to 17.9°C, recorded on 24 December, the minimum air temperature at 2 m from ground level has reached the -21.3°C and at the surface of the snow to -26.2°C.

The trees de-acclimation from middle of December 2014, was favored by the completion of the minimum amount of chilling hours required by endodormancy for apricot, peach and sweet cherry, approximately 616 hours until 15 December (according to SpecWare 9.0 Pro software), hourly temperatures between 0 and 7°C. With this software, chilling hours are calculated as the amount of time spent below 7°C and above 0°C. From the specialized literature (Allan 1999, Mahmood et al., 2000, Garcia, 2001, Dennis, 2003) chilling requirements for the apricot are between 300 and 600 hours, for peach between 400 and 700 and for sweet cherry between 500 and 1300 hours, according to cultivars). When the minimum chilling requirement has been satisfied, trees begin to lose the ability to re-acclimate to hardiness levels obtained earlier in the winter, and may only partially re-acclimate.

Under the conditions of the completion at Maracineni, Arges County, of this huge temperature amplitude of 39.2°C (figure 2) in only 7.7 days, the flower buds of the apricot trees cultivars were affected in a percentage of more than 95 (94-98.5 % in the cultivars Valeria, Carmela, Viorica, Rares and Dacia). The flower buds of peach trees were also affected in a percentage which varies between 20 and 43 % according to cultivar (Collins, Red Haven, Southland, Springold, Triumf and Filip), a percentage not affecting the level of yield. Some cultivars of cherry being more sensitive to cold (Skeena, Ferrovia and Kordia) also suffered losses between 16 and 44%, without reducing fruit yield either. Significant damages in apricot and peach orchards also occurred in the south-west area of Romania on sandy soils (Corabia agrometeorological station, where the minimum air temperatures of -23°C were recorded on 01.01.2015), in bearing orchards, only in restricted areas, where the microclimate favored accumulation and stagnation of cold air.

In other areas of the country, following the analysis carried out on branches harvested at mid-January (flower buds in a state of ecodormancy) by the specialists of research and development stations for fruit growing (RDSFG), there were no significant damages reported. So at RDSFG Bistrita at minimum temperatures of -12.4°C in the last five-day period of December and at -18.2°C in the second 10-day period of January, there were no damages; at RDSFG Constanta at minimum temperatures of -10.4°C in the first interval and -16.1°C in the second, the apricot and peach damages were below 15 %; at RDSFG Cluj there were no damages; at RDSFG Iasi at minimum temperatures of -16.0°C at the end of December and -18.5°C at mid-January there were no damages; at RDSFG Voinesti at minimum temperatures of -20.0°C in December and -19.6°C in January, there were no damages, and at RDSFG Targu-Jiu at -22.2°C in the first interval and -22.8°C in the second there were no damages.

3.2. The effect of the extreme values of air temperature from December 2015 – January 2016 and February – March 2016

December 2015 – January 2016

After Sandu and Mateescu (2016), December 2015 has been on average for Romania, the second hottest month out of all Decembers after 1979, recording average values by 2.1ºC up to 2.9ºC higher than multiannual values (1961-2015). The month of January 2016 also presented mean temperatures by 3.6ºC to 1.5ºC lower than normal values.

In the winter between the years 2015-2016, the lowest minimum temperatures (below -15°C) occurred in two waves of cold: in the first five-day interval of January - the first wave (figure 6), and in five-day interval five and four of the same month, the second wave (from 19 up to 24 January, wave which persisted for more time, especially in the southern part of Romania, figure 8). However, the lowest air temperatures (recorded in the days of 19-20 and 24 of January 2016) fell by only 1-3°C below -20°C, not reaching the critical level of -24°C for apricot orchards (figure 8).

The explanation of the large flower bud's losses for this species, especially in the Southern part of Romania, could be in the fact that resistance to frost of the trees was greatly reduced (de-acclimation) due to the hot periods (figures 3, 4 and 5) that preceded the two cold waves (figures 6 and 8), and in particular by the sudden appearance of minimum temperatures below -15°C (figure 4), within only a few days (3-8). At the whole country scale, the temperature differences between the maximum temperatures of 27 December 2015 and the minimum temperatures of 1-3 January 2016 interval were very high, ranging from 18 to 32°C, depending on the region (figure 7). The biggest differences (over 30°C) occurred in the Getic and Curvature Subcarpathians, Getic Plateau and in the northern and central Moldavia. The lowest thermal stress (differences below 18°C) occurred in the western and northern Transylvanian Plateau and in the Western Plain.

In parallel, an area located on the eastern Getic Plateau, centered on Maracineni village in Arges County was in more detail analyzed, where there were temperature differences between the maximum values of 27 December 2015 and the minimum of 1 January 2016, as much as above 32°C (34.6°C, figure 4). Analyzing the dynamics of the daily air temperatures from Maracineni, using the absolute values (figure 4) and the daily probabilities (figure 3), it was found that the appearance of the first cold wave in 30 December 2015 - 4 January 2016 period was very similar to the dynamics of the temperatures from the previous year.

Air temperatures dropped sharply after a very warm period between December 20 to 28, which caused trees de-acclimation (especially in apricot, peach and cherry), and then the minimum temperatures remained below -10°C for another 4 days. It may be noted in figure 3, that in only 3.7 days apart from maximum temperatures of up to 19.7°C, registered on December 28, the air temperature dropped by 34.6°C, reaching 14.9°C on the first of January 2016.

Also in the same location, in the second wave of sudden cooling of the weather, between 11 (13.8°C) and 20 January (-17.3°C), the air temperature dropped by 31.1°C into a period of only 8 days (figure 4). This time, low temperatures (-15°C) occurred over a longer duration, a week, especially in the southern part of Romania (figure 8).

February – March 2016

Another stress factor, this time from the ecodormancy period, was the very high air temperature of February 2016. For Maracineni, Arges County location, the monthly mean temperature of the air was 5.7°C, being by 5.5°C above the multiannual mean (0.2°C between 1969-2015). The probability of this monthly temperature was 98.1%, being the highest values able to occur only once in 53 years.

Moreover, according to National Meteorological Administration Bucharest, in many areas of the country, the average temperature deviation from the period of 1981-2010 exceeded 6°C (especially in Transylvania and in the northwest and southeast part of Romania). Under these circumstances for many fruit tree species, the growing season started in late February. For apricot and peach, the onset of flower bud bursting and flowering were triggered by 7-10 days earlier than normal. Therefore, frosts in the range of 17 to 21 March (figures 9 and 10) found the apricot in blooming period (BBCH 65, according to Hack et al., 1994) and peach in pink petals (BBCH 57). Most damages recorded in this period occurred in apricot species.

Thanks to the two critical periods, first by de-acclimation of fruit trees and then by freezing the flower buds in January, in two mild weather spells followed by cold waves episodes, and the second by affecting the flowers by late frosts from 17-21 March, the damages were treated separately for each climatic accident. Following the analysis carried out in the Mid-January and in the third 10-day period of March, by the researchers of RIFG Pitesti and of RDSFG Baneasa, Bistrita, Constanta, Iasi, Falticeni, Targu Jiu, Voinesti and RDCPGS Dabuleni, damages were reported for the main fruit species, as follows:

Apple damages did not occur in any area of the country;

For pear, no significant damages occurred in any area of the country. However, some losses (below 30%) occurred by affecting the buds in the phase of bud burst (BBCH 53) for some cultivars (Red William fruit trees debilitated due to temporary excess of soil moisture in autumn 2015), in the southern county of Arges (Stolnici station);

For plum, damages occurred only at the RDCPGS Dabuleni (50%) and at RDSFG Bistrita (10%) due to frosts in the bud burst phenophase. serious damage (70-80%) occurred in the southern county of Arges by freezing in January due to the closed fruit buds (BBCH 51) of the trees from orchards in decline (Tuleu gras and Carpatin cultivars).

In sweet cherry, there were higher damages by freezing during the dormant flower buds in January at RIFG Maracineni, cultivars grafted on GiSeLa 5 (Ferrovia 73%, Skeena 60%, Kordia 28% and Daria 34%) and at RDSFG Falticeni damages below 21%. Due to the action of late frosts in the phenophase of bud burst (BBCH 51) 30% of fruit buds were affected at RDCPGS Dabuleni and in the bud swelling stage (BBCH 51) at RDSFG Bistrita (between 5 and 35% damages);

In sour cherry, there were only small damages (10%) due to late frosts from March, in the phenophase of bud burst (BBCH 53);

In peach trees, fruit buds loss due to January frosts were recorded at RDCPGS Dabuleni (35%) and at Maracineni in a very small percentage (14%). There were significant damages (up to 100%) in declining trees from the southern part of Arges County (Stolnici). Also, there were great damages in March due to late frosts at RDSFG Voinesti (60%) and at RDCPGS Dabuleni - 60% of flower buds in the phase of pink button (BBCH 57). Damages much lower (under 20%) were reported at RDSFG Constanta for some cultivars (Springcrest, Cardinal, Redhaven and Southland) occurring in the phenophase of beginning of flowering (BBCH 61);

In nectarine, there were smaller losses, below 15% at RDSFG Baneasa and Constanta;

The apricot was the most affected species by climate accidents of the review period, especially in March. As much as 50% of flower buds died in January at RDCPGS Dabuleni, but only less than 12% and 4% at RDSFG Baneasa and Constanta, respectively. Due to late frosts, 95% of apricot flowers were affected at RDSFG Voinesti (BBCH 65), between 80 and 95% at RDSFG Constanta and Iasi, between 70 and 80% and 42% at RDCPGS Dabuleni.

In quince and walnut were not reported losses.

4. Conclusions

The experiment was carried out at RIFG Pitesti, Maracineni, Arges County in the winters between 2014-2015 and 2015-2016 years. We presented also, based on meteorological data National

Meteorological Administration Bucharest, the thermal extremes emergence and rapid temperature oscillations country-wide. In the first case thermal oscillation occurred between December 24, 2014 and December 31, 2014 - January 1, 2015. In the second case the variation in air temperature was analyzed in two periods: between 27 - 28 December 2015 and 1 January 2016, and from 11 January to 19 - 24 January 2016.

Between 24 and 31 of December 2014, during only 7.7 days, from the maximum of up to 17.9°C, recorded on 24 December, the minimum air temperature at 2 m height from ground level reached -21.3°C and at the snow surface -26.2°C. Under the conditions of the completion at Maracineni, Arges County, of this huge temperature amplitude of 39.2°C, the flower buds of the apricot trees cultivars were affected in a percentage of more than 95 (94-98.5 % in the cultivars Valeria, Carmela, Viorica, Rares and Dacia).

In the winter between the years 2015-2016, thanks to the two critical periods, first by de-acclimation of fruit trees and then by freezing the flower buds in January, in two mild weather spells followed by cold waves episodes, and the second by affecting the flowers by late frosts from 17-21 March, the damages were treated separately for each climatic accident.

The apricot was the most affected species by climate accidents of the review period, especially in March. As much as 50% of flower buds died in January at RDCPGS Dabuleni, but only less than 12% and 4% at RDSFG Baneasa and Constanta, respectively. Due to late frosts, 95% of apricot flowers were affected at RDSFG Voinesti (BBCH 65), between 80 and 95% at RDSFG Constanta and Iasi, between 70 and 80% and 42% at RDCPGS Dabuleni. In the descending order of the damages suffered, the apricot was followed by peach and sweet cherry.

Increased frequency of the extreme events, reported as a consequence of climate change, is a major risk factor for growing thermophilic species, or cultivars and rootstocks not adapted to the temperate - continental climate of Romania. To reduce the negative impact of these phenomena, it is necessary to rework the horticulture zoning based on models using Geographic Information Systems (GIS) by combining binary and suitability layers developed from the most important climatic and soil parameters, and with databases from the past 30 years or with forecasted data.

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References

1. Allan, P., 1999. Measuring winter chilling in areas with mild winters. Deciduous Fruit Grower 49(10): S1-S10.
2. Anthony, R.D., Sudds, R.H. and Clarke, W.S., 1936. Low temperature injury to orchards in. Pennsylvania and adjoining states in the fall and winter of 1935-36
3. Birsan, M.V., Dumitrescu, A., 2014. ROCADA: Romanian daily gridded climatic dataset (1961-2013) V1.0. Administrația Națională de Meteorologie, București, Romania, doi: 10.1594/PANGAEA.833627.
4. Bojariu, R., Bîrsan, V.M., Cică, R., Velea, L., Burcea, S., Dumitrescu, A., Dascălu, S.I., Gothard, M., Dobrinescu, A., Cărbunaru, F., Marin, L., 2015. Schimbările climatice – de la bazele fizice la riscuri și adaptare. Editura Printech, București, ISBN 978-606-23-0363-1, 200 pp.
5. Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N. and Upham, P., 2014. International trends in public perceptions of climate change over the past quarter century. Wiley Interdisciplinary Reviews: Climate Change.
6. Chitu, E., Sumedrea D., Mateescu E., Tănăsescu N., Septar L., Corneanu G., Platon I.V., Petre Gh., Răţoi I., Păltineanu Cr., Jakab-Ilyefalvi Z., Petre V., Sumedrea M., Cristian M.F., Iancu M., Duţu I., Mazilu Cr., Ancu S., Butac M., Cârdei E., Corneanu M., Sârbu S., Iurea E., Beșleagă R., Croitoru M., Nicolae S., 2014. Tehnologii pomicole şi modele inovative de limitare a impactului negativ al schimbărilor climatice. Editura Invel Multimedia, ISBN: 978-973-1886-89-3, 175 p.p.
7. Chitu, E., Giosanu D., Mateescu E., 2015. The Variability of Seasonal and Annual Extreme Temperature Trends of the Latest Three Decades in Romania. Agriculture and Agricultural Science Procedia. Volume 6, 2015, doi:10.1016/j.aaspro.2015.08.113, pages 429–437.
8. Dennis, Jr. F. G., 2003. Problem in standardizing methods for evaluating the chilling requirements for the breaking of dormancy in buds of wood plants. HortScience. 38: 347-350.
9. Fuchigami, L.H., Weiser, C.J., Kobayashi, K., Timmins, R. & Gusta, L.V. 1982. A degree growth stage (ºGS) model and cold acclimation in temperate woody plants. In: Li, P.H. & Sakai, A. (eds.). Plant

cold hardiness and freezing stress. Vol. 2. New York, Academic Press. p. 93-116.
10. Garcia, M.E., 2001. Cold Hardiness of fruit trees in Vermont. Acrobat Distiller 4.05 for Windows presentation. http://www.uvm.edu/~fruit/treefruit/tf_horticulture/ColdhardinessoffruittreesinVT.pdf
11. Guédon, Y. and Legave, J.M., 2008. Analyzing the time-course variation of apple and pear tree dates of flowering stages in the global warming context Ecol. Model, 219 (2008), pp. 189–199.
12. Gustaa, L.V. and Wisniewskib, M., 2013. Understanding plant cold hardiness: an opinion. Physiologia Plantarum 147, ISSN 0031-9317: 4–14.
13. Hack, H., Gall, H., Klemke, Th., Klose, R., Meier, U., Stauss, R., Witzenberger, A., 2001. Growth stages of mono-and dicotyledonous plants. BBCH Monograph. 2. Edition, 2001. Federal Biological Research Centre for Agriculture and Forestry. Edited by Uwe Meier. 158 p.p.
14. Kalberera, S.R., Wisniewskib, M., Aroraa R., 2006. Deacclimation and reacclimation of cold-hardy plants: Current understanding and emerging concepts. Plant Science. Volume 171, Issue 1, July 2006, Pages 3–16.
15. Larcher, W. 1968. Die Temperaturresistenz als Kostitutionsmerkmal der Pflanzen. Deutsche Akademie für Landwirtschaftswissenschaft, Berlin, Tagungsberichte 100: 7-21.
16. Larsen, H.J., 2010. Evaluating Tree Fruit Bud & Fruit Damage from Cold. Trees & Shrubs no. 7.426.
17. Legave, J.M., Giovannini, D., Christen, D., Oger, R., 2009. Global warming in Europe and its impacts on floral bud phenology in fruit species. Acta Hortic., 838 (2009), pp. 21–26.
18. Mahmood, K., Carew, J. G., Hadley, P., and Battey, H., 2000. Chill Unit models for the sweet cherry cvs. Stella, Sunburst and Summit. J. Hort. Sci. and Bio. 75: 602-606.
19. Marini, R. and Schupp, J., 2016. Cold Hardiness of Fruit Trees. Tags: Pomology, Young Growers. Posted: January 14, 2016.
20. Pagter, M., Arora, R., 2013. Winter survival and deacclimation of perennials under warming climate: physiological perspectives. Physiol Plant. 2013 Jan;147(1):75-87. doi: 10.1111/j.1399-3054.2012.01650.x. Epub 2012 Jun 23.
21. Pagter, M., J. F. Hausman and R. Arora. 2011. Deacclimation kinetics and carbohydrate changes in stem tissues of Hydrangea in response to an experimental warm spell. Plant Sci. 180: 140–148.
22. Parker, J. 1963. Cold resistance in woody plants. Bot. Rev. 29: 123–201.
23. Sandu, I. and Mateescu E., 2016. Tendințe în evoluția regimului climatic în România – analiza la nivel regional și sezonier. Prezentare la „Dezbaterea națională - Fenomene climatice extreme (II), Impactul acestora în agricultură și silvicultură”, desfășurată la ASAS București pe 27 oct. 2016.
24. Shaw, C., Bulkeley, H., Caney, S., Newell, P., Pidgeon, N., Shove, E., Turner, K., 2014. 14. Moving the climate debate forward: Re-thinking rights, risks and responsibilities.
25. Szymajda, M., Zurawicz, E., Sitarek, M., 2014. Freezing injuries to flower buds after three winters (2010/2011 – 2012/2013) and their influence on yielding in different Peach (*Prunus persica* (L.) BATSCH.] genotypes. 10th International Plant Cold Hardiness Seminar - Stress recognition triggers plant adaptation. 17-21 August 2014, Kornik – Poznan.

Figures

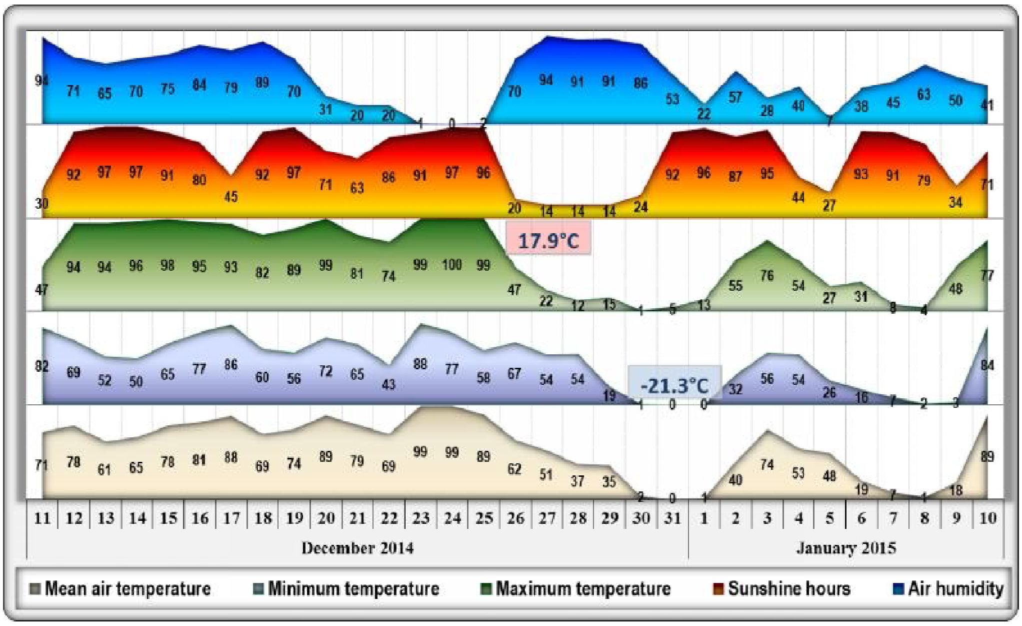


Fig. 1. The Probability (%) of recording daily values lower than those specific to the period December 11, 2014 - January 10, 2015, at Maracineni, Arges County (1969-2015)

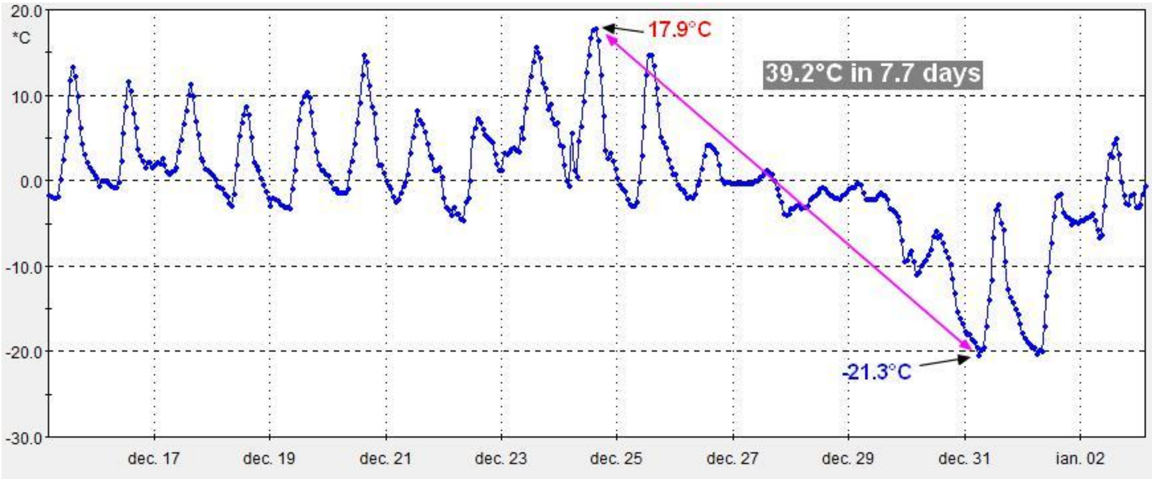


Fig. 2. The dynamics of the air temperature at 2 m from ground level in the range of 15 December 2014 - January 2, 2015 at the weather station Maracineni, Arges County.

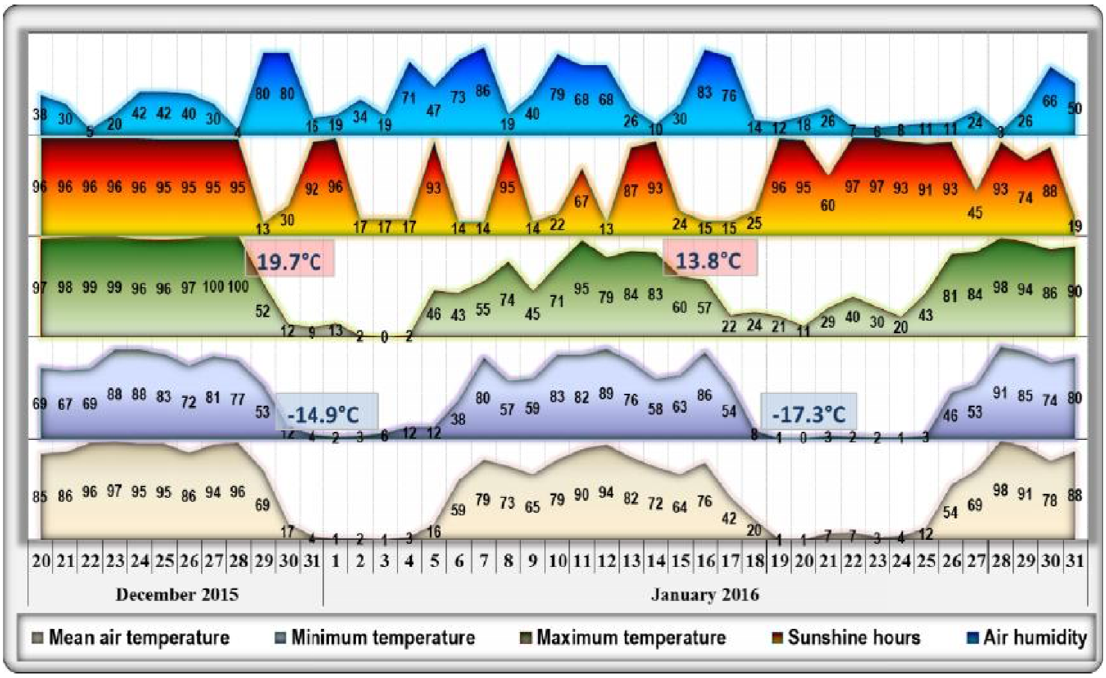
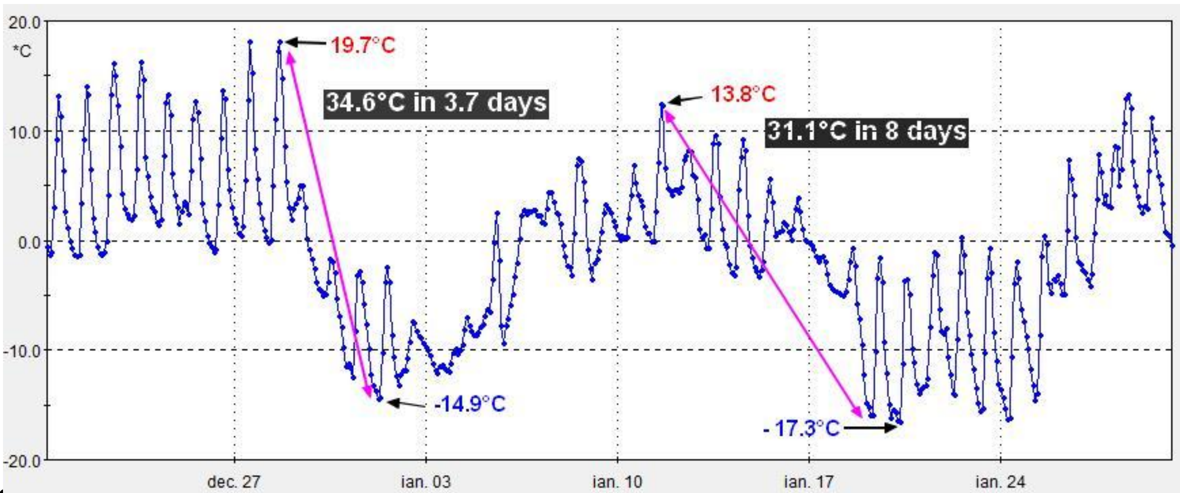


Fig. 3. The Probability (%) of recording daily values lower than those specific to the period December 20, 2015 - January 31, 2016, at Maracineni, Arges County (1969-2015)



Fi… ds of apricot tree, peach and sweet cherry at Maracineni, Arges County (20 December 2015 - 31 January 2016)

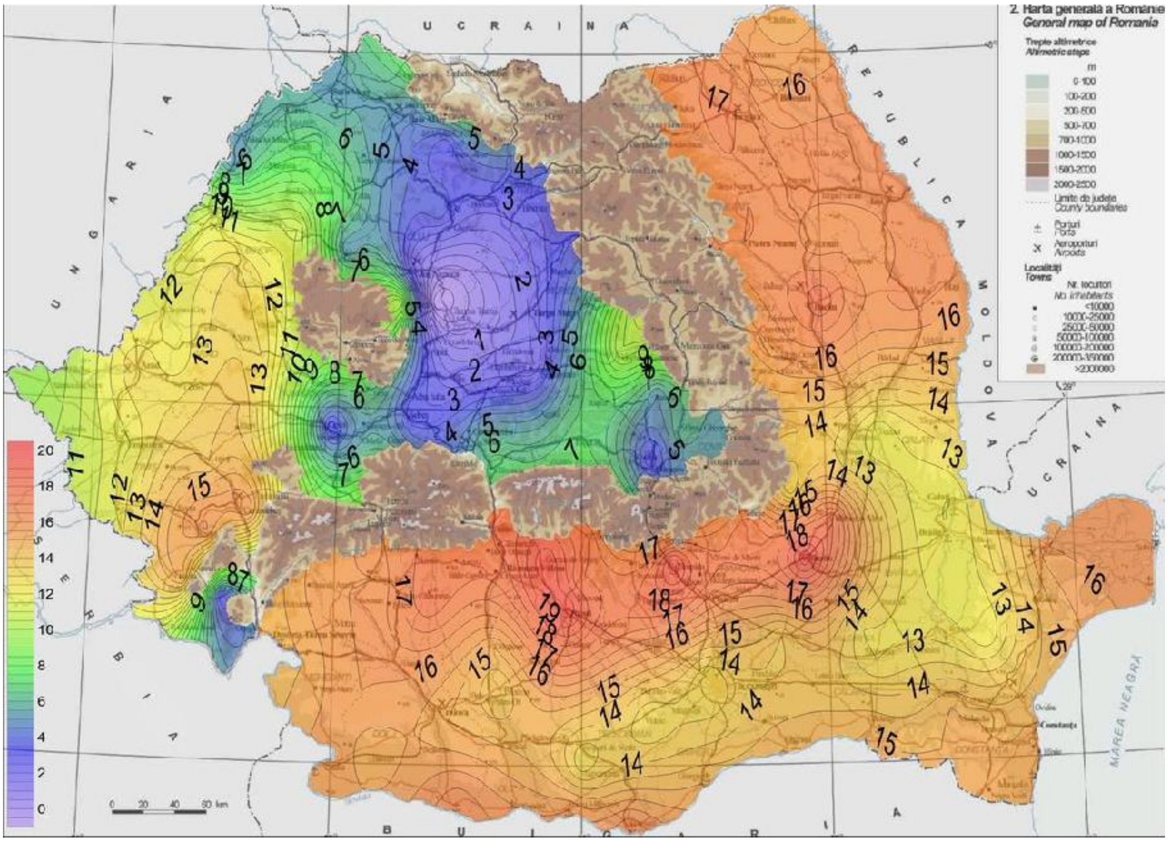


Fig. 5. The maximum air temperatures of 27 December 2015 (Surfer 9.0 software cartogram - kriging interpolation data after 120 meteorological stations of ANM Bucharest)

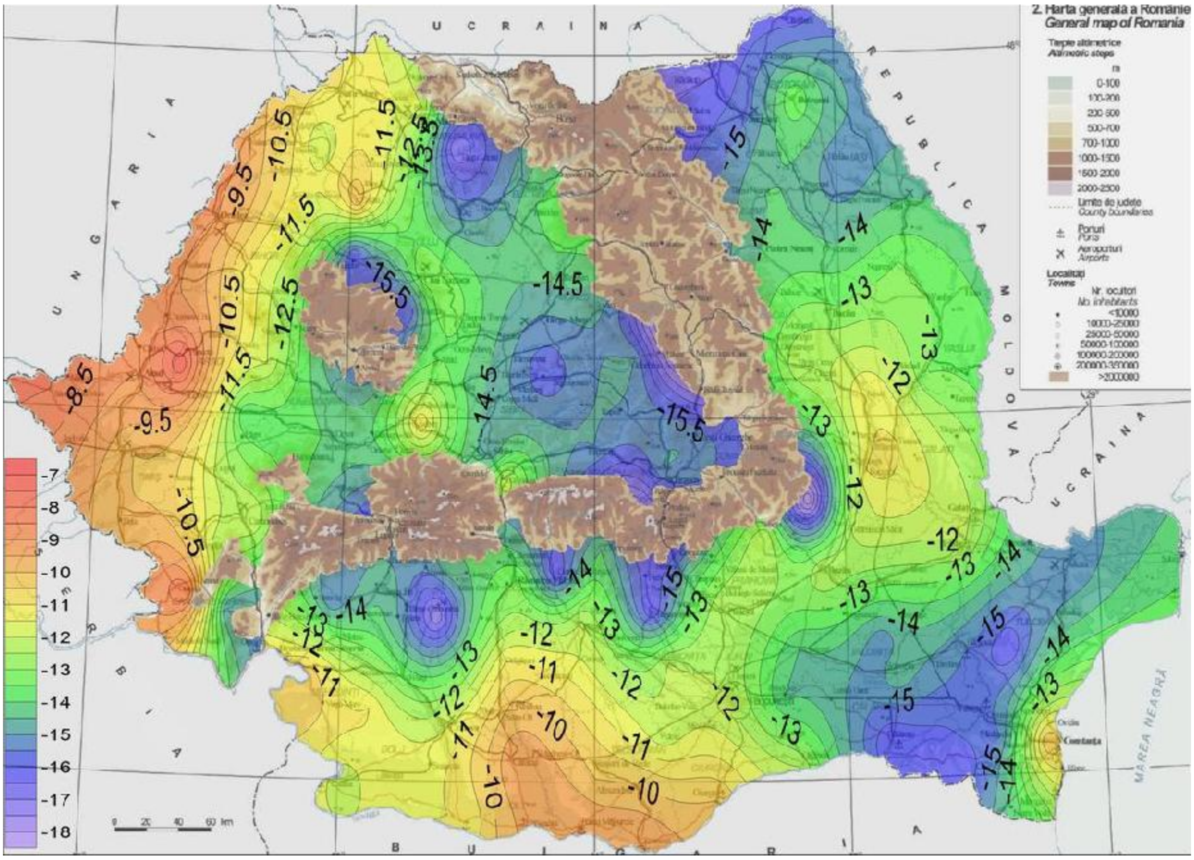


Fig. 6. The minimum air temperatures from 1 to 3 January 2016 days (Surfer 9.0 software cartogram - kriging interpolation data after 120 meteorological stations of ANM Bucharest)

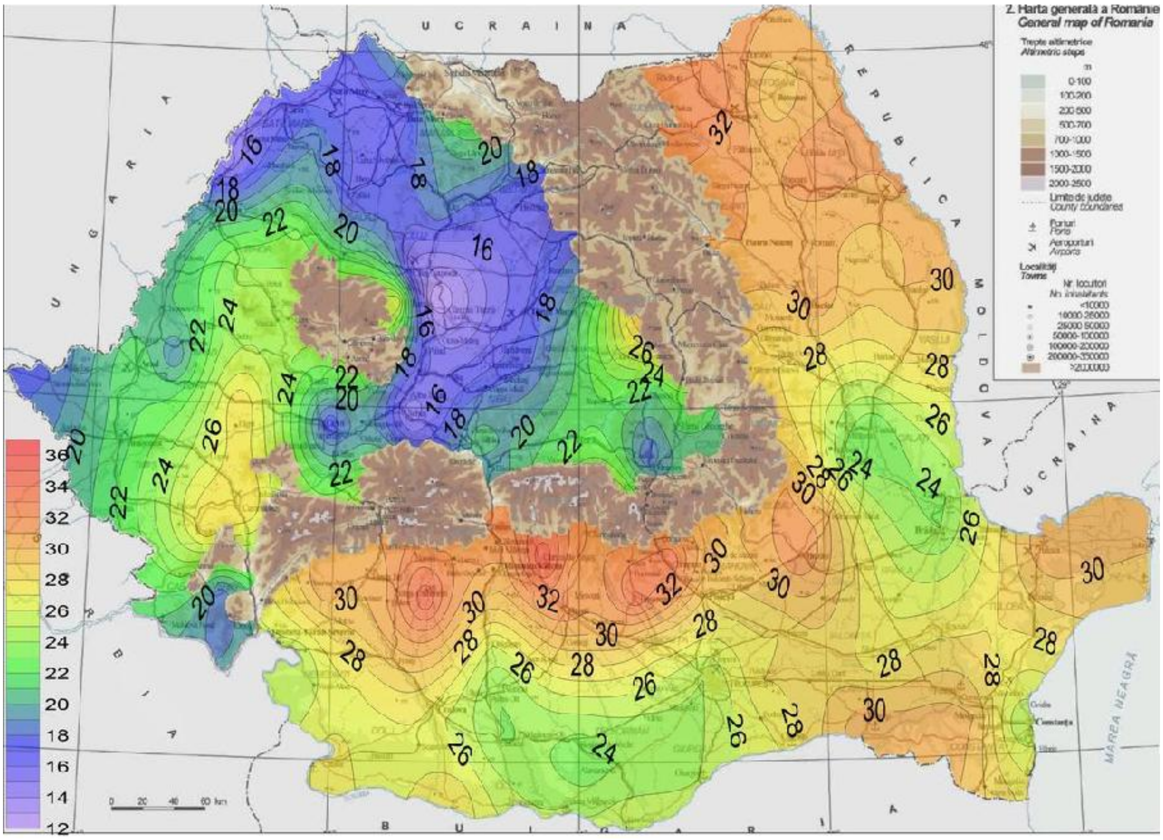


Fig. 7. Spatial distribution of the difference in air temperature (°C) between December 27, 2015 and January 1 to 3, 2016 in Romania (Surfer 9.0 software cartogram - kriging interpolation data after ANM Bucharest)

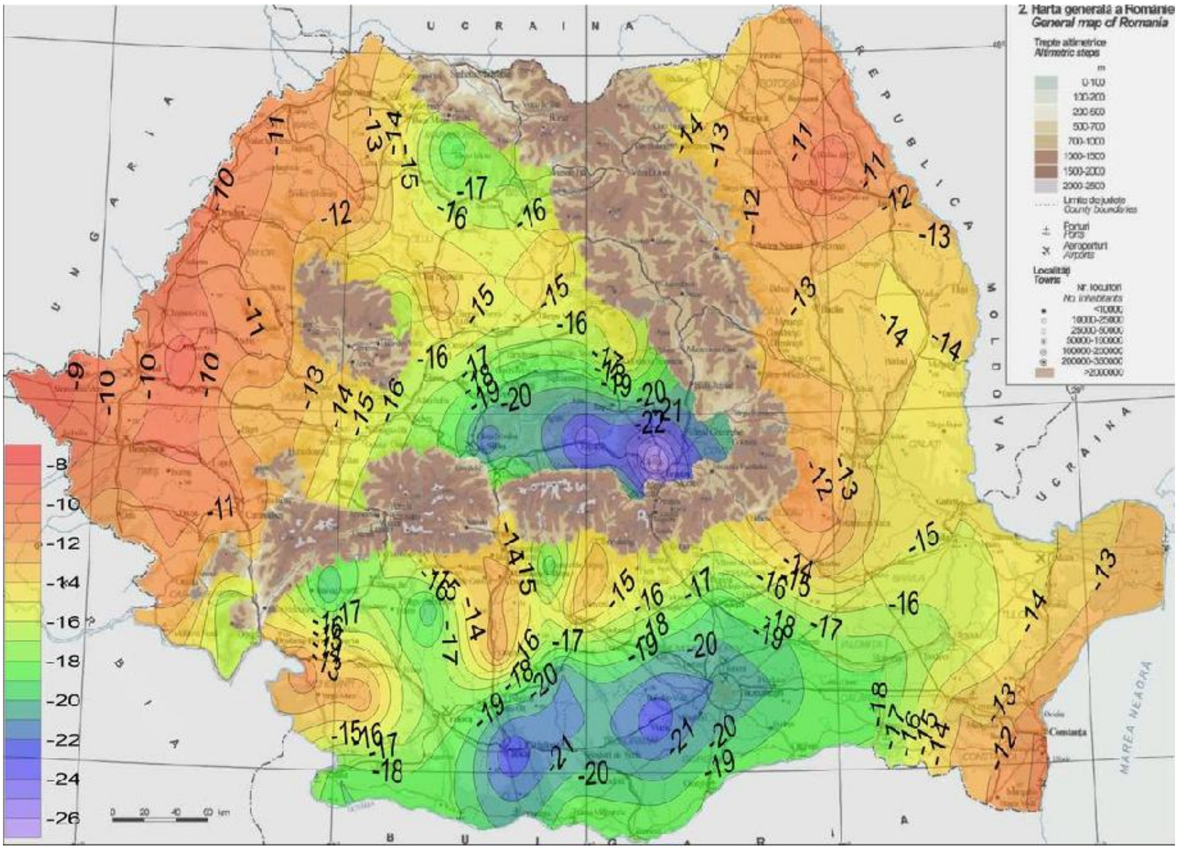


Fig. 8. Minimum air temperatures between 19 to 24 January 2016 (Surfer 9.0 software cartogram - kriging interpolation data after ANM Bucharest)

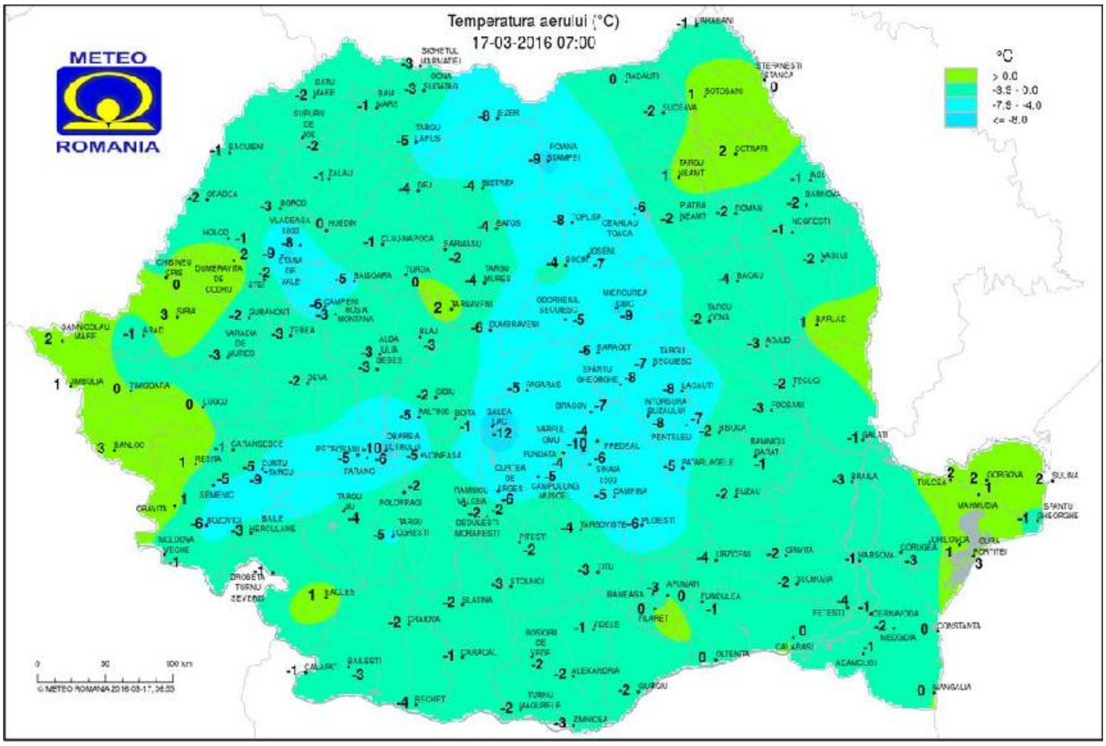


Fig. 9. Minimum air temperatures on March 17, 2016 (NMA Bucharest)

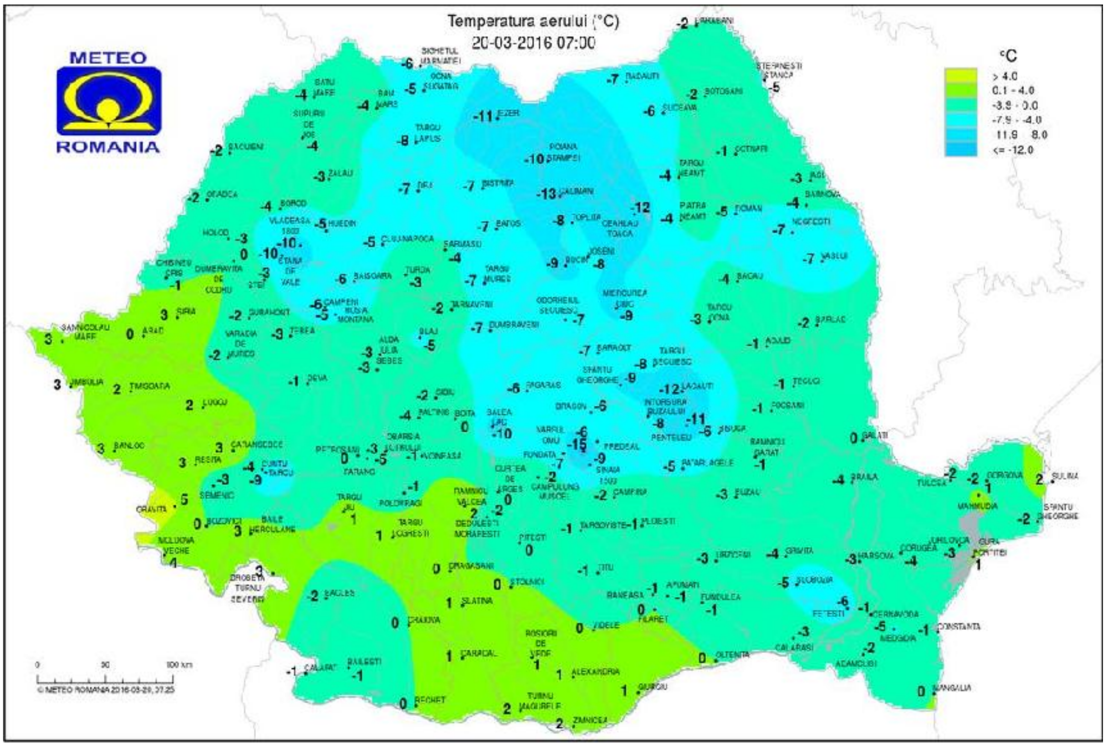


Fig. 10. Minimum air temperatures on March 20, 2016 (NMA Bucharest)