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IMPACT OF SOOT POLLUTION ON RADIATION AND WATER BALANCE CHARACTERISTICS IN MAIZE

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Abstract

Investigations were carried out on maize contaminated with atmospheric soot (black carbon, BC) under field conditions. The examinations included basic plant growth and developmental properties (leaf area index, LAI), a few radiation indicators and water balance terms. Out of water balance members the evapotranspiration, from heat balance the albedo – reflecting the reflectance of solar radiation- and net radiation were taken into account in field study. Energy proportioning, the latent and sensible heat fluxes helped get information about relationship between two different budgets, the water and heat balances of contaminated maize. The advantage of our research was the pioneer work to simulate atmospheric soot pollution from transport under non-laboratory conditions.

Key Words: evapotranspiration, albedo, black carbon, maize

Összefoglalás

Kutatásunk során kukorica növényt szennyeztünk légköri eredetű korommal (black carbon, BC) szabadföldi körülmények között. Vizsgálataink kiterjedtek az alapvető növény növekedés-fejlődési mutatók (levélfelület-index (LAI)) mellett a növény sugárzásháztartására és vízháztartására. Vízháztartási méréseink során az evapotranszspirációt, a sugárzásháztartási jellemzők közül az albedót, mely a különböző felszínek sugárzás visszaverő képességét mutatja, a nettó sugárzási egyenleget, mely szoros összefüggésben van az albedó alakulásával, a látens és szenzibils hőt vizsgáltuk, melyek segítségével a párolgásról és az állományban maradt energiáról kaptunk információt.

Kutatásunk egyedisége a közlekedésből származó koromszennyezés hatásának szimulálása volt, mely során a nem laboratóriumi körülmények közötti kölcsönhatások megfigyelésére összpontosítottunk.

Kulcsszavak: evapotranszspiráció, albedó, korom, kukorica

Introduction

Black carbon (BC) is product of the incomplete combustion of carbonaceous fuels. This contaminant has direct contact with the plants and indirect one to animals or humans. BC emissions result in air pollution and can lead to a variety of health impacts (USAID, 2010). Recent studies show that BC is a major contributor to global warming and the warming effect of BC is surpassed only by carbon-dioxide gas (Baron et al., 2010). The road traffic emission have emerged as the major cause of poor air quality (Brophy et al., 2007). Diesel and petrol fuelled vehicles are responsible for the generation of wide range of pollutants, depending on vehicle technology (Colvile et al., 2001).

Zhan et al. (2012) reported that BC can make up a significant proportion of the organic carbon in soil, but the amount of bound BC differed considerably among soil types. Diesel exhaust BC contain nearly 40 hazardous pollutants. This mixture contains carbon particles that are very small in size. These small particles may be deeply inhaled and causes respiratory disease (Song et al., 2012; Wargo et al., 2006).

Most studies of human health effects of air pollution were not composition specific, but there is evidence that small soot particles are the most harmful pollutants (Künzli et al., 2000). These toxic materials such as carbon particles are also deposited on the surface of plants (Mondal et al., 2014).

In the literature little information is given on the impact of solid pollutants which come from dry deposition (Olszyk et al., 2003). The aim was to expand the knowledge of this slightly under-investigated research topic using maize as test crop.

Materials and Methods

The impact of black carbon on the growth, evapotranspiration and radiation balance of maize grown at various water supply levels was studied at the Agro-meteorological Research Station in Keszthely, Hungary during 2010-2012 growing season. Maize was selected as test plants because of its high acreage in the world (160 million ha (FAO 2010). A short growing season maize variety seemed to be suitable for our experiment. The plant responses were examined as a result of contamination, which is repeatable to other plant species even maize hybrids A Swiss-bred maize hybrid, *Sperlona* (FAO 340) was sown in the experiment at a plant density of 70,000 plants ha^{-1}, a widely used plant density under Hungarian climatic conditions for growing grain maize.

The soil was Ramann's brown forest soil with a mean bulk density of 1.46 mg m^{-3} in the top 1 m of the profile and an available water capacity of 150 mm m^{-1}. Nutrients (180, 80 and 120 kg ha–1 N, P and K, respectively) were applied in spring, immediately prior to sowing. The usual agronomic measures (plant protection, weed control) recommended for the location by the staff of the University of Agricultural Sciences, Keszthely, were applied.

Of the two water supply treatments, the rainfed variant was sown in field plots, while Thornthwaite type compensation evapotranspirometers were used for the "ad libitum" treatment. These were metal containers (ET-chambers) with a volume of 4 m^3 (2x2 m in area, with a depth of 1 m), filled with the monolith of the surrounding field, layered as in the natural state. The working principle was to record the components of the water balance each day, expressing evapotranspiration as the residual term. To minimise soil water and canopy differences, the area surrounding the ET was irrigated. Due to the fixed nature of evapotranspirometers, the experiment was laid out in a block design with four replications, while the dry plots were arranged in a randomised complete block design with five replications. The plots had the same area (4 m^2) as the evapotranspirometers. The treatment codes used in the experiment were as follows:

Treatment	Code
Water supplies:	
Rainfed plots	P
Evapotranspirometer chamber	ET

Contamination levels

No pollution (control)	C
Crop pollution with BC	BC

The BC used by the Hankook Tyre Company (Dunaújváros, Hungary) to improve the wear resistance of tyres was used as pollutant. This pollutant enters the atmosphere directly during vehicle transport. The size distribution is characterised by 10% below 3.13 μm, 50% below 18.8 μm and 90% of the total soot quantity below 50.6 μm. The pollutant is chemically "pure", i.e. it is free of other contaminants, such as heavy metals, so the reproducibility of the experiment is not problematic, unlike that of tests on other air pollutants. Relatively small doses were applied (3 g m^{-2}), repeated at weekly intervals. Although the experiment could not simulate the perfect composition of vehicles exhaust (lack of heavy metals), but any negative impact observed using "pure" BC, could be more intense in the field. A motorised sprayer (SP 415) was used to apply the pollutant.

The leaf area index was measured each week on the same 12 sample plants in each treatment using an LI 3000A automatic planimeter (LI-COR, Lincoln, NE).

Pyranometers of the CMA-11 type (Kipp & Zonen, Vaisala) were installed on columns of adjustable height in the centre of the 0.3 ha plots designated for albedo measurements. The height of the sensors was raised each week as the plants grew, so that they were always at least 1.5 m above the canopy. Data were collected using a Logbox SD (Kipp & Zonen, Vaisala) datalogger in the form of 10-minute means of samples taken every 6 seconds. Either these 10-minute means or the hourly or daily means calculated from them were used for the analysis.

The meteorological data were obtained from the local QLC-50 automatic climate station. Data analysis was performed using the STATA 5.0 computer package (Stata Corporation, 1997). The t-test was used to determine significant differences between the dry matter yields of polluted and control plants and of rainfed and ET-grown plants. In time series analysis two-tailed t-test was applied. Significant level was settled to 5% ($P<0.05$).

Results and Discussion

Weather conditions and the effects of maize phenology

The first year (2010) of the study period was characteristic of a humid weather, while the next two seasons were arid ones. Compared to the seasonal mean rainfall of the last century (1901-2000), there was 40% higher seasonal precipitation sum, during 2010. Oppositely, there were 44% and 29 % less amounts of rainfall in 2011 and 2012, respectively, comparing to the last century's seasonal average precipitation sum. The seasonal mean air temperatures were 1.2 °C and 1.6 °C higher in 2011 and 2012 than that of the long-term mean. In 2010, the season's mean air temperature was close to the climatic norm.

July is a significant month for maize development, because the tasselling happens at this time. Fortunately, neither the rainfall sum, nor the air temperatures differed significantly from the climatic norms each July of the observation.

The length and occurrence of maize phenophases was not affected by the soot pollution. Similarly, the plant height of the maize was also not impacted by the soot contamination (data not shown).

The BC had significant effect on LAI of maize only in 2011 (*Figure 1.*). Significant LAI increments of 14.9% ($P<0.0001$) and 10.7% ($P<0.0001$) were measured in the rainfed and ET (polluted) treatments respectively. BC also grew the LAI in the other two years of the experiment (2010 and 2012) to a certain extent (2-5%), but the changes were not significant. Study of Usman et al. (2016) confirmed our result. They demonstrated clearly that addition of BC increased the vegetative growth, yield and quality parameters of tomato in irrigated treatments.

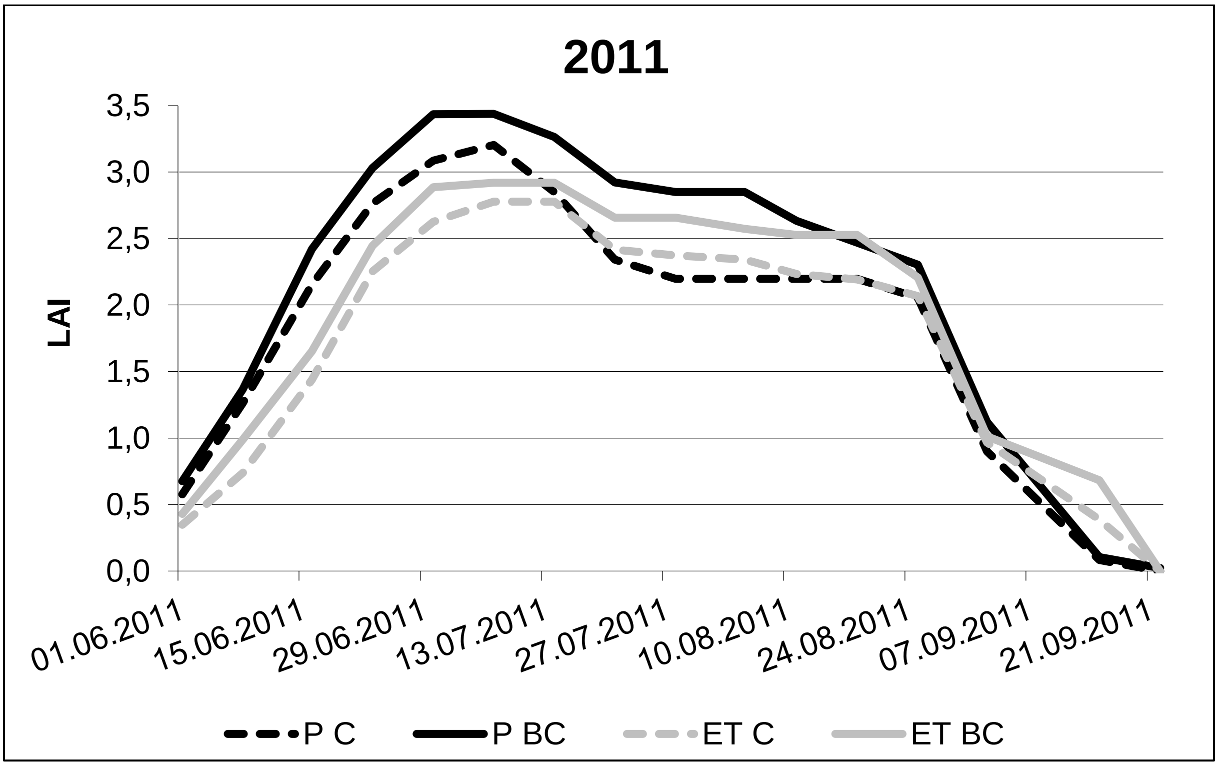

Figure 1. Variation in maize leaf area indexes (LAI) measured in the plots (P) and evapotranspirometers (ET), (BC-Black Carbon, C-Control) in 2011

Changes in irradiation and water regime parameters

The evapotranspiration rate was greatly influenced by the season's actual weather conditions. Cumulative evapotranspiration was the lowest in 2010, when the weather was wet/humid. Increases in total water losses of the control maize were 1.2% and 19.8% during 2011 and 2012 in comparison to rainy 2010. For the same time period (2011-2012), the upward tendency in the amount of water loss was the same for the contaminated plants; 11.5% and 22.5% higher water uses were observed in polluted plants comparing to the season's results of 2010. Water loss in dry 2011 was closer to cumulative evapotranspiration of wet 2010 than water loss in dry 2012 due to variation in seasonal temperatures. Seasonal mean air temperature in arid 2011 was nearer to wet 2010 than to dry 2012. In evapotranspirometers, as the water supply is unlimited, the impact of precipitation is less than the effect of temperatures.

The effect of soot pollution was also investigated within the seasons on (*Figure 2.).* Although only moderate differences were occurred during 2010 and 2012, the impact of BC contamination on total water loss was significant. Sum of evapotranspiration of BC treated maize was higher with 11.82% (P<0.0001) in 2011, than the total water loss of control maize. The relationship between evapotranspiration and size of LAI was very close. The higher the change in LAI, the larger water losses were observed. Accordingly to largest LAI sizes, the highest total water losses were measured during 2011.

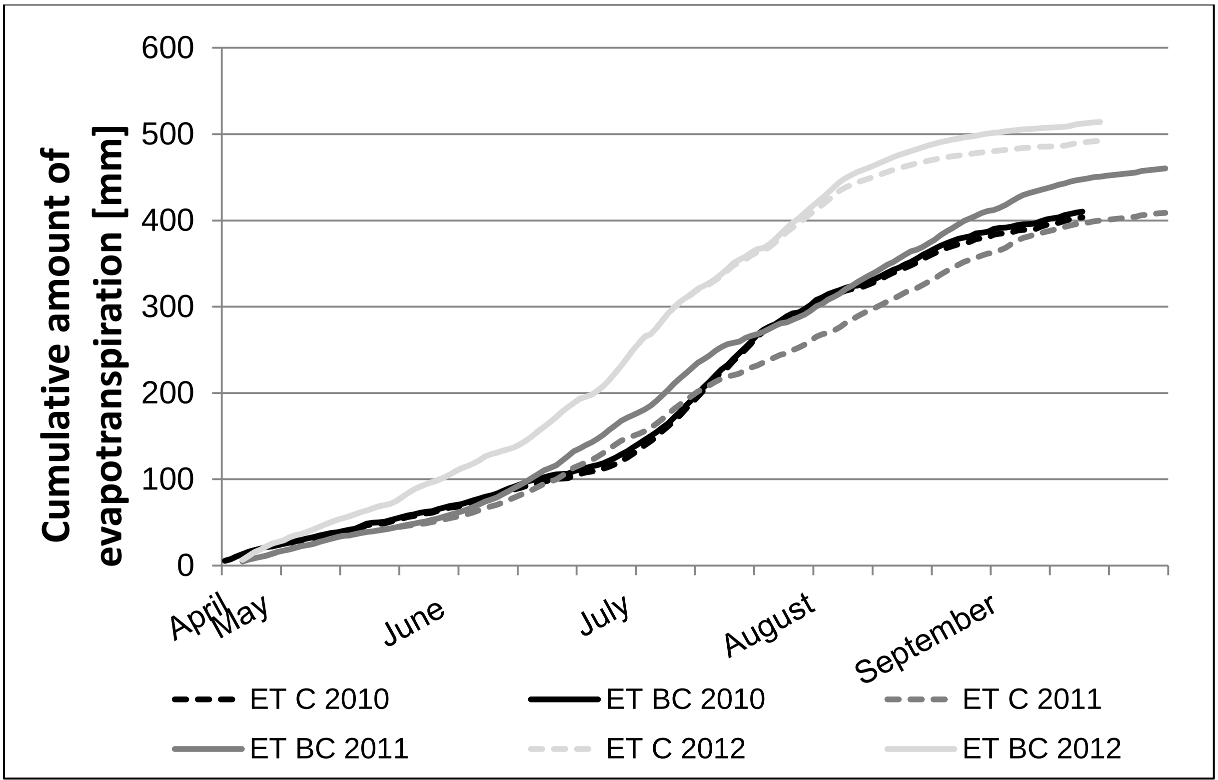

Figure 2. The cumulative amount of evapotranspiration (mm) in the control (C) evapotranspirometer (ET) and in the soot contaminated (BC) evapotranspirometer between 2010 and 2012

The evapotranspiration rate was also studied depending on the leaf surface size. The treated maize lost significantly more water (6.41% (P<0.008)) only in 2010. Evapotranspiration results of polluted maize increased like a tendency during the next two seasons (2011: 2.61% ns; 2012: 4.37% ns).

The next studied parameter was the albedo, a widely applied solar radiation property. The albedo is an easily measurable indicator of surface reflectance that allows the comparison of radiation characteristics of different surfaces, including plants. The albedo showed the highest stability among the studied parameters. The soot pollution reduced significantly the values of the albedo each season. The albedos of BC treated maize were 17.34% (P<0.0001), 21.75% (P<0.0001) and 14.45% (P<0.0001) lower in 2010, 2011 and 2012, respectively, than the albedo of the non-contaminated control maize. The reflectance of solar radiation depended on weather conditions. The difference was higher when there was less precipitation.

The following solar radiation balance characteristics provide information about the energy use and distribution of maize. The latent heat is the energy applied for evapotranspiration, and the sensible heat is used for heating processes (plant canopy air, the plants itself etc.). In the latent heat, there was no significant difference between the polluted and control plants in 2010 (*Figure 3.*).

However the higher evapotranspiration rates in the treated plots were due to higher LAI in 2011. This was confirmed by the 10.9% (P<0.0001) increase in latent heat of soot contaminated plots. In 2012, the increase was only 1.13% (P<0.0001), but it was also significant.

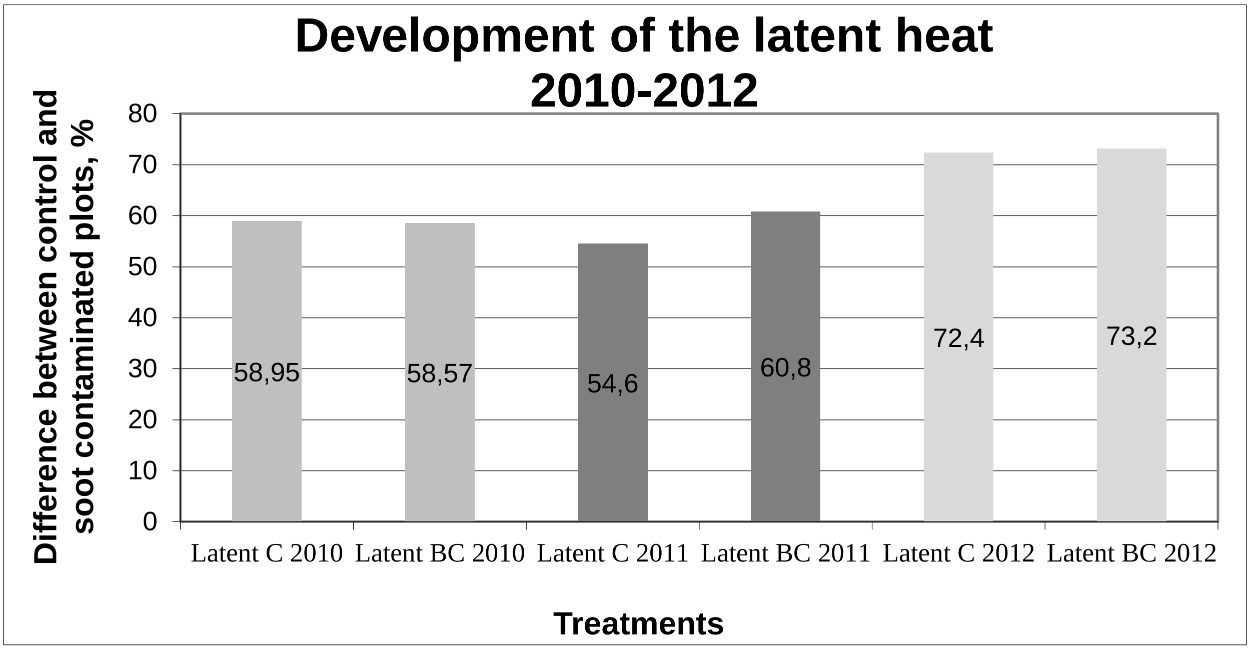

Figure 3. Development of the latent heat between 2010 and 2012 in the soot contaminated (BC) and in the control (C) plots.

Analysing the canopy structure of different maize treatments, we found that the soot contaminated plot had more closed plant stand each season than that of the control ones. Closed plant stands hinder radiation penetration causing cooler canopy microclimate. This modification was reflected in the amount of sensible heat (*Figure 4*). In 2010, like a tendency, but later on 14.8% (P<0.0001) and 3.02% (P<0.0001) significant decreases in sensible heat flux of polluted maize canopies were observed in comparison to sensible heat flux of control maize.

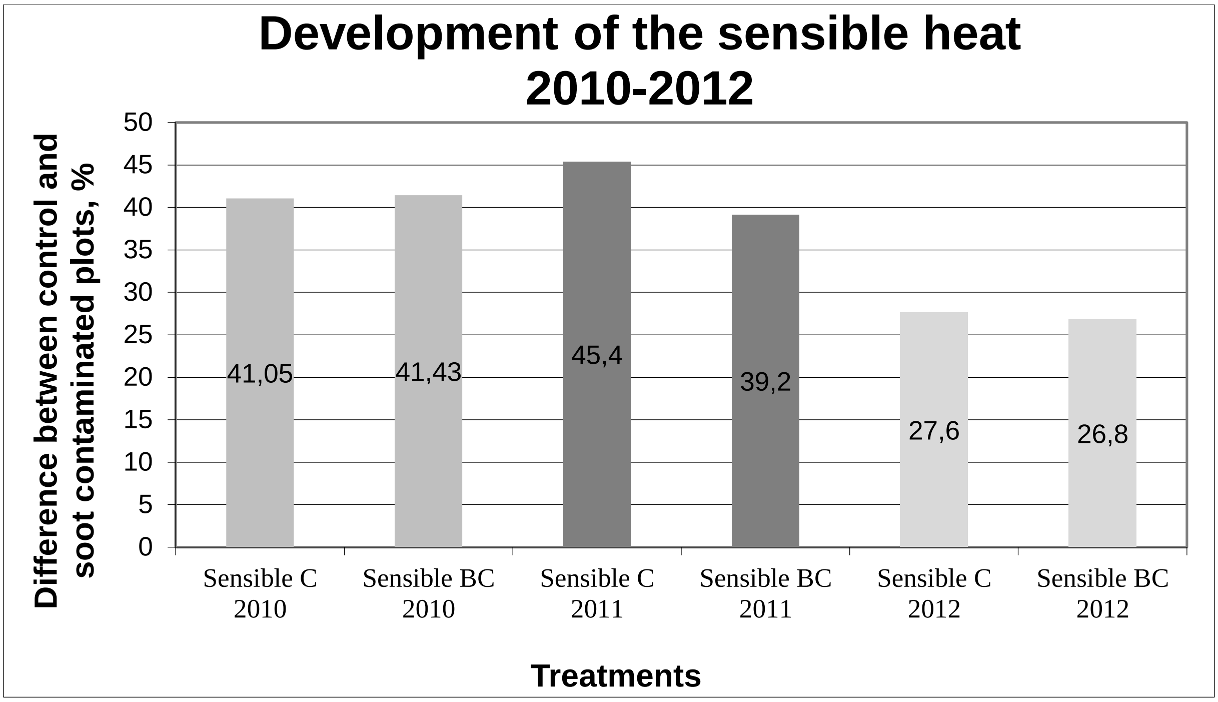

Figure 4. Development of the sensible heat between 2010 and 2012 in the soot contaminated (BC) and in the control (C) plots

The last observed parameter was the net radiation that was closely related to the size of albedo. Decline in albedo resulted in higher radiation absorption (*Figure 5.*). Significant differences in net radiation between the treated and control maize was detected each season. The increments of net radiation of the soot contaminated maize were 3.83% ($P<0.0001$), 4.21% ($P<0.0001$) and 3.16% ($P<0.0001$) in 2010, 2011 and 2012, respectively than that of the net radiation of control maize.

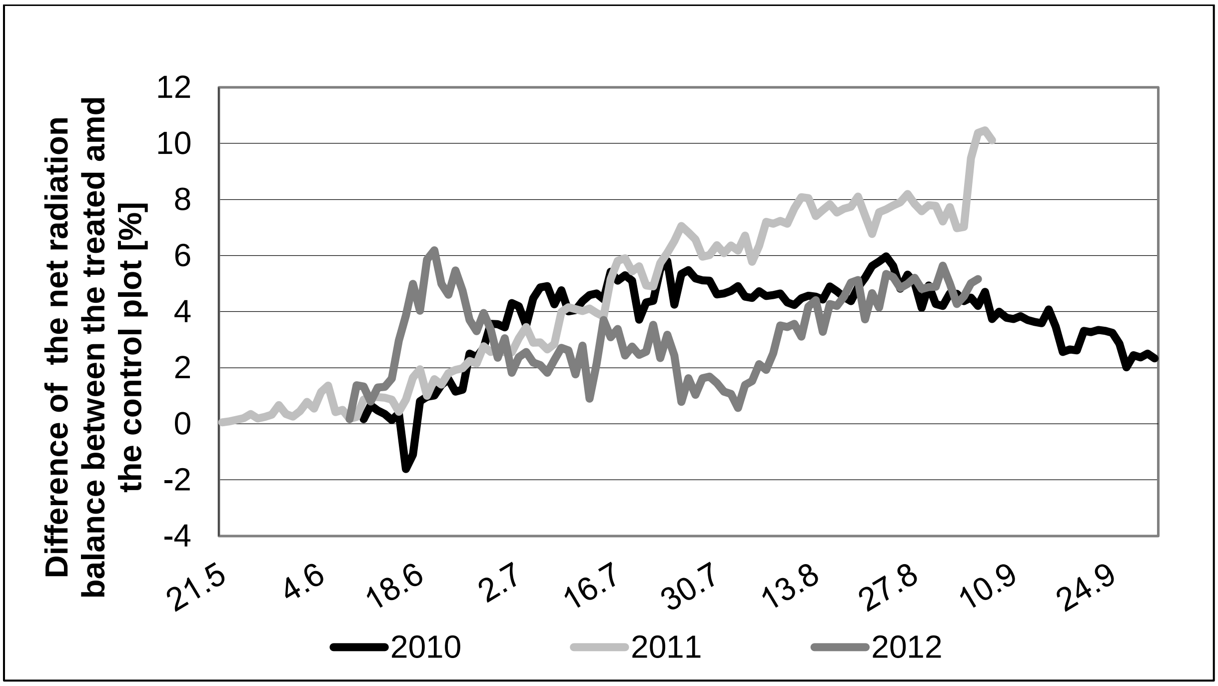

Figure 5. Difference of the net radiation of the soot contaminated plot compared to the control plot in %

Conclusions

The soot pollution did not affect the length and occurrence of the maize phenological phases. Assimilatory surface sizes of plants (LAI) showed significant changes, but only in 2011. However, in the remaining two seasons, the soot increased the leaf area of plants like a tendency. This modification was not expected when starting the experiment. The possible reason of this unexpected event may be that the maize used the soot such as extra carbon source, as demonstrated in foliar fertilization experiment earlier by Glaser (2007). Zhu et al. (2014) also reported positive effects of maize biomass in all soils amended with biochar compared to soils without biochar. The authors observed that liming effect of biochar improved plant growth through alleviating Al toxicity and P deficiency, especially in poor acidic red soils.

Small sized LAI of 2011 was probably due to low precipitation amounts. Slighter rainfall sum for 2012 also influenced the maize LAI, but more moderately than in the course of previous season. Plentiful precipitation probably washed out the soot from the contaminated leaf surface during 2010 limiting the development of soot influence on plant characteristics (LAI).

Size of LAI strongly influenced the evapotranspiration intensity. The greater transpiratory surface of BC treated crops might be one of the reasons of their increased evapotranspiration rates (Anda and Illes, 2012).

The season's weather highly influenced plant's radiation characteristics. Declines in albedo regarding soot contaminated plants were significant each season. Decrease in albedo caused better energy retention of maize. This extra energy was devoted to increasing evapotranspiration rate of polluted plants. In rainy weather conditions, when the soot has been washed out from the plant surface, decrease in size of albedo is more limited and the obtained evapotranspiration water loss is also less. However, in arid weather conditions the BC adhering to the plant surface forced the evapotranspiration of contaminated plants.

Solution for reducing the negative impacts of the soot deposition could be the irrigation, as characteristics of maize grown in ET (non-limited water supply) demonstrated better plant characteristics than polluted rainfed maize. To get more generalizable results about impacts of BC on crops, further investigations are needed with respect to other crop species.

Acknowledgement

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THE IMPACT OF FOLIAR FERTILIZATION ON THE NECTAR PRODUCTION AND APICULTURAL VALUE OF SUNFLOWER (*HELIANTHUS ANNUUS L.*)

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Abstract

Beside black locust (*Robinia pseudoacacia*) the sunflower is the second most important bee pasture in Hungary. New species and hybrids are generally considered as the sources for different honey flow of the nectariferous plant. However, the quantity and quality of the nutrition supply of the growing area can more effectively influence the honey flow of sunflower than the genetic potential of the crop. From the agro-technical point of view the nectar production of sunflower cannot be increased through the enlargement of the growing area but by increasing the nectar production in our dissertation.
We analysed the correlation between the nectar production and the nutrition supply of the crop in near Mocsa (47°40'37,9''N 18°10'52,0''E). We observed that the essential micro- (Zn and Cu), and macro-elements (Mg and Ca) applied as foliar fertilizers increased the quantity of nectar production. Foliar fertilizers of applied compounds ($Zn(OH)_2$+$ZnCO_3$, $Cu(NH_3)_4$, $MgCO_3$, $CaCO_3$) were produced from industrial by-products of high purity. We used ICP-AES analytical measuring method to measure the exact active substance. Compared to the control foliar fertilizer agents induced positive quantitative change in one floret in the dosage range of 0.086-0.341 mg/flower and in the average of three sample taking days (n=864). We examined the data with non-parametric significance method. Compared to the control ($p<0.05$) every sunflower hybrid showed higher nectar production due to tetramine-copper application.

Key words: sunflower, micro-, and macro-elements, foliar fertilization, nectar, bee-pasture

Összefoglalás

Magyarországon a napraforgó méhészeti szempontból a második legfontosabb méhlegelő az akác után. A növény eltérő mézeléséért az új fajtákat, hibrideket okolják. A napraforgó mézelését azonban sokkal inkább befolyásolhatja a termesztési terület tápanyag ellátottságának mennyisége és minősége, mint a vetett növény genetikai potenciálja. A napraforgó nektártermelésének növelése agrotechnikai szempontból nem a vetésterület növelésével, hanem a növény nektártermelésének fokozásával érhető el. Munkánkban a napraforgó nektártermelése, és a tápanyag ellátottság közötti kapcsolatot vizsgáltuk Mocsa település közelében (47°40'37,9''N 18°10'52,0''E). Az esszenciális mikro- (Zn, Cu), és makró elemek (Mg, Ca) lombtrágyaként való alkalmazásának, a termelt nektár mennyiségére gyakorolt hatását figyeltük meg. A lombtrágyázáshoz használt vegyületeket ($Zn(OH)_2$+$ZnCO_3$, $Cu(NH_3)_4$, $MgCO_3$, $CaCO_3$) nagy tisztaságú ipari melléktermékekből állítottuk elő, amelyek pontos hatóanyagtartalmát ICP-AES műszeres analitikai módszerrel határoztuk meg.Az alkalmazott lombtrágyák a napraforgó hibridnél a három mintavételezési nap (n=864) átlagában a kontrollhoz képest pozitív mennyiségi változást mutattak egy csöves virágra vetítve 0,086-0,341 mg $\cdot$ virág^{-1} tartományban. Az adatokat nem parametrikus szignifikancia vizsgálatnak vetettük alá. Minden napraforgó hibridnél a réz-tetramin kezelés mutatott szignifikáns nektár mennyiségbeli növekedést a kontrollhoz képest ($p<0,05$).

Introduction

In Hungary, we cannot expect an enlargement of the sunflower growing area of about 600.000 hectares, or 593 600 hectares (FAO, 2013) because of crop rotation requirements. Sunflower is allogeneic and entomophilous plant. This crop species has no specialized pollinating wild bees in Europe (Benedek and Manninger, 1972). Only honey bees (A*pis mellifera*) can provide effective pollination. Sunflower is grown in all counties of Hungary, however, its distribution is not even, therefore beekeepers have to migrate in order to reach better honey yields (Ruff, 1999; Frank, 1989). Beekeepers blame exclusively the new hybrids for differing honey flow and do not pay enough attention to the nutrient supply of the plants (Zajác et al., 2006; Lajkó, 2001; Nikovitz and Szalainé, 1984).

In Hungary, the quantity of applied fertilizers grew rapidly between 1940 and 1985 (Láng and Csete, 1992), although it decreased by 80% in the 1990s (Csathó and Radimszky, 2007). The utilization of various fertilizers containing nitrogen, phosphor and potassium has been slightly increased in the last decade in Hungary (KSH, 2014). Most soils in Hungary show microelement deficiency (Várallyay et al., 2009). Fresh manure may contain high enough quantity of microelements although the microelement content of the organic fertilizer will not be fully available for the plants in the first year (Zorn et al., 2007). During the past 10 years the utilization of organic fertilizers reduced by 2.3 t/ha in Hungary (KSH, 2014). Foliar fertilization can be applied economically to complete the crop's requirement on microelements (Szakál et al., 1988).

Since the beginning of 20th century we have known that zinc and copper (Sommer and Lipman, 1926; Sommer, 1931) have an essential function in plant physiological processes, and since the middle of 9th century we have known the same about magnesium and calcium (Benton, 2014). Copper has a biochemical role, as enzyme activator it works as a catalyser in redox reactions. It acts like magnesium and zinc in cytochrome c oxidase enzyme as enzyme building substance (Carr and Winge, 2003). Zinc being a component of tryptophan (a precursor of indole acetic acid (IAA)) influences the growth of plants. Interacting with indole acetic acid Ca^{2+} ions play a role in cell elongation and differentiation as well as in stabilizing the middle lamella of primary cells walls (Wehr et al., 2004; Carpita and McCann, 2000). Mg^{2+} ion has an essential function in the structure of the chlorophyll porphine skeleton in the photosynthesis. It has a function as a bridging element for the aggregation of ribosomal subunits *(*Cammarano et al*.*, 1972*).* Clearing the role of microelements in nectar production of sunflower could tangibly benefit to the beekeepers.

Our hypothesis was that the nutrition has larger role in the nectar production of the sunflower than that of the hybrid effect. The purpose of this experiment was to define the efficacy of the compounds used as foliar fertilizer on the quantity the nectar of sunflower.

Material and Method

Foliar fertilizers of five different concentrations and quality were applied on four sunflower hybrids. $ZnCO_3$+$MgCO_3$ and $Cu(NH_3)_4$+$CaCO_3$ foliar fertilizers were applied in quantities of 10 l h-1 in each case, further on 20 l ha-1 of $Zn(OH)_2$+$ZnCO_3$ and 3 l ha-1 of $Cu(NH_3)_4$ plant conditioner were applied on the crop. 10 m^2 large plots of the four Dow Seed hybrids (8N 358 CLDM, 8H 288 CLDM, MG 305 CP, 8M 449 CLDM) was. Hybrids of the Dow AgroSciences are classified either as conventional or high oleic (with oleic contents of greater than 84%). In many cases, the sunflower oil has a high proportion of heart-healthy mono-unsaturated fat, which confers health benefits and improved cooking characteristics. There splots were treated with the above mentioned doses of foliar fertilizers. Beside every hybrid we included one control plot (untreated one). It was 8 plots by hybrids. An isolation distance of 1.4 m was left between the plots.

The substances applied were produced from industrial by-products of high purity (Szakál et al., 1988). The micro- and macro-element agents of the foliar fertilizers were analysed with the method of inductively coupled plasma atomic emission spectroscopy (ICP-AES) and according to the Hungarian Standards (MSZ 21470-50:1998). Using three different measures 1-2.5-5ml samples of foliar fertilizers were sent to digestion according to the above described standard. Three different dilutions of every digested sample (1x, 10x, 100x) were analysed with the method of ICP-AES.

Table 1. Contents of active substances of the foliar fertilizers applied in our study based on analytical measurements

foliar fertilizer compound	quantity of active substances
$Cu(NH_3)_4 + CaCO_3$	5.57% Cu; 2.41% Ca
$ZnCO_3 + MgCO_3$	1.2% Mg; 1.18% Zn
$Cu(NH_3)_4$	5.65% Cu
$Zn(OH)_2$ + ZnCO3	10.71% Zn

Foliar fertilizers shall be applied at phenological stages of 53-57-59 on BBCH scale (Free, 1993). We applied them on 64^{th} day from sowing (13^{th} June 2014). We applied top dressing on the crop with 150 kg/ha NPK in dosages of 10:20:20. There were 50 000 sown germs per hectare in all the four different hybrid crops.

During the sampling period of three days the temperatures varied between 30-34C°. There was no rainfall in this period. The air humidity measured between 40-72%.

Nectar samples were taken from disc florets isolated with tulle netting and spacing 24 hours before (Free, 1993). Three discs being in identical flowering period were isolated per plot. Samples were taken twice a day at 7-11 AM and at 13-17 PM. Sampling was repeated on 3-5th July 2014 with 24 hour-differences. Pre-fabricated glass capillary tubes were used to take samples. We applied pipettes of narrowed inner diameter of 1mm at the end of the glass capillaries of 2.2 mm diameter. Samples were taken from 5 tubiferous florets with one pipette. Samples were taken from the female and male flowers at the same growth stage with the help of the glass pipettes and capillary effects.

We used bees wax balls to close the glass capillaries after sampling. Because the glass capillaries and the bee wax balls have different masses we weighed and numbered them on a four decimal precision analytical balance type Ohaus Adventure Pro AV264. After taking the samples we weighed the numbered capillaries on the same analytical balance in a laboratory. The fifth of the difference of net respectively gross capillary masses provided the nectar yield of one tubiferous floret in 24 hours. We compared the nectar yields of the four hybrids received as a result of the treatments.

We processed the received data in a chart data base using the programme Microsoft Office Excel 2007. Statistical evaluation was prepared with the programme IBM SPSS Statistics 20. We used Kolmogorov-Smirnov test to analyse the values of nectar samples and the distribution of the sample masses. We analysed the three-day nectar yields of hybrids treated with foliar fertilizers with Kruskal-Wallis test. Null-hypothesis was accepted if the mean values were the same in every group, i.e. the p-value exceeded 0.05 at a confidence interval of 95 %. Alternative hypothesis was accepted if the mean values of each group differed, i.e. p-value was lower than 0.05 at a confidence interval of 95 %. If the Kruska-Wallis test resulted in an alternative hypothesis we analysed the difference between the control and the treatments with Mann-Whitney test. If there is a null hypothesis the varying values belong to identical mean values based on the data of the three days and we can accept the null-hypothesis if the p-value exceeds 0.5 at a confidence interval of 95%. If there is an alternative hypothesis the mean values of the varying values received on the three days considerably differ. We can accept the alternative hypothesis if the p-value is lower than 0.05

at 95% confidence interval. Samples from the control plots were analysed with Levene-test and One-Way ANOVA because of the normal distribution of sample masses.

Results

Results of nectar yields of the four hybrids show the effect of foliar fertilizer treatment. The Kolmogorov-Smirnov test showed that the different quantities of the nectar samples taken from treated plots have not shown normal distribution. The Mann-Whitney test showed the following values for the differences in nectar production of the treated hybrids:

The average nectar yields of the hybrid 8N 358 CLDM treated with foliar fertilizers $Cu(NH_3)_4$ (0.49±0.24 mg · one flower^{-1}), $Cu(NH_3)_4$+$CaCO_3$ (0.37±0.19 mg · one flower^{-1}), $ZnCO_3$+$MgCO_3$ (0.46±0.31 mg · one flower^{-1}), $Zn(OH)_2$+$ZnCO_3$ (0.42±0.27 mg · one flower^{-1}) show significant increases compared to the control plots (0.29±0.13 mg · one flower^{-1}) ($p<0.05$) (Table 2.).

The average nectar yields of the 8H 288 CLDM hybrid treated with $Cu(NH_3)_4$ (0.55±0.29 mg · one flower^{-1}), $Cu(NH_3)_4$+$CaCO_3$ (0.40±0.19 mg · one flower^{-1}), $ZnCO_3$+$MgCO_3$ (0.61±0.31 mg · one flower^{-1}), $Zn(OH)_2$+$ZnCO_3$ (0.63±0.44 mg · one flower^{-1}) foliar fertilizers show significant increases compared to the control plots (0.29±0.14 mg · one flower^{-1}) ($p>0.05$) (Table 2.).

The average nectar yields of the MG 305 CP hybrid treated with $Cu(NH_3)_4$ (0.51±0.35 mg · one flower^{-1}), $Zn(OH)_2$+$ZnCO_3$ (0.42±0.27 mg · one flower^{-1}) foliar fertilizers show significant increases compared to the control (0.28±0.16 mg · one flower^{-1}) ($p<0.05$) (Table 3.).

The average nectar yields of 8M 449 CLDM hybrid treated with $Cu(NH_3)_4$ (0.62±0.33 mg · one flower^{-1}), $ZnCO_3$+$MgCO_3$ (0.46±0.31 mg · one flower^{-1}) foliar fertilizer showed significant increases compared to the control plots (0.30±0.13 mg · one flower^{-1}) ($p<0.05$) (Table 3.).

In contrast the plots treated the Kolmogorov-Smirnov test produced normal distribution for the control plots. According to the One-Way ANOVA analysis the following sunflower hybrids of 8N 358 CLDM (0.29±0.13 mg · one flower^{-1}), 8H 288 CLDM (0.29±0.14 mg · one flower^{-1}), MG 305 CP (0.28±0.16 mg · one flower^{-1}), and 8M 449 CLDM (0.30±0.13 mg · one flower^{-1}) produced no significant differences in the nectar production ($p>0.05$).

Compared to the control three out of four hybrids of 8N 358 CLDM, 8M 449 CLDM and MG 305 CP produced the highest nectar yields as the result of $Cu(NH_3)_4$ foliar treatment, as follows: increases in nectar yield of 73.47%, 89.57%, 92.66%. Compared to the control 8H 288 CLDM hybrid produced 117.70% in increase, the highest nectar yield, as a result of $Zn(OH)_2$+$ZnCO_3$ foliar treatment.

The hybrids 8N 358 CLDM, 8M 449 CLDM, and MG 305 CP had samples of normal distribution (0.54±0.31 mg · one flower^{-1}) as a result of $Cu(NH_3)_4$ foliar treatments as shown with the Kolmogorov-Smirnov test. Based on One-Way ANOVA analysis the nectar mass production of the three hybrids showed no significant differences (p>0,05).

Table 2. The role of fertilization in the nectar productions of the 8N 358 CLDM and 8H 288 CLDM sunflower hybrids, in milligrams (mg · one flower^{-1})

Dates of samplings	sunflower hybrids									
	8N 358 CLDM					8H 288 CLDM				
	foliar treatmnets									
	$Cu(NH_2)_4$	$Cu(NH_2)_4$+ $CaCO_3$	$ZnCO_3$+ $MgCO_3$	$Zn(OH)_2$+ $ZnCO_3$	control	$Cu(NH_2)_4$	$Cu(NH_2)_4$+ $CaCO_3$	$ZnCO_3$+ $MgCO_3$	$Zn(OH)_2$+ $ZnCO_3$	control
	mean±SD									
03.07.2014	0.50±0.25	0.29±0.17	0.32±0.26	0.32±0.14	0.26±0.11	0.43±0.24	0.39±0.20	0.42±0.12	0.37±0.20	0.29±0.15
04.07.2014	0.32±0.18	0.32±0.12	0.56±0.40	0.45±0.30	0.30±0.15	0.59±0.24	0.40±0.18	0.67±0.24	0.72±0.53	0.30±0.14
05.07.2014	0.61±0.24	0.49±0.21	0.49±0,20	0.48±0.32	0.32±0.15	0.64±0.36	0.42±0.20	0.73±0.42	0.81±0.41	0.29±0.14
	sum mean±SD									
	0.49±0.24	0.37±0.19	0.46±0.31	0.42±0.27	0.29±0.13	0.55±0.29	0.40±0.19	0.61±0.31	0.63±0.44	0.29±0.14

Table 3. The role of fertilization in the nectar productions of the MG 350 CP and 8M 449 CLDM sunflower hybrids, in milligrams (mg · one flower^{-1})

Dates of samplings	sunflower hybrids									
	MG 305 CP					8M 449 CLDM				
	foliar treatmnets									
	$Cu(NH_2)_4$	$Cu(NH_2)_4$+ $CaCO_3$	$ZnCO_3$+ $MgCO_3$	$Zn(OH)_2$+ $ZnCO_3$	control	$Cu(NH_2)_4$	$Cu(NH_2)_4$+ $CaCO_3$	$ZnCO_3$+ $MgCO_3$	$Zn(OH)_2$+ $ZnCO_3$	control
	mean±SD									
03.07.2014	0.31±0.25	0.33±0.11	0.14±0.11	0.30±0.14	0.27±0.17	0.62±0.29	0.34±0.13	0.14±0.11	0.47±0.23	0.26±0.18
04.07.2014	0.54±0.43	0.49±0.30	0.28±0.17	0.40±0.28	0.30±0.16	0.51±0.23	0.40±0.40	0.54±0.24	0.67±0.26	0.31±0.14
05.07.2014	0.70±0.25	0.53±0.42	0.42±0.20	0.56±0.31	0.26±0.18	0.74±0.41	0.51±0.25	0.68±0.28	0.79±0.32	0.29±0.15
	sum mean±SD									
	0.51±0.35	0.45±0.31	0.28±0.20	0.42±0.27	0.28±0.16	0.62±0.33	0.42±0.28	0.46±0.31	0.64±0.30	0.30±0.13

Discussion

All of the hybrids 8N 358 CLDM, 8H 288 CLDM, MG 305 CP and 8M 449 CLDM gave different reaction for the foliar fertilization regarding the nectar production. Foliar fertilizer can be brought out together with other agro-technical treatments, for example, plant protection agents.

Our results point that the nutrition is an important factor in the nectar production of sunflower hybrids. After using foliar fertilizer more nectar are available on the same bee pasture at the same time. It means that within a unit of time more nectar can be brought into the hives and it may increase the profitability of bee keeping.

Among the applied foliar fertilizers $Cu(NH_3)_4$ (copper-tetramine treatment) proved to be the most effective on three out of four hybrids. The physiological function of copper seems justified. Comparing the untreated controls we observed that there were no significant differences among the nectar yields of hybrids. Beekeepers mean consider that differences in hybrids account for uneven nectar production (Zajácz et al., 2006). Our investigations revealed that nutrient supply is a similarly important factor as the hybrid effect is.

Conclusion

Control hybrids on the same plot did not show any significant differences in nectar yield. Increasing nutrient supply with higher micro-and macro-elements applied as foliar fertilizers significantly increased the nectar quantity of every hybrid used in this trial.

We can conclude that the nutrient supply have more significant role in nectar production than the effect of hybrids. Applying micro- and macro-elements in foliar fertilizers readily available for plants can contribute to the apicultural value of different sunflower genotypes/hybrids.

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EFFECT OF HATCHERY, GENOTYPE, MONTH OF HATCHING AND NUMBER OF EGGS IN ONE HATCHING UNIT ON HATCHABILITY OF HEN, GOOSE AND DUCK EGGS

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Abstract

The research was based on the national poultry hatching database, supplied by the Department of Animal Registration and Breeding Organization of the Hungarian National Food Safety Authority. Summarizing our previous works, the evaluations were extended to hen, goose and duck species - altogether 17 breeds and 27 hybrids -, 16146 hatching units, about 274.3 million eggs in year 2010. The effect of hatchery, genotype, month of hatching and number of eggs in one hatching unit on hatchability was analyzed by univariate analysis of variance (GLM). Phenotypic correlation coefficients were calculated between hatchability, hatching time and number of eggs in one hatching unit. The corrected overall mean values of hatchability of eggs of different poultry species were as follows: hen 82.96%, goose 61.56% and duck 64.59%. The differences between the genotypes in case of each species were significant. The meat and liver type hybrids showed lower hatchability than the mixed-use genotypes. The hatchability of goose eggs in summer months was almost 10% lower, than the mean value of the population. The hatchability of large units was approximately 8-10% better, than that of smaller units. Low, and significant correlation (r = -0.17-0.27; P<0.01) was found in respect of the examined parameters. Based on the results it can be stated that, the longer is the hatching time, the worse is the hatchability of poultry eggs.

Key-words: genotype, hatchability, hatching time, hatching unit

Összefoglalás

A Szerzők a NÉBiH Állattenyésztési Igazgatóság, Tenyésztés Szervezési és Teljesítményvizsgálati Osztálya által rendelkezésre bocsátott országos baromfikeltetési adatbázist dolgozták fel. Jelen munkát - a korábbi eredményeket összegezve - a 2010-es évre, három fajra (tyúk, lúd és kacsa), ezen belül 17 fajtára és 27 hibridre terjesztették ki. A munka során így összesen 16146 keltetési tételhez (kb. 274,3 millió tojáshoz) tartozó kelési idő és ugyanennyi keltethetőségi adat állt a rendelkezésükre. A keltethetőséget befolyásoló számos tényező közül a keltető üzemnek, a genotípusnak, a keltetési hónapnak és az egy tételben keltetett tojások számának hatását vizsgálták. A tényezők befolyását a tulajdonságokra többtényezős variancia-analízissel értékelték. A kelési idő, a keltethetőség, valamint az egy tételben keltetett tojások száma között fenotípusos korrelációs együtthatókat határoztak meg. A tojások keltethetőségének korrigált főátlaga a következő volt: tyúk 82,96%, lúd 61,56%, kacsa 64,59%. A genotípusok közti különbségek minden esetben szignifikánsak voltak. A hús- és májtípusú hibridek rosszabb keltethetőséget mutattak, mint a vegyes hasznosítású genotípusok. A lúdtojások keltethetősége a nyári hónapokban mintegy 10%-kal rosszabb volt az éves átlagnál. A nagy tételben keltetetett tojások keltethetősége 8-10%-kal jobb volt annál, mint amit a kisebb tojásszámú tételek esetén tapasztaltak. A vizsgált paraméterek között jellemzően laza kapcsolatokat találtak (r = -0,17-0,27;). Az eredmények alapján úgy tűnik, a keltetési idő hosszabbodásával a különböző baromfi fajok tojásainak a keltethetősége romlik.

Kulcsszavak: genotípus, kelési idő, keltetési tétel, keltethetőség

Introduction and literature review

Hatchability of fertile eggs is a formal, physical, chemical and biological property that - with an adequate hatchery technology - allows normal development of the embryo, and hatching of a vital chick from the egg. The hatchability is a complex trait, which may depend on the regular shape and the chemical composition of eggs, the proportion of each ingredient in the egg, and in fact on the genotype of the embryo (Horn, 2000). Hatchability is affected by a number of hereditary and environmental factors. Such factors are the type of parent stock, inbreeding and cross-breeding, the time that parent stocks spent in production, the weight of the eggs, the quality of the eggs (shell thickness, shape, pollution etc), the incubation temperature, egg storage time before incubation, and the feed quality of parent birds respectively (Butler, 1991; Oloffs et al., 1997; Bogenfürst, 2004; Peruzzi et al., 2012). The factors listed above are also under the influence of a number of genetic and environmental factors, regardless of genetically determined viability and vitality of the embryo. Generally, laying and mixed-use types show a better hatchability of eggs, than meat, or liver types.

Van de Ven et al. (2009) found, that the hatchability of fertile eggs in different technological circumstances was 93.67-95.53% for the Cobb 500 broiler, and 95.76-97.60% for the Ross 308 broiler respectively. In the study of Ulmer-Franco et al. (2010) the size of eggs influenced significantly the hatchability of Cobb 500 broilers. O'Dea et al. (2006) found during the hatching of Hubbard Hi-Yield Hybrid eggs, that hatchability was changing with the increasing age of the parent stock. Reijrink et al. (2009) reported that the duration of storage time before incubation affected the percentage of hatching of Cobb broilers.

In the study of Dale Gillette (1977) the Emden goose eggs showed 73.4% hatchability. Hatchability of eggs from Italian geese was between 68.1-75.6% in the study of Wang et al. (2002). According to Bednarczyk and Rosinski (1999), the seasons have a significant impact on the hatchability of Italian goose eggs. They found hatchability over 80% in March, April and May, while in July it was only about 60%, concerning fertile eggs.

Sauveur and de Carville (1986) found that average fertility of the Pekin duck eggs was 95%, and the hatchability was between 78-81 %. According to Sarpong and Reinhart (1985), the duck eggs hatchability increased when the eggs were sprayed during the time of hatching. According to Chowdhury et al. (2004), the season effect is very significant on the hatchability of duck eggs. El-Hanoun et al. (2012) found that the age of parent stock affects the hatchability of Peking duck eggs. Yuan et al. (2013) found significant differences between hatchability of plain and stripe patterned Peking duck eggs.

Based on the literature it can be stated that the hatching parameters of eggs produced by domestic fowl, domestic goose and domestic duck species are influenced by a number of factors. Using the knowledge above the aim of our work was to study the effects of hatchery, genotype, month of hatching and number of eggs in one hatching unit on hatchability. We have to emphasize that our study concentrated primarily on data communication, presentation and on the objective comparison of the "raw" data of registration books.

Material and methods

The research was based on the national poultry hatching database, supplied by the Department of Animal Registration and Breeding Organization of the Hungarian National Food Safety Authority. Summarizing our previous works (Bene et al., 2013, 2014), the evaluations were extended to hen, goose and duck species - altogether 17 breeds and 27 hybrids -, 16146 hatching units. Hatching data of about 274.3 million eggs were analyzed in year 2010.

The hatchability was calculated by using the following formula: (Horn, 2000).

$$\text{hatchability (\%)} = \frac{\text{viable day old chicks (pcs)}}{\text{total number of eggs being put into the incubator (pcs)}} \times 100$$

Among the influencing factors the effect of hatchery, genotype, month of hatching and number of eggs in one hatching unit was examined on hatchability. Hatching unit means one hatching cycle, namely the number of eggs being put into the incubator(s) at the same time in one hatchery. Based on the size of hatching units (number of eggs in one hatching unit) different groups were formed. These, as well as the basic statistical parameters calculated in our work are shown in Table 1 for the various species. The hatching month was determined by the starting date of incubation of eggs.

The effects of factors on hatchability were examined by univariate analysis of variance (General Linear Model, GLM) for the three species separately. During our research the hatchery, genotype, hatching month, and number of eggs in one hatching unit were considered as fixed effects. The used three models were written as follows:

$$\hat{y}_{ijkl} = \mu + H_i + G_j + M_k + I_l + e_{ijkl}$$

(where $\hat{y}_{ijkl}$ is the hatchability of hen, goose or duck eggs, which hatched in „i" hatchery, in „j" genotype and in „k" month with „l" unit size; μ = overall mean value; H_i = the effect of hatchery; G_j = the effect of genotype; M_k = the effect of hatching month; I_l = the effect of number of eggs in one hatching unit; e_{ijkl} = residual).

In those cases, where the F-test showed significant difference, Tukey-test (for different number of elements) was used to reveal the differences between levels of factors.

Phenotypic correlation coefficients were calculated on hatching time, hatchability and number of eggs in one hatching unit for each species separately.

Preparation of data was done with the help of Microsoft Excel 2003 and Word 2003 programs. SPSS 9.0 (1998) statistical software was used for the univariate analysis of variance and correlation analysis.

Table 1. Basic statistical parameters of the examined database

Parameters	Hatching database			
	Hen	Goose	Duck	Total
Total number of hatching units (N)	8625	3829	3692	16146
Hatching unit groups*:				
1	2203	499	868	3570
2	2015	1240	792	4047
3	1710	793	892	3395
4	1058	482	500	2040
5	779	305	245	1329
6	447	510	150	1107
7	413	-	245	658
Least amount of eggs in one hatching unit (pcs)	11	6	291	6
Most eggs in one hatching unit (pcs)	231000	21180	36454	231000
Average number of eggs in one hatching unit (pcs)	27433	2337	7772	12514
Total eggs inlaid in hatchers (rounded to thousand pcs)	236611	8948	28695	274254
All hatched eggs - number of day old chicks (rounded to thousand pcs)	181088	5586	19805	206479
Hatchability (%)	^{a}75.02	^{b}60.69	^{c}66.81	P<0.01
- s	13.08	15.86	12.71	
- cv%	17.44	26.13	19.02	
- minimum	0.03	1.75	3.12	
- maximum	100.00	100.00	91.90	
Hatching time (day)	^{a}21.61	^{b}30.07	^{c}28.40	P<0.01
- s	0.51	0.49	0.50	
- cv%	2.38	1.61	1.76	
- minimum	19.00	28.00	26.00	
- maximum	24.00	32.00	30.00	

treatments without the same superscript differ significantly (P<0.05)
*number of eggs in hatching unit group are as follows: hen: 1. ≤4999, 2. 5000-19999, 3. 20000-34999, 4. 35000-49999, 5. 50000-64999, 6. 65000-79999, 7. 80000≤; goose: 1. ≤500, 2. 500-1499, 3. 1500-2499; 4. 2500-3499, 5. 3500-4499, 6. 4500≤; duck: 1. ≤3999, 2. 4000-6499, 3. 6500-8999, 4. 9000-11499, 5. 11500-13999, 6. 14000-16499, 7. 16500≤

Results and discussion

The effects of the studied factors on hatching of eggs laid by hens, domestic ducks and domestic geese, and the percentage of each factor in the phenotype are presented in Table 2. The impact of all factors demonstrate P<0.01 significance level in the case of all three species.

Importance order of these factors was different species by species. Regarding domestic fowl the role of the examined factors on hatching was as follows: number of eggs in one hatching unit had dominant effect (65.83%), hatchery (17.77%), genotype (8.89%) and hatching month (3.73%) had smaller role. In contrast, regarding domestic geese species the influence of hatching month (36.54%) and hatchery (34.22%) on hatchability was nearly the same, and the number of eggs in one hatching unit (17.66%) and genotype (10.76%) had smaller role. In the case of domestic duck species, genotype (39.34%) was the most influential factor on hatching, followed by hatchery (31.76%), the number of eggs in one hatching unit (19.49%) and hatching month (8.52%).

Table 2. The effect and rate of different factors on the hatchability

Factor	Hen		Goose		Duck	
	P	%	P	%	P	%
Hatchery	<0.01	17.77	<0.01	34.22	<0.01	31.76
Genotype	<0.01	8.89	<0.01	10.76	<0.01	39.34
Hatching month	<0.01	3.73	<0.01	36.54	<0.01	8.52
Number of eggs in one hatching unit	<0.01	68.53	<0.01	17.66	<0.01	19.49
Error	-	1.07	-	0.82	-	0.89
Total	-	100.00	-	100.00	-	100.00

Hatchability showed significant differences between the individual hatcheries in all of the three species. The difference between hatcheries showing minimum and maximum hatchability levels was 20-35%. The lowest hatchability was found in those hatcheries, where the average hatching time was the longest.

Hatchability of different species and genotypes is shown in Table 3. Observing domestic fowl, the hatchability of the New Foxy Chick (95.74%) and the Red Master S757 (91.58%) was exceptional. Their results were 10% higher than the average of the population (82.96%). Among mixed-use types the New Hampshire (88.52%), while among meat hybrids the Hubbard JA57 (89.65%) showed the best results. The lowest level of hatchability (75.78%) was found in the case of the Shaver Rusticbro meat type hybrid. Comparing the results, the levels of hatchability we found, were either lower or the same as the levels presented in the scientific literature. Van de Ven et al. (2009) and Ulmer-Franco et al. (2010) observed much higher levels of hatchability in the case of Ross 308 and Cobb 500. Meanwhile O'Dea et al. (2006), Elibol and Brake (2008), and Reijrink et al. (2009) compared different Hubbard and Ross hybrids and found very similar hatchability levels as we did.

Observing domestic goose genotypes, the best hatchability (71.69%) was experienced in the Hungarian Lowland White type, the rate was much (10%) higher than the average of the goose population (61.56%). There were some other types with remarkable levels of hatchability, such as the Golden Goose W hybrid (68.11%), the White Hortobágy (67.74%), and the Bábolna Emden White (67.14%). The Anabest G liver type hybrid showed the lowest (55.26%) hatchability level. The hatchability levels being revealed in our observations were lower than those can be found in the scientific literature (Dale Gillette, 1977; Bednarczyk and Rosinski, 1999; Wang et al., 2002).

Table 3. The hatchability of eggs of different genotypes

Species	Type, breed or hybrid	Genotype	Hatchability±SE (%)
Hen	Mixed type hen breeds	Transylvanian Naked Neck	80.39±2.32
		White Hungarian	83.87±3.34
		Plymouth White	84.84±3.86
		Partridge Color Hungarian	80.92±3.52
		Speckled Hungarian	79.24±2.36
		New Hampshire	88.52±3.70
		Yellow Hungarian	84.75±3.24
	Mixed type hen hybrids	Bábolna Tetra-H	80.68±1.09
		Red Master S757	91.58±1.42
		Shaver Avicolor	81.94±1.24
		Shaver Farm	80.19±0.68
		Shaver Farm Master	79.14±1.14
	Meat type hen hybrids	Cobb 500	81.85±0.74
		Cobb Sasso 150	83.01±2.17
		Hubbard Flex	79.25±0.86
		Hubbard JA57	89.65±2.57
		Hubbard F15	79.34±1.33
		New Foxy Chick	95.74±1.83
		Ross 308	79.54±0.69
		Shaver Master Gris	83.48±1.17
		Shaver Redbro	81.46±0.88
		Shaver Rusticbro	75.78±2.56
Goose	Mixed type goose breeds	Babat Hungarian Upgraded	59.18±2.08
		White Hortobágy	67.74±1.27
	Meat type goose breeds	Hungarian Lowland White	71.69±1.40
		Bábolna Emden White	67.14±1.11
		Orosháza Hungarian	55.76±1.59
	Liver type goose breeds	Babat Grey Landes	56.51±1.14
		Bábolna Grey Landes	65.76±2.32
		Kolos Grey	56.00±1.65
		Orosháza Grey	59.80±1.32
	Meat type goose hybrids	Golden Goose W	68.11±1.29
		Grimaud G35	60.33±1.95
		Kolos White	62.55±1.43
		Lippitsch	62.09±0.98
	Liver type goose hybrids	Anabest G	55.26±1.24
		Gourmaud SI 14	55.32±1.22
		Maxipalm	61.66±0.76
Duck	Meat type duck breed	Szarvasi K-94	67.24±0.71
	Meat type duck hybrids	Cherry Valley Super M3	64.60±0.72
		Gourmaud ST5 Medium	66.84±1.66
		Gourmaud ST5 Heavy	69.21±1.92
		Grimaud Star 53	61.69±1.10
		Wiesenhof Vital	57.97±0.81

Comparing domestic duck genotypes, the highest hatchability level (69.21%) was experienced in the case of Gourmaud ST5 Heavy hybrid. The Szarvasi K-94 breed (67.24%) and the Gourmaud ST5 Medium hybrid (66.84%) also had remarkable hatchability levels. The Wiesenhof Vital meat type hybrid had the worst result (59.97%). Our experienced hatchability levels were either similar (Chowdhury et al., 2004; El-Hanoun et al., 2012), or lower (Sarpong and Reinhardt, 1985; Onbaşılar et al., 2011) than those we found in the references.

The effect of hatching month on hatchability is presented in Table 4 and Figure 1. Regarding domestic fowl there was only 2.33% difference between the two months showing minimum and maximum hatching rate.

Table 4. Hatchability according to hatching month

Hatching month	Hen		Goose		Duck	
	Mean	SE	Mean	SE	Mean	SE
January	^{a}82.13	0.89	^{ab}64.71	0.78	^{a}67.31	0.76
February	^{a}81.93	0.85	^{a}65.67	0.68	^{ab}66.97	0.73
March	^{bc}83.19	0.84	^{a}65.64	0.68	^{cde}64.78	0.74
April	^{d}84.26	0.85	^{bc}63.60	0.66	^{cf}63.65	0.76
May	^{cd}83.94	0.87	^{d}58.78	0.66	^{bde}65.50	0.76
June	^{abe}82.65	0.93	^{e}51.97	0.76	^{cdf}63.84	0.82
July	^{ab}82.13	0.94	^{e}52.63	1.04	^{g}61.33	0.81
August	^{abc}82.93	0.95	^{df}59.30	1.07	^{fg}62.07	0.85
September	^{abcd}83.02	0.97	^{bfg}62.29	1.28	^{fg}62.05	0.88
October	^{cde}84.02	0.99	^{acg}64.11	1.34	^{ae}65.99	0.91
November	^{abc}82.86	0.99	^{acg}64.16	1.14	^{ae}65.75	0.89
December	^{abc}82.48	1.01	^{ac}65.81	1.16	^{ae}65.87	0.91
Corr. overall mean value	82.96	1.94	61.56	0.46	64.59	0.53
P	<0.01		<0.01		<0.01	

treatments without the same superscript differ significantly (P<0.05)

Hatchability in case of domestic goose species were the lowest in summer months, namely in June and July (51.97-52.63%, respectively). Hatchability rate were significantly (P<0.01) higher in the winter, spring and summer months. Between the two months with extreme values the difference was remarkable 13.84%. A rate of 70% of the eggs in the examined 3829 hatching units was hatched in the first five months of the year. Our results are consistent with the statements of Bednarczyk and Rosinski (1999), thus the season has a great impact on the hatchability of goose eggs. Observing hatchability of duck eggs, the lowest rates were found in summer, especially in July and August (61.33-62.07%, respectively). Our results are similar to the findings of Chowdhury et al. (2004), and Kamar (1961), thus the month of hatching has significant effect on the hatchability of duck eggs.

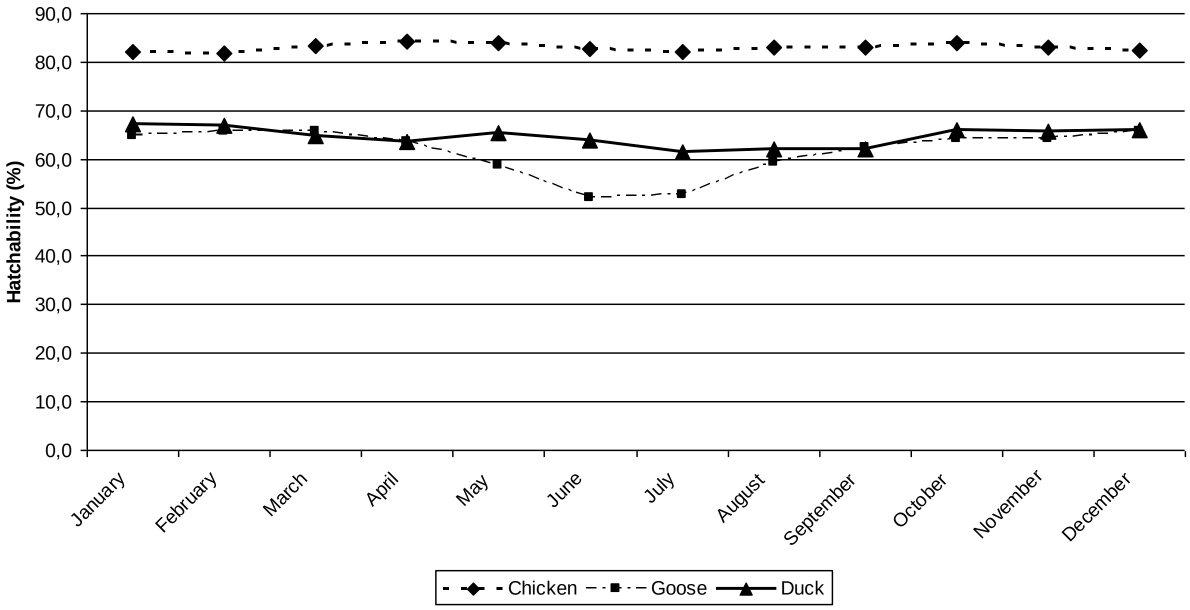

Figure 1. The hatchability in different months

Hatchability linearly increased with the number of eggs in one hatching unit concerning all poultry species (Table 5). It can be concluded that hatchability of eggs in larger units, possibly in large scale conditions, is 8-10% higher than in smaller units. These results are similar to the statements of Heier and Høgasen (2001).

Table 5. The hatchability according to number of eggs in one hatching unit

Hatching unit group*	Hen		Goose		Duck	
	Mean	SE	Mean	SE	Mean	SE
1	^{a}76.23	0.75	^{a}56.40	0.72	^{a}60.09	0.63
2	^{b}78.78	0.83	^{b}60.15	0.55	^{b}61.73	0.67
3	^{c}82.23	0.86	^{b}61.00	0.59	^{c}63.58	0.66
4	^{d}84.64	0.89	^{c}63.50	0.72	^{d}65.18	0.71
5	^{e}85.75	0.93	^{c}64.77	0.86	^{e}67.31	0.85
6	^{e}86.95	1.01	^{c}63.51	0.73	^{de}66.48	1.03
7	^{e}86.14	1.03	-	-	^{e}67.76	0.94
Corrected overall mean value	82.96	1.94	61.56	0.46	64.59	0.53
P	<0.01		<0.01		<0.01	

treatments without the same superscript differ significantly (P<0.05)
*number of eggs in hatching unit group are as follows: hen: 1. ≤4999, 2. 5000-19999, 3. 20000-34999, 4. 35000-49999, 5. 50000-64999, 6. 65000-79999, 7. 80000≤; goose: 1. ≤500, 2. 500-1499, 3. 1500-2499; 4. 2500-3499, 5. 3500-4499, 6. 4500≤; duck: 1. ≤3999, 2. 4000-6499, 3. 6500-8999, 4. 9000-11499, 5. 11500-13999, 6. 14000-16499, 7. 16500≤

None of the poultry species showed any significant correlations between the number of eggs in one hatching unit, hatching time and hatchability (Table 6). The correlation coefficients obtained were statistically reliable, but they only show a very loose relationship (r= -0.17-0.27; P<0.01). Our results, parallel with the findings in the references (Ichione, 1972; Ulmer-Franco et al., 2010), suggest that hatchability is decreasing with the increase of hatching time.

Table 6. The calculated correlation coefficients

Correlation coefficients		Hatching time			Hatchability		
		Hen	Goose	Duck	Hen	Goose	Duck
Number of eggs in one hatching unit	Hen	**0.23			**0.13		
	Goose		**0.10			**0.18	
	Duck			**-0.08			**0.27
Hatching time	Hen				**-0.16		
	Goose					**-0.17	
	Duck						**-0.15

**P<0,01

Conclusions

The following statements can be settled after analyzing 16146 hatching unit data of altogether 44 genotypes - 17 breeds and 27 hybrids - of three poultry species.

The overall mean values of hatchability are as follows: domestic fowl 82.96%, domestic goose 61.56% and domestic duck 64.59%, respectively. Based on our results it is presumable that hatchability can be optimal in the case of all tested genotypes if the hatching environment and technology, and the hatching equipment are appropriate.

The hatchery had significant effect on hatchability in the case of all poultry species. The incubation is a technologically very carefully programmed process, during which a number of parameters (temperature, humidity etc.) are changed at specific manner in the specific phases. Our database included the data of numerous hatcheries. All of them might have differed from one another in either the level of technology and management, or the settings, or the programming of hatching time.

Similarly to the literature information, the mixed-use genotypes showed better hatchability than meat-, or liver-type hybrids. The reason for this may be that the type of meat and liver hybrids have been selected primarily for meat, or liver production, and less attention has been devoted to reproduction. It is well known that there are negative correlations between the traits of meat- and liver-production and reproduction.

It can be concluded that hatchability of eggs in larger units is 8-10% higher than in smaller units. Hatching large number of eggs at the same time requires large scale conditions, industrial technology and incubators, in which the environment of hatching can be easily regulated. The technological conditions of small scale farms are less appropriate. It is also possible that the smaller farms receive lower quality hatching eggs for incubation than large-scale hatcheries.

Hatchability in case of domestic goose species was determined primarily by hatching month. During the summer months - especially in June and July - the hatchability was almost 10% lower than the average of the population, and it was about 15% lower than in the late winter and early spring period. This is probably maybe caused by the seasonality of reproduction of the goose species. Geese are originally migratory birds, and the growing length of daylight will result in a regression of the gonads (so called "photorefracter" phase), which would result in reduction of quantity and quality of germ cells, which ultimately leads to lower hatchability. Besides, intensive hatching egg production is predominant in chicken production, relatively frequent in duck and rare in goose, so environmental effects are the highest in goose hatching egg production, increasing the seasonality. These results are entirely consistent with the existing literature information (Péczely et al., 1984, 1993).

The results of our research suggest that hatchability is decreasing with the increase of hatching time.

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CLIMATE CHANGE AND ITS EFFECT ON SOME PHYSIOLOGICAL PROCESSES OF THE AGRICULTURAL PLANTS

A literature review

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Abstract

Climate change is one of the most important issues because of its impacts the human being. Greenhouse gases (GHGs), among others, including carbon dioxide (CO_2), nitrogen dioxide (NO_2), and methane (CH_4) are the main components causing global warming. Different kinds of sources exist; the two most important ones are industrial emission and agricultural activities. Increasing Earth's surface temperature, changing precipitation and losing coastal land due to sea level increase are the phenomenon of climate change that can be easily identified every day. Agricultural activities are strongly associated with the climatic conditions, because most of the plant's physiological processes such as photosynthesis, stomatal resistance, canopy temperature and flowering time are affected by environmental factors as light, temperature and CO_2 concentration. Therefore, understanding of these phenomena and its effects on agricultural activities will assist us in finding good solutions for better adaptation to climate change.

Key words: Global warming, climate change, greenhouse gases, temperature, precipitation, photosynthesis, stomatal resistance, flowering time.

1. Introduction

In this decade we can hear a lot of information about global warming and its actual effects on our planet's life. Global warming is currently a widely discussed topic on which opinions greatly vary (Specht et al., 2016) and it is also one of the most important challenges currently facing the world (Aydin, 2010). On one side, there are climatologists, who are convinced that global warming will lead to a climatological catastrophe. On the other side, few references say that the temperature change is caused by natural climate fluctuations (Foong, 2006; Knox, 1999; Barker et al., 1999). The adverse impacts of global warming that can be catastrophic and a potential threat to the human existence, an important environmental issue is affecting entire ecosystems in the world (Melillo, 1999). These impacts include wide-scale socioeconomic changes, such as degradation and losses of natural resources, increased risk of hunger and above all waves of human migration and dislocation, especially lower agricultural production and lower crop yields (El-Sharkawy, 2014).

The GHGs including water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) that are the main contributors to climate pattern change (Gul et al., 2009; GCRIO, 2011; Ozbayrak et al., 2011; EPA, 2013a,b), primarily responsible for current global warming (Brysse et al., 2013). They are expected to raise global average temperature over the next century by 1.8-4.0 ^{0}C, with the largest increases at higher latitudes (IPCC, 2007). The most gases emission from the agricultural activities are CO_2, CH_4, and N_2O which are the most potent long-lived GHGs (Robertson et al., 2004; IPCC, 2007) with the existing atmospheric water vapor trap the latent heat in the form of infrared radiation (El-Sharkawy, 2014).

2. Greenhouse gases (GHGs)

2.1 Carbon dioxide (CO_2)

The temperature of Earth increases significantly with CO_2 concentration. Between 1860 and 1990 global warming was 1 ^{0}K, CO_2 contributed only 0.4 ^{0}K (Onorato et al., 2011). Physically based, mathematical climate models known as General Circulation Models, indicate, depending on the model used, that doubling the level of atmospheric carbon dioxide from 350-360 ppm will raise the average global surface temperature by 1.5-4.5 ^{0}C (Climate Change, 1992). This atmospheric CO_2 concentration will probably reach 700 ppm that can result in the rising of Earth's temperature from 1.5 to over 5 ºC by the end of this century (Metz et al., 2007; Da Matta et al., 2010).

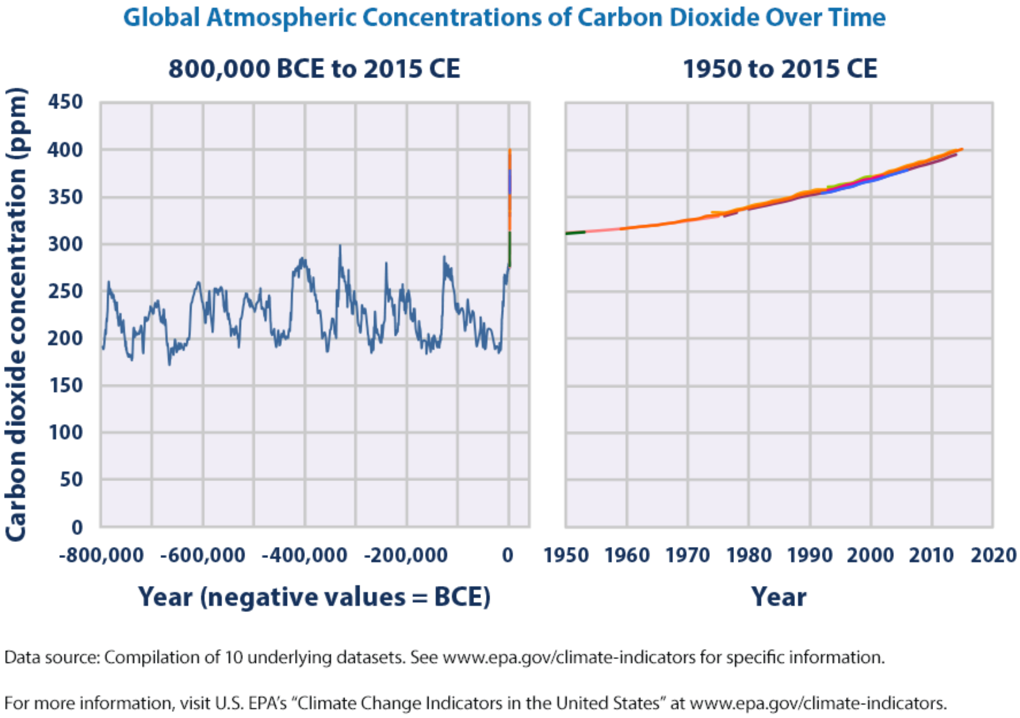

*Figure 1. Concentration of Carbon dioxide in past 800000 years before 1950 C.E and from 1950 to 2015 C.*E (https://www.epa.gov/climate-indicators/climate-change-indicators-atmospheric-concentrations-greenhouse-gases (date 16/8/2016))

According to United States Environmental Protection Agency (EPA, 2016) (Figure 1) trends in changing atmospheric CO_2 over the past 800,000 years, atmospheric CO_2 concentration changed between 180 ppm (800000 years before 1950 C.E) and 280 ppm (400000 years before 1950 C.E). From the preindustrial concentration of about 280 ppm, CO_2 concentration increased steadily to 400 ppm since the 2nd half of the 19th century and in the 20th century (in 2015), CO_2 has accounted for more than 50% of all GHGs and is expected to account for 55 % or more over the 21st century (Houghton et al., 1990; Keeling et al., 1989; Liu et al., 1995). About 50–60 % of total carbon emissions originate from consumption of fossil energy sources, such as coal, natural gas, and oil. From 1850 to 1980, about 150–200 billion tons of carbon were released from the burning of fossil fuels. Humans emitted 6 gigatons of carbon per year into the atmosphere from fossil fuel burning and cement production during the 1990's, yet only about half of this amount of carbon accumulated in the atmosphere (IPCC, 2001; Pataki, 2003). The average GHG emissions (CO_2) per unit of product (grain yield) from 1964 to 2005 were estimated to be 268 t CO_2/t grain. The highest GHGs emissions per annum were 386 t CO_2/t grain of cereal maize occurring in both 1983 and 1988 when both the average grain yields and the total harvested area were calculated in cereal maize field (Grace et al., 2011). Every year, current estimates are about 10–12 billion tons of carbon being released into the atmosphere, thus, contributing to global warming and climate change (Dale et al., 1993). In 2011, the top ten emitters, in terms of billions tons of CO_2 annually, were listed in a decreasing order: China (8.715), USA (5.490), Russia (1.788), India (1.725), Japan (1.180), Germany (0.748), Iran (0.624), South Korea (0.610), Canada (0.552), Saudi Arabia (0.513) (http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html#.V31Z0fl97IU). The current loading of CO_2 to the atmosphere is 4.1 Pg C $y^{-}1$ (Canadell et al., 2007).

2.2 Nitrous oxide (N_2O) and methane (CH_4)

Nitrous oxide and methane are significant long-lived GHGs and are the main long-lived greenhouse gases that result with global warming potential (GWP) 298 and 25 times that of CO_2 (Wassmann and Dobermann, 2006; Myhre et al., 2013; Robertson et al., 2000; Kreye et al., 2007; IPCC, 2007). Agricultural activities release significant amounts of CH_4 and N_2O into the atmosphere (Cole et al., 1997; Paustian et al., 2004). Globally, anthropogenic sources of N_2O and CH_4, which are dominated by agriculture, increased by nearly 17 % from 1990 to 2005 (Robertson and Grace, 2004; Forster et al., 2007) and 50-60 % of total anthropogenic CH_4 and N_2O emissions, respectively in 2005 (Chen et al., 2014). About 85 % of N_2O of the global flux from human sources is from agriculture with about 50 % of the global flux from de-nitrification and nitrification in agricultural soils (IPCC, 2007b). CH_4 is produced from the biological decomposition of organic materials under anoxic conditions and can be biologically oxidized in dry soils (Mosier et al., 1998a; Garcia et al., 2000). The input of nitrogen (N) fertilizers into agricultural systems are considered the dominant source of N_2O emissions from agricultural soils (Mosier et al., 1998b; Mosier and Kroeze, 1999; Grant et al., 2004; Cai et al., 2007; Bouwman 1996; Brown et al. 2000; Maggiotto et al., 2000). Moreover, N_2O emissions are projected to increase by 35-60 % till 2030 due to increasing using of N fertilizer in cultivation and animal manure production (FAO, 2002).

Rice fields have been identified as a major source of increasing atmospheric CH_4, accounting for approximately 15-20 % of global CH_4 emissions from all sources. N_2O is also produced from rice fields because of mid-season drainage and moist irrigation (Wang et al., 2013). According to Nishimura et al. (2004) over 80 % of a whole year's GWP by CH_4 and N_2O emission was contributed during rice cultivation from a paddy field used a Japanese typical conventional water and fertilizer management system. In the NPK treatment, CH_4 emission was comparably lower at the initial rice growth stage and increased with the development of soil reductive conditions and rice growth. Net CH_4 emission rates almost dropped to near zero values at the grain maturation stage, irrespective of the treatment (Kim et al., 2013). It is a well-known fact that CH_4 emitted from rice fields is transported mostly (60–90 % of total CH_4 emission) through the aerenchyma of rice plants rather than by molecular diffusion of the water–air interfaces or the release of a gas bubbles (Butterbach-Bahl et al., 1997; Aulakh et al., 2000). Since the apparent growth of the rice plant is maximized at the reproductive stage, the well-developed aerenchyma might also provide an effective channel for CH_4 gas to exchange between the atmosphere and the anaerobic soil (Nouchi et al., 1990; Butterbach-Bahl et al., 1997). In addition, the higher release of root exudates, which are good substrates for methanogenic archaea (Pusatjapong et al., 2003) increased CH_4 emissions at this stage (Aulakh et al., 2001). Vegetable cropping systems represent for one of the most intensively managed agricultural systems due to their high N fertilizer inputs, frequent irrigation and intensive cropping rotations (multiple harvests within one year). Annual N fertilizer inputs are 3-4 times greater in vegetable fields than in fields used for other crops (Huang et al., 2004; Ju et al., 2006).

3. Signs of climate change

3.1 Temperature rise

According to the Environmental Protection Agency, global warming is defined as the recent and ongoing rise in earth surface temperature (Gul et al., 2009; GCRIO, 2011; Ozbayrak et al., 2011; EPA, 2013a,b). In the last century, trends in global warming, air temperature increased at the rate of 0.075 ºC per decade over the entire 1900–2000 period (Mitchell and Jones, 2005; Girvetz et al., 2009). Nowadays, evidence indicated that the global mean surface temperature of Earth (Figure *2*) has increased over the last century by approximately 0.85 ^{0}C between 1880 and 2012, and surface temperatures across the globe are predicted to rise an additional 0.3-4.8 ^{0}C by the end of this century (IPCC, 2014); in the pre-industrial temperature was predicted that was increasing, in the range of 1.4-5.8 ^{0}C by the end of the 21st century. This increasing in global mean temperature might be reached by 2050–2080 if the emission levels of trace greenhouse gases keep rising (Metz et al., 2007).

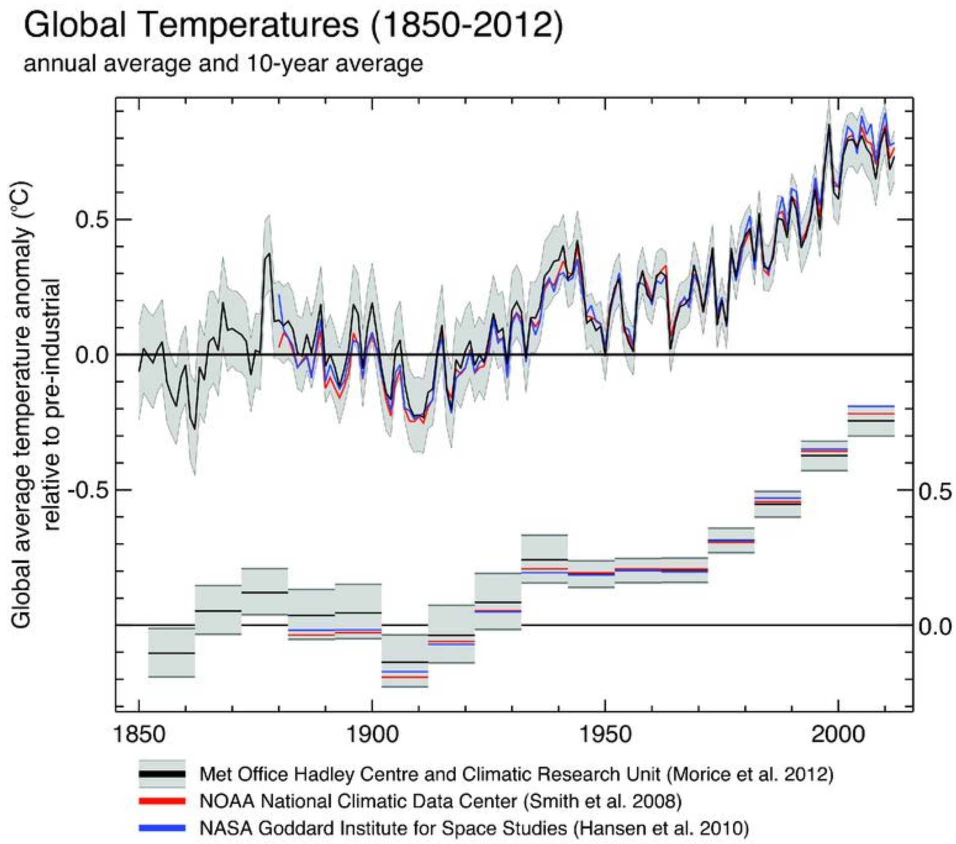

Figure 2. Observed globally averaged combined land and ocean surface temperature anomaly 1850-2012 (IPCC, 2014)

The first decade of the 21st century was actually the warmest on record (NASA, 2010; SMHI, 2010). It is clear that the climate is changing and the temperature is projected to undergo a relatively high rise in Sweden compared to the overall global mean change (Hansen et al., 2006; SMHI, 2010; Leijonhufvud et al., 2010). Trust, warming trends varies among regions of the world, Jones and Wigley (1990) analyzed available land and marine meteorological records from 1967 to 1986 and they noted that most regions in both Northern and Southern hemispheres had experienced marked warming. Few parts in the Northern Pacific and Atlantic Oceans were the only exception that experienced cooling to some extent (Otsenki, 1992; Houghton et al., 2001). Analysis of expected regional climate in the Carpathian Basin using ENSEMBLES model simulation were described by Miklos et al. (2010) the results suggested that the temperature of the selected region is expected to increase about 1-2 ^{0}C, and 3-4 ^{0}C for 2021-2050, and 2071-2100, respectively. Based on the project PRUDENCE (Bartholy et al., 2007b) expected climate change estimations for the Carpathian basin the 2071-2100 period is expected the largest warming in summer time. The mean annual temperature in Yunnan Province is projected to increase by an average of 1.6-2.5 ^{0}C by 2050 (Zomer et al., 2015). Tibetan alpine meadows are particularly sensitive to global climate change; the average surface temperature in Tibet is expected to increase 2 ^{0}C more than the global average by 2050 (Thompson et al., 2000). Recent analysis across 16 locations throughout both hemispheres and seasons predicted variable increases in seasonal air temperature in 2050 as compared to averages in 2000 (Jaggard et al., 2010). All locations are anticipated to become warmer. For example, the mean spring temperature in Manitoba (Canada) will increase from 3.7 °C to 6.4 °C; similar increases are predicted for Harbin, northern China, and Tambov, Russia. Urban areas are a subject to increased temperatures due to the influence of global warming and urbanization (Arnfield, 2003; Oke et al., 1991; Oke, 1987) and various countermeasure techniques have been studied.

In a global warming perspective, increasing earlier and warmer in springs, together with slightly warmer summers have waited. Wang et al. (2014) found that temperature the sensitivity decreased with the increase of spring temperature variability. Most meteorological stations in Europe, East Asia, and Alaska recorded a significant increase in annual maximum and minimum temperature specifically during the winter and spring. However, summer warming remains not significant (Schwartz et al., 2006). Global climate changes and associated increased winter temperatures in the Northern latitudes (Klimov et al., 2004). The air temperatures in Harbin are predicted to rise from 4.8 °C to 8.8 °C during autumn (Jaggard et al., 2010).

However, other projected estimates suggest about the nature of global warming that indicates the likelihood of an asymmetric change in temperature, where night-time minimum temperature increases more rapidly than the day-time maximum temperature (Dhakhwa and Campbell, 1998). There is substantial spatio-temporal, seasonal, and inter-annual variability in the warming trend. A faster increase in night-time temperature than day-time temperature was reported for Jiangsu province (Yuan et al., 2007). Recently, a trend of increasing differential between day-time and night-time temperatures has been observed in the literature, with more focus on higher nighttime temperature (Prasad et al., 2008; Prieto et al., 2009; Mohammed et al., 2009, 2011)

3.2 Precipitation

Other phenomena associated with climate change such as rainfall variability and higher drought frequency are becoming increasingly intense (El Yaacoubi et al., 2014). In addition, it is predicted that there will be longer periods without rain, followed by heavier rainfall events (Pitman and Perkins, 2008). Increased temperature has a large impact on stream flow. For example, a 1 ^{0}C increase in temperature can result in a 15 % decrease in the stream flow in the Murray-Darling Basin (Cai and Cowan, 2008). In Australia, the climate change is predicted to cause increasing of 4-5 ^{0}C in temperature by 2100, along with a decrease in rainfall of between 7.6 and 22.8 %, depending on the region (CSIRO, 2008). The expected change of annual total precipitation is not significant in the Carpathian Basin. The winter and autumn precipitation is likely to increase while summer and spring precipitation is likely to decrease during the 21st century (Miklos et al., 2010; Bartholy et al., 2007a, 2007b; Pieczka, 2012).

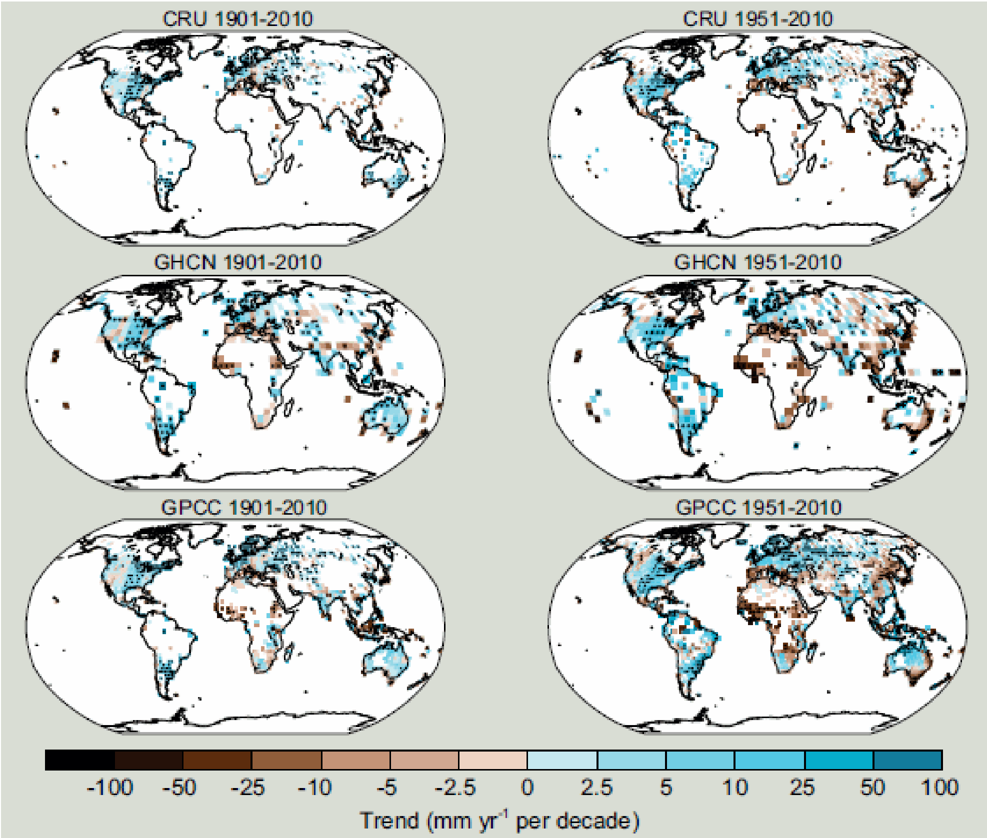

Figure 3. Maps of observed precipitation change over land from 1901 to 2010 (left-hand panels) and 1951 to 2010 (right-hand panels) from the Climatic Research Unit (CRU), Global Historical Climatology Network (GHCN) and Global Precipitation Climatology Centre (GPCC) data sets

Source: IPCC (2013)

Figure 3 shows the precipitation change averaged over global land areas since 1901 is low prior to 1951 and medium afterwards. It has been reported that global precipitation over land has increased by 3 % over the last century (Gerten et al., 2008). However, local precipitation trends vary considerably (IPCC, 2013) and precipitation has decreased since 1950 over many areas (Dai, 2013). Averaged over the mid-latitude land areas of the Northern Hemisphere, precipitation has increased since 1901. For other latitudes area-averaged long-term positive or negative trends have low confidence. There are likely more land regions where the number of heavy precipitation events has increased than where it has decreased. The frequency or intensity of heavy precipitation events has likely increased in North America and Europe. On other continents, the changes in heavy precipitation events are at most medium. Changes in the global water cycle in response to the warming over the 21st century will not be uniform. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase, although there may be regional exceptions, projected changes in the water cycle over the next few decades show similar large-scale patterns to those towards the end of the century, but with smaller magnitude.

4. Impact of the rise of GHGs and climate change on some agricultural crops

4.1 Physiological processes

- Photosynthesis

Photosynthesis is the only process capable of utilizing the energy of sunlight to produce organic matter from inorganic elements. Atmospheric carbon dioxide, the basic material of photosynthesis, reaches the site of the biochemical process through the stomata (Anda and Kocsis, 2007). Elevated CO_2 enhances leaf photosynthetic rates of most field crops regardless of their photosynthetic pathway (i.e., C_3, C_4, and CAM), while reducing stomatal conductance (Kimball, 1983; Kimball et al., 2002). Higher atmospheric CO_2 concentration may influence positively to plant production once the substrate for photosynthesis and gradient increase between the ambient air and mesophyll cells (Anda and Kocsis, 2007). For example, a doubling of atmospheric CO_2 concentration may increase the photosynthetic rate of plants, always increases crop productivity (Allen, 1990; Kimball, 1983a,b; Porter, 1992; Rogers and Dahlman, 1993). Increasing concentration of atmospheric CO_2 increases the rate of photosynthesis in C_3 plant species such as small grains, legumes, most trees and root crops grown under controlled conditions and reduces amount of used water in both C_3 and C_4 species such as corn sugarcane, sorghum, and millet (Brown and Rosenberg, 1997). The increase in net photosynthesis in C_3 species has been reported as high as 50-100 % when CO_2 concentration doubles compared to 10 % in C_4 species (Van et al., 1977). Kimball (1983a, 1983b, 1986) estimated that a doubling CO_2 concentration, holding other factors constant, could lead to a 34±6 % increase in agricultural yields of C_3 plants and a 14±11 % in C_4 plant with a 95 % confidence interval.

Fodor and Pásztor (2010) used the 4M crop simulation model to quantify some indices of the agro-ecological potential of Hungary and its future development under climate change. Their results indicate that the yields of the spring crop as maize, sunflower, etc. will decrease while higher yields might be expected for the autumn crops. Under high temperatures during the growing season significantly increased the proportion in the total yield of deformed tubers and tubers sprouted in the soil prior to harvest (Gaba and Tsror, 2014). Lobell and Field (2007; Wand et al., 1999; Ainsworth and Rogers, 2007) argued that the yield loss associated with global warming for C_3 crops (e.g., wheat and common beans) may reach values up to 6 % per ^{0}C and that for C_4 crops (e.g., maize, sorghum) by up to 8 %. Based on a systematic assessment, Knox et al. (2012) showed that by the 2050s, the yields in Africa could decline by up to 17 % (wheat), 5 % (maize), 15 % (sorghum) and 10 % (millet). For the southeast region of the United States, Carbone et al. (2003) demonstrated that predicted future climatic conditions decrease sorghum productivity by up to 51 %. Lobell et al. (2011) estimated that climate change from 1980 to 2008 has already reduced global production of maize by 3.8 % and wheat by 5.5 % relative to a counterfactual without climate change (Lizumi and Ramankutty, 2015). Higher leaf temperatures may have important consequences on the longevity and photosynthetic capacity of the individual leaves and at the canopy level, as aging may be accelerated and shortening the growing season (Ellis, 1990; Kimball et al., 1995; Van and Goudriaan, 1996).

- Stomatal resistance

The study of stomata is the primary importance in plants, due to their role in connecting photosynthesis and transpiration with the basic material for photosynthesis, CO_2, enters the plant tissues through the stomata, from where water vapor leaves the leaf (Anda and Kocsis, 2007). The larger the diameter of the stomata, the more CO_2 can enter the plants, but higher the water loss. In a moderate climate, the plants partially close their stomata, especially in the afternoon hours because of the limiting soil water availability (Anda, 2006).

CO_2 as a component of the atmosphere also has an influence on stomatal movements, thus plays an important role in impacting assessment of the global warming (Morison and Gifford, 1983; Cure and Acock, 1986; Dickinson et al., 1991; Long, 1991; Kimball et al., 1993; Jackson et al., 1994; Van den Geijn and Goudriaan, 1996; Bunce, 2004). This is not surprising because the aperture of the stomata determines the amount of incoming CO_2 and outgoing water vapor (Anda and Dióssy, 2010). The increasing level of CO_2 concentration has an effect through modification of stomata behavior on photosynthesis, water use efficiency and crop yield. Stomatal movements may change in response to elevated CO_2. Two responses of crops to elevated CO_2 are an increase in the rate of photosynthesis and a decrease in stomatal conductance (Van et al., 1977). The partitioning of net radiation on the leaves under elevated CO_2 concentration is modified due to a decrease in stomatal conductance, which causes a decrease in transpiration leading to an increase in leaf temperature (Kimball and Idso, 1983;Jones et al., 1985; Streck, 2005). However, decreasing the stomatal activity can be considered as an advantageous side of global climate change on the plant's water balance because they keep water inside the leaf undergo hot day (Anda and Dióssy, 2010). Therefore, it may be associated with the increased stomatal resistance resulted from growth in ambient CO_2 concentration. Transpiration is not only affected by the stomatal opening but also by the driving force for exchanging the water vapor from the leaf surface to the surrounding atmosphere. The water vapor pressure was decreasing by the increasing CO_2 level (Anda and Kocsis, 2007).

- Canopy temperature

According to Anda (2006) the cob layer (canopy) temperature is important in plant studies, since the assimilatory (or transpiration) surface is the most developed and the intensity of physiological processes are the highest at this level and they also have the capability of modifying local microclimate has come into focus on the issue of adaptations to climate change. If the canopy is sufficiently extensive, the plants may have positive feedback on the process of global warming by enhancing the amount of energy transmitted to the surrounding air. It means that the local warming may be more intense. At canopy level, warming and elevated CO_2 strengthened the influence of an external rise in air temperature. It is cooler inside the stand, as the canopy is able to compensate for external warming. The higher CO_2 level balanced out the decrease in available soil water by decreasing the opening of the stomata. At doubled CO_2 it was observed that the higher the air temperature and the lower the sensible heat. Due to the warmer surrounding air, intensive plant cooling was required, but in the model run in Keszthely, there was sufficient water in the soil for cooling purposes (Anda and Kocsis, 2007).

The incoming radiation remains after reflection from the stand and transmission to the soil provides a source of energy for heating processes (sensible heat flux) and evapo-transpiration (latent heat flux). If there is no water limitation, the main user of energy is evapo-transpiration from the plant stand (Anda and Kocsis, 2007). The within-canopy air temperature is one of the users of sensible heat flux. The air temperature has a regulatory role and governs the plant temperature and the intensity of biochemical processes (Anda, 2006). In Hungary, the average ratio of sensible to latent heat consumption is 70:30 (Anda and Kocsis, 2007) which is why the proportion of energy bound in photosynthesis was neglected in some research on plant microclimate (Jones, 1983). Earlier study in mid 1990s that use the infrared heaters (IRH) over open-field plots to study the response of ecosystems to global warming (Harte and Shaw, 1995; Harte et al, 1995). The temperature rise of a rice canopy through IRH warming is essentially the same as the warming provided by radiant heating from the sun and sky because it directly heats the canopy. The air in and above the canopy is subsequently warmed by convective sensible heat exchange with the canopy (and cooled by latent heat exchange). If the constant of temperature rise mode of operation is used, as was done herein, the warming by IRH can be directly related to a degree of canopy warming expected through global warming (Wall et al., 2011; Kimball et al., 2011; De et al., 2011). The amount of energy required to achieve a specified increase in canopy temperature by IRH is influenced by canopy conductance in response to soil moisture conditions, light intensity, temperature, humidity, and wind speed (Kimball, 2005). Less energy is required when the stomata are closed, such as occurs under water stress or at night. However, with warmer leaves, higher vapor pressure occurs in the sub-stomatal cavities in the infrared-warmed canopies, which can create unrealistic vapor pressure gradients between the inside of the leaves and air (De et al., 2011; Kimbal, 2005).

- Flowering time

Under climate warming, plants will undergo novel selective pressures to adjust reproductive timing. Adjustment between reproductive phenology and environment is expected to be higher in arctic and alpine habitats because the growing season is considerably short. As early and late flowering species reproduce under very different environmental conditions, selective pressures on flowering phase and potential effects of climate change are likely to differ between them (Giménez-Benavides et al., 2010). According to Abu-Asab et al. (2001) flowering in angiosperms is an important phenological phase. Plants in temperate areas, such as the mid-Atlantic region of North America, are adapted to an annual seasonal cycle with a winter dormancy period that is sensitive to temperature and light. Flowering time is directly related to temperature.

To investigate potential changes in first-flowering times that were examined the first-flowering records of 100 plant species, representing 44 families of angiosperms, for 29 years of the 30-year period 1970–1999 (1984 not recorded) in the Washington, DC area. Evidence for global warming is inferred from spring advances in first-flowering in plants. The trend of average first-flowering times per year for the study group shows a significant advance of 2.4 days over a 30-year period. When 11 species exhibited later first-flowering times are excluded from the data set, the remaining 89 species showed a significant advance of 4.5 days. Significant trends for earlier flowering species range from −3.2 to −4.6 days, while those for later flowering species range from +3.1 to +10.4 days. Advances of first flowering in these 89 species are directly correlated with the local increase in minimum temperature (Abu-Asab et al., 2001). Indeed, the temperature increase is linearly correlated with earliness of flowering dates. The rate of flowering earliness varies from one species to another, although some studies have shown that this trend is not always linear (Pope et al., 2013). In the Northern hemisphere, Legate et al. (2008) underlined advances in apple (*Malus Domestica Borkh.*) flowering dates during the 1980–2011 period in France and other European countries (Legave et al., 2013). In the Southern hemisphere, Grab and Craparo (2011) confirmed flowering advances in apple through an advanced full bloom around 1.6 days/decade over the period 1973–2009. In Cordoba, an increase in mean temperature of 1 ^{0}C during March-April–May induced an advance in olive full blooming of 7.6 days (Orlandi et al., 2009) with a projected flowering advance of 6.2 days/^{0}C by the end of the twenty-first century in Western Mediterranean (Osborne et al., 2000). Concerning almond species, advanced blooming dates after warm periods of dormancy were already highlighted in Spain (Alonso et al., 2011). Early blooming cultivars have shown the higher variation in blooming dates because of a slower heat completion and more variable temperatures during February. As a consequence, late blooming cultivars would show more stable blooming dates because their higher heat requirements are quickly satisfied by the higher temperatures during March (Alonso et al., 2011). Flowering advances were similarly reported in many other fruit tree species (Lu et al., 2006; Crepin ˇ sek ˇ et al., 2012; Miller-Rushing et al., 2007; Abu-AsabMones et al., 2001).

As it is the case of growth, the largest increases in reproductive output and in changes in flowering time have been measured in cultivated C_3 plants (Jablonski et al., 2002; Springer and Ward, 2007). Most (but not all) that exhibited differences in flowering timing at elevated CO_2 display accelerated flowering. To a less extent, reproductive output of undomesticated (wild) C_3 plants also tend to increase in response to CO_2 enrichment, while flowering time responses are more variable (Springer and Ward, 2007). The effects are less clear for C_4 plants, due to more limited available information. This is an area in critical need of additional research, particularly for wild perennial C_4 grasses in which south-central South America appears to be a major geographic center of origin of C_4 lineages (Sage et al., 2011).

4.2 Capacity of food production

Impacts of climate change on natural resource potential and on its viability to feed the world about 14–16 billion ha of ice-free land on Earth, about 1.3–1.6 billion ha are used for crop cultivation (about 15–18 % irrigated, and the remaining are rainfed systems), and about 3.0–4.0 billion ha are used for pastures and animal feed. Forests constitute about 28–30 % of ice-free land surface. Cropping systems, pastures, and forests account collectively for approximately 50–60 % of the Earth's land covers (Houghton 1990; FAO 2007; Tubiello et al., 2007). Numerous studies have suggested that the climatic variability and climate change can have adverse impacts on global food production and food security, the changing climate is not only projected to lead to introduce new crops, but also opportunities for crop pests and pathogens to thrive in the absence of long cold periods. Increased temperatures, changed precipitation patterns and new cultivation practices may lead to a dramatic change in crop health. Examples of diseases and insect pest problems predicted to increase in incidence and severity due to global warming are recorded (Roos et al., 2011). Climate change threatens crop harvests not only by storm, flooding and drought caused physical damage, but also by heat stress induced changes in physiological processes. For example, in China alone, there are six recorded heat damages in the past 50 years, and in particular, heat stress affected 3 million hectares and reduced grain production by 5 million tons in 2003 (Tian et al., 2009). The major inter annual-scale climatic modes, such as the El-Nino Southern Oscillation, has been playing a key role by often leading to droughts and decrease in crop yields that could further result in famine in some food insecure regions (Hansen et al., 2011; Maxwel and Fitzpatrick, 2012; Iizumi et al., 2014). Drought regions in the United States in 2012, heat waves and associated Russian wheat embargo in 2010-2011, and droughts in Australia in 2006-2008 led to low levels of cereal stock and steep increases in food prices, likely worsening the access to affordable food for many consumers, including the poor in import dependent on countries (FAO, 2007, 2010, 2012). An unfavorable climate, such as too wet or too dry condition, affects the cropping intensity as well. For instance, in the Vietnam Mekong Delta where triple rice cropping system is operated, the annual number of completed cropping cycles is affected by variations in the timing and areal extent of flooding in wet season as well as those of salinity intrusion in dry season (Sakamoto et al., 2006; Kotera et al., 2014). Due to the severe floods in 2000, the second-season rice (planted in the middle of dry season and harvested before the onset of wet season) in that year grown in the upstream area of this region was fully and continuously submerged immediately after the heading, leading to crop failure except for the floating rice varieties (Kotera et al., 2014). "In contrast, the below-normal seasonal rainfall in 2004 reduced water availability for irrigation due to high salinity, and the dry season rice in that year could not be harvested" (FAO, 2011).

5. Conclusion

Climate change, whether they are artificial or natural, continue to be a subject of intense scientific, public, and controversial political debate worldwide, particularly in the past two decades (Kerr, 1997; Soon and Baliunas, 2003; Perrow, 2010; Rivera and Khan, 2012). Because of its impacts can be catastrophic and a potential threat to the human existence, effects entirely ecosystems in the world (Melillo, 1999). Most of the GHGs have been, and still are, the product of human activities, namely, the excessive use of fossil energy in industrialized countries; deforestations in the humid tropics with associated poor land use management; wide-scale degradation of soils under crop cultivation and animal or pasture ecosystems; and the most important source of agricultural activities (de-Ritcher et al., 2016). The consequence of climate change on climatic condition which can be easy to define through Earth's surface temperature increasing, changing precipitation, sea level increasing. Therefore, climate change impacts on the plant's physiological processes such as photosynthesis, stomatal resistance, canopy temperature, flowering time that leads to affect capacity food production supporting for feeding the world population at its present size (about 7.2 billion) and hopefully can meet the demand of the ever expanding human population (about 10 billion by the end of this century). As reported by Aydin (2010), it is essential for everyone, especially those in the scientific community to have a full appreciation of the issue as well as the potential solutions to the problem so that they can initiate the necessary changes to the economies, resource utilization, behavior, and general approach to nature.

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POSSIBILITIES OF USING HUCUL HORSE (CARPATHIAN PONIES) AT RIDING SCHOOLS BASED ON THE RESULTS OF BEHAVIOURAL TESTS

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Abstract

Nowadays Hucul breed is less popular in Hungary compared to the half-bred horses. However, by the versatile exploitation, stature, bearing capacity and frugality, the breed was able to occupy a more significant role at riding schools, hobby horse owners and riders. Temperamental and behavioural qualities of the training horses have essential role in teaching beginners or children and at therapeutic courses. Cooperation with the trainer and the rider and friendly, calm behaviour are fundamental requirements using these breeds. By reforming the traditional performance test system, uniquely in the national horse breeding practise, the Hungarian National Pony and Small Horse Breeders' Association lays considerably more emphasis on besides the general value traits (confirmation, origin, performance, summarising exterieur) moreover to achieve better understanding of temperamental and behavioural characteristics (internal value traits summarising interieur). Apart from physical appearance / conformation and origin; temperament, rideability and obedience of ponies and small horses are evaluated at a horse muster based on an accurately defined skill test. Knowing and examining these features (similarly to foreign practise) as well as using its objective results is a rightful claim in terms of safe training, sport-, hobby- and therapeutic riding in today's modern horse breeding. In this paper, temperament and nature of Hucul breed were examined

with the help of several easily performed behavioural tests. It was also investigated whether the breed is suitable for teaching beginner riders.
Key-words: Hucul horse, behavioural tests, training horse, qualifying treats of horses

Összefoglalás

A hucul fajta napjainkban még kisebb népszerűségnek örvend a félvér fajtákhoz képest Magyarországon, azonban sokoldalú hasznosíthatósága, termete, teherbíró képessége és igénytelensége alapján nagyobb szerepet kaphatna a lovas iskolák és hobbilótartók/lovasok állományaiban. A kezdő vagy gyermek lovasok oktatásában, a terápiás célú foglalkozások során kiemelt szerepe van az oktatólovak vérmérsékleti és viselkedésbeli tulajdonságainak. Az oktatóval és lovassal való együttműködés, a barátságos és nyugodt viselkedés alapkövetelmény az ilyen jellegű lóhasználat során. A hazai lótenyésztési gyakorlatban egyedülálló módon a Póni és Kislótenyésztők Szövetsége a hagyományos teljesítményvizsgálati rendszert átalakítva nagyobb hangsúlyt fektet a lovak általános értékmérő tulajdonságai mellett (küllem, származás, teljesítmény összefoglaló néven exterieur) a vérmérsékleti és viselkedésbeli tulajdonságainak (belső értékmérő tulajdonságok összefoglaló néven interieur) megismerése is. A küllem és származás bírálata mellett pontosan meghatározott készségvizsga alapján bírálják a tenyészszemlén résztvevő pónik és kislovak vérmérsékletét, lovagolhatóságát illetve kezelhetőségét. Ezen tulajdonságok ismerete és vizsgálata (a külföldi gyakorlathoz hasonlóan) illetve objektív eredményeinek felhasználása jogos igény, a biztonságos kiképzés, sport, a hobbi és a terápiás lovagoltatás részéről a mai modern lótenyésztés felé. Munkánk során a hucul fajta vérmérsékletét és természetét vizsgáltuk különböző egyszerűen elvégezhető viselkedési tesztek segítségével illetve kerestük a választ arra, hogy a fajta alkalmas-e kezdő lovasok oktatására.

Kulcsszavak: hucul ló, viselkedési tesztek, oktató ló, lovak értékmérő tulajdonságai

Introduction and objectives

Behaviour and character of riding school horses contributes greatly to beginner riders' safe training as well as pleasant and relaxed atmosphere. Without the contribution of horses, trainers undertake an impossible task. Choosing the appropriate horse bred or being devoted for training duties, requires thorough consideration, as their breeding and training is time-consuming and expensive. Consequently, it is of high important, especially at national level, that the chosen/bred horse meets the expectations and suits our requirements.

The quality and skills of the present training horses in Hungary have improved a lot recently thanks to organised instructor and coach training and legal control. However, they could even be better. Instructors and riding schools can choose from extremely heterogeneous stud and most of the time at the majority of riding schools there are only very limited financial resources for this.

According to experts, Hucul breed is considered to be even-tempered, kind, reliable and easily manageable which is recommended for adults and children, either for hobby or for races. This breed is less favoured in Hungary. However, in the surrounding countries (Romania, Poland, Slovakia and Austria) it is extremely popular thanks to its favourable use, traits and being undemanding (Mihók, 2006).

Our aim is to popularize Hucul breed by presenting the results of the applied ethological tests examining its behavioural and temperament features and, as a completion of documents of the breed in riding schools with the help of scientific methods.

Qualifying traits of training horses

Breeding and educating training horses used with beginner riders is a specific field of exploitation and horses have to fulfil numerous requirements.

In the case of horses the qualifying traits are determined by the direction of exploitation, too. The real value of training horses used for training beginner riders is set by the following characteristics: proper conformity and body features and the related value of locomotion; behaviour-temperament, character, relationship with people; cognitive skills trainability and teach ability; qualification.

The appearance of the horse is not only an aesthetic factor, but also an important aspect influencing the direction of exploitation. Horse breeding is the area among domestic animals where it is the easiest to conclude the possible performance based on the appearance of the animal. General body features have an important role in shaping locomotion. That is why they are important in therapy and in the case of hoses used in riding schools.

Locomotion of the training horse is an essential qualifying trait. In general, the stride should be regular four-cycled regardless of the pace, the hind legs must not step beyond the tracks of the front ones. Horses should be able to lengthen or shorten its step. Trotting should be convenient and easy to sit.

Besides appearance and locomotion, behaviour is the other significant feature of training horses. Horses have to be calm, patient and cooperative during training.

In the practise of horse breeding horses are mainly evaluated by conformity and body as well as pedigree and other objectively measurable performance parameters, so these are the primary breeding aspects.

Behavioural patterns and demands regarding temper are only mentioned and examined by regulations of very few breeds, though recognised foreign riding schools, besides exterieur, increasing importance is attached to interieur examination, cognition and testing. German horse breeding practise is an excellent example of it, as interieur exam is an integral part of their performance evaluation system.

The term interieur exam is not found in the documentation of Hungarian horse breeding, so no answer is provided to our question. Despite if one starts browsing in international literature, there are numerous hits to choose from.

The expression interior means all the different behavioural habits, individual traits and temperament of the horses. The most important positive characteristics are calmness, kindness, strong and well-balanced nervous system, general intelligence (attention, ability of evaluating, solving situations) and appropriate social behaviour. Undesirable characteristics: being fearful, nervous, scared, biting, refusing doing tasks and antisocial behaviour.

Behavioural and nervous system of the horses living near people is categorised into four different groups, which means differences while working with them and treating them: 1. *Sanguine* (the most unfortunate type) - calm, balanced, friendly, has good work skills, vivid, but easy to manage. 2. *Choleric* (unbalanced nervous system) vivid, but difficult to manage, tend to resist. 3. *Phlegmatic calm, slow, lazy*. 4. *Melancholic* (unbalanced nervous system) calm, but gets irresistant easily, unreliable (Novotni, 2011).

Hucul breed is of a human scale, kind breed the most important of its advantageous characteristics is its unbelievable good nervous system (Dögei, 2009). According to Krisztián Boros, the manager of Jósvafő stud at Aggteleki National Park and one of the Hungarian experts of Hucul horses, this breed has a much stronger nervous system and can regenerate much easier than its family members. This gives an obvious advantage at races (Kégl, 2013). Hucul horses have always been characterized by unconditioned willing to work. This makes them unparalleled (Mihók, 2001).

Breeding, situation and exploitation of Hucul breed in Hungary

The primary aim of Hucul breeding in Hungary is to keep the gene bank stocks as well as to Hucul horses suitable for small mountain farms and forestry and also for sport especially children's sport. The supervision of the Hucul breeding is performed by the Pony and Small Horse Breeders' National Association located in Debrecen. Hucul breeds can be registered earliest at 3 years of age, based on their pedigree and according to the performance testing.

The performance examination of the breed is special, it is not adjusted to the performance oriented types, but it is a skills examination. The skills exam consists of compulsory and optional elements. The compulsory tasks are needed for the studbook registration and to recognise them as breeding horses. The optional tasks are part of higher level (sport) tests increasing its usage (and commercial) value, describing the type's workability skills in details and referring to their breeding value as well. Performing the optional elements contribute to the studbook classification, too.

Temperament, manageability and character have to be evaluated 1-10 points considering aspects, such as kindness, easy manageability, calm behaviour, which enable them to be used with children. Horses that are dangerous for the environment, people and other horses, or those which seem to be haphazard, uncertain or malicious cannot be registered at the studbook. Estimated stock in Europe is 2000 heads (Fehér, 2014).

There are 254 brood mares and 16 reproductive stallions in the 2012 Hungarian breed register and 100 Hucul foals are born per year on average. The number of heads of the breed shows a slow but gradual increase year by year. Aggteleki National Park has a significant role in this improvement - as nearly one third of the Hungarian Hucul stock is owned by this national park - the Budapest Zoo and the Szigetcsép breeding of Hunovo Ltd. Two people who also play an important part in the breeding, Gabor Magyar PhD and József Vörös, should also be mentioned. They have a significant mare stock. The breed is slowly growing in popularity, there are more and more owners possessing some Hucul mares registered in the studbook from year to year (Németh, 2012).

Hucul breed can widely be used. Originally it is a pack-horse and military forces also bred, exploited and liked it as a pack-horse being a very strong footed mountain horse. It was also a service horse for mountain hunters serving in the Carpathians, having to carry out all kinds of duties. It pulled mountain battery, the bigger ones served as saddle horses. The idea of exploiting them as pack-horses emerged even during World War II. Today this role has been ignored, but its wonderful temperament has made it an ideal hobby horse. It is an excellent hobby horse, exceptionally valuable as a driving horse, which obviously does not mean that well-trained Huculs do not provide the riders with explicit riding experience. They do not require a tranter even when used casually (Mihók, 2001). Nowadays using Hucul horses in sports, driving, special military (Hucul path) and free time activities has become more remarkable. These days, it is most popular with traditional and hobby riders in Hungary, but the type's significance in sports achievements is being discovered. This can best be proved in Hucul paths, which is an obstacle course where 16 natural or man-made obstacles have to be built. This course is remarkably similar to the military off-road races, but contains more „colourful" tasks (Vörösné, 2011). The contest among Hucul horses was worked out by Polish scientists at the University of Krakow. Coupled horses have to carry out 20 tasks all of them testing manageability and the nervous system (Dögei, 2009).

Vörösné (2011) describes her experiences with Huculs as follows: „It is ideal as far as size, character and temperament are considered. It can easily learn, accept unusual situations and maintain a good contact with humans. Thanks to its and kindliness, the breed is suitable for satisfying demands from the smallest to adults, from handicapped people to athletes. Its history and today's aims of breeding and also the criteria for breeding have created a horse that is definitely man's best supporter and friend. In horse therapy a team mate is needed in the first place, which can perfectly be represented by this small horse. It can be used manifold thanks to its intelligence. The very same horse can look after a shy child on its back, help with riding school tasks, pull a cart or even perform on a jump course or Hucul path."

Material and methods

We carried out tests in three out of four significant Hungarian breedings as well as our own Hucul horses (the two mares come from Vörös József's herd).

Table 1 shows the introduction of the breedings, the use of the horses and composition of their gender. Behavioural tests were conducted on the horses in the order shown in Table 2.

Table 1. Summary of examined studs

Venue (stud)	Rep. stallion/ stallion	Mare	Gelding	Sum	Date of test	Keep[*]	Use[#]
Almas	-	2	-	2	05.09.2011	B + S	R
Gyűrűs	-	17	2	19	05.10.2012	P	R, D, T, H
Szigetcsép	2/2	11	10	21	12.10.2013	S + R	R, D, T, H
Jósvafő	4/4	7	5	12	26.10.2013	B + S	R, D, T, H
Altogether	6/6	37	17	64			

[*]B = box; S = stock yard; P = pasture; R = semi-roof

[#]R = riding with children; D = driving; T = therapy; H = Hucul path;

Table 2. The description of the ethological tests

	Name of test	Reference to authors works	Measured. time		Measurable parameters
1.	Modified open field test	Grandin, 1993 ; Dantzer and Morméde, 1984; Fraser, 1992; Visser et al., 2001; Wolf et al., 1997	300 sec	-	Temperament – behavioural patterns, social isolation
2.	New object test	Grandin,1998; Szabó and Tóthné, 2006	60 sec	-	Temperament – fear generated by new object
3.	Fear tests:		Max time	Scores of manageability	
3./1.	Tarp or bridge test	Takács, 2007; Pirsich, 2009; von Borstel et al, 2012; Sommer et al., 2006; Mihók, 2002	180 sec	Between 1 and 5	Behavioural pattern generated by well foreseen visual stimulus
3./2.	Suddenly opening umbrella test		180 sec	Between 1 and 5	Behavioural pattern generated by unforeseen, sudden visual stimulus
3./3.	Water squirt test		-	Between 1 and 5	Behavioural pattern generated by a sudden but familiar stimulus
3./4.	PET bottle test		-	Between 1 and 5	Behavioural pattern generated by a sudden, unknown audio stimulus
Collecting background information					
Questionnaire 1			Name, origin, age, gender, breeding, feeding and using circumstances of horse		
Questionnaire 2			21 item horse personality questionnaire		

Results and discussion

We used the cumulative behavioural variables based on the motivational background of the hoses taken from Szabó and Tóthné's (2006) works. Comparing the results of the two experiments, there were differences between behaviour of the tested English thoroughbred and our Hucul horses. Thus the behavioural variables determined by them had to be complemented with behavioural patterns like peaceful standing/ resting, feeding/grazing, weltering/scratching and scraping.

Szabó and Tóthné (2006) do not mention behavioural instances in connection with feeding and body care in their open field test carried out in English thoroughbred horses. However, in our experiment the examined Hucul horses spent a significant amount of time with feeding. According to our observations, the primary aim of exploring their immediate environment was to find further nutrition. Naturally, they also monitored their broader environment, but we found that continuous stepping aimed at finding possible nutrition rather than observing stimuli (e.g. smell of the previous horses). During the open field test we learned that they are less sensitive to social isolation. Fast, locomotor movements (part of escape behaviour) and playful behaviour were much rarer compared to the time spent on feeding. Analysing the video recordings of the modified open space test comparing the results of the breedings and keeping methods we found that the behaviour is not influenced significantly by the keeping method. We examined the differences of the variables between the breedings with the Kruskall-Wallis non-parametric test because of the low number of items and the lack of normality. Variables marked with an asterisk show significant differences (Hajdú et al., 1994).

According to the results of our experiments differences found in the behavioural habits of the herds do not origin from keeping methods, so we examined the age and the possible effects of gender of the horses. We found that age group shows a significant difference in one variable, peaceful standing only. The other variables do not depend on the age group. In Hucul bred the comparison in gender shows, that gender does not influence the variables significantly. In case of mares and geldings there is only a difference in gallop. Stallions show difference separately from both groups in the sniffing standing and sniffing walking variables. Besides these, variables peaceful standing and manuring show differences between mares and stallions. We applied Kruskall-Wallis, Mann-Whitney and in the case of non-rate scale variables Chi-square tests for the comparisons. To sum it up, the performance of the horses is not influenced by age and gender - except for the above mentioned variables - in the examined Hucul studs.

The gap between the rates of the variables can be explained by the different combination of genders in the breedings (see Table 3).

The most time spent in resting was typical of the mares with a foal in Gyűrűs Herd. Mares with foal produced the most neighs in our experiments (0.47 on average) too, because foals could easily get away from their mothers and they required their presence less, so mares signalled that they should return with a neigh. The balanced behaviour of mares is shown by the fact that they spent approximately same time on feeding (52.53 seconds on average) and watching (60.26 second on average).

Table 3. The results of temperament test I. (modified open field test)

Behavioural patterns recorded during test and their motivation	Behaviour not related to exploring surroundings				Behaviour aimed at exploring immediate surroundings		Behaviour aimed at exploring broader surroundings		Quick locomotor movement – parts of escape behaviour, factors signalling sensitivity level		Tension marker/ discontentment indicator	Playful behaviour	Ground marking, tension indichaviour	Bearing social isolation – seeking kins
	Resting	Feeding	Body care											
	peaceful standing/resting	grazing	weltering	scratching	sniffing standing	sniffing walking	watching	continuous striding	continuous trot	continuous gallop	scraping	buck/ rollick	manuring (p)	neigh (p)
p	*	NS	NS	NS	**	*	*	NS	NS	NS	NS	*	NS	NS
Av	8.8	67.6	0.7	0.8	16.1	21.7	40.9	15.5	3.6	1.0	0.1	0.4	0.0	0.3
GY	16.3	52.5	0.0	0.7	9.5	13.2	60.3	24.7	1.4	0.5	0.0	0.0	0.0	0.5
SZ	10.9	72.0	0.0	1.6	12.2	20.5	37.3	16.6	5.6	1.9	0.3	1.0	0.0	0.4
JO	0.0	74.4	2.1	0.0	27.1	28.6	30.0	16.0	1.9	0.0	0.0	0.0	0.1	0.0

Average (Instances measured in piece and second)
Av = average of studs; GY = Gyűrűs stud; SZ = Szigetcsép stud; JO = Jósvafő stud
*$p<0.05$; **$p<0.01$

In the Szigetcsép stud the 0.44 neighs on average were mainly produced by the geldings. They proved to be more sensitive to isolation. It did not manifest in any other, accident inducing behaviour with any geldings.

Compared to the other herd horses in Jósvafő, stud spent more time exploring their immediate surroundings than sniffing standing. Eight stallions (the biggest number among the groups) of Jósvafő stud took part in our experiments. Besides feeding, the stallions put considerable emphasis on exploring their immediate and broader surroundings. This behaviour was the same with stallions in Szigetcsépi stud, too.

Knowing the temperament of training horses alone has little information on their exploitation, so we put four ethological tests modelling scariness in different daily situation. The extrinsic manifestation of fear and being scared and the strength of the reaction can be influenced by temperament. Manageability and control are important features in everyday work and training especially in a riding school, regarding the beginners and children. Scariness and head-shyness are undesirable characteristics, as horses can slip out of control, which can lead to dangerous or life-threatening situation. The different fear tests try to explore how horses react to scary or unknown situations and how they can handle these situations, how much time they need to solve it, to what extent let they control themselves, how much they trust in people. Our tests were based on foreign tests with the difference that while in foreign tests a rider is mounted on the horse in most cases, in our tests the horse is led on a halter. The tasks modelled dangerous everyday situations that can occur while working or training with horses. Tests can be repeated, and the results measured in seconds can serve as objective and comparable data. During the tests the behaviour of the horses is scored - similarly to the foreign pattern. Scoring was conducted by the person leading the horse and the person taking part in the experiment. Scores on behaviour were given between 1 and 5 based on predetermined requirements. (Our scoring system was based on the strict behavioural and manageability criteria of the evaluation system for performance of Hungarian National Pony and Small Horse Breeders' Society. The average of handler's and the test leader's scores was calculated. Special attention was paid to provide audio stimuli besides visual cues. These stimuli were completely different. The results of the experiments are shown in Tables 4 and 5.

We asked our helpers to walk with the horse on a halter rope-lunge along an approximately 1.4 x 2.0 meter blue tarp during the tarp or bridge test. To perform the task the horse had maximum 180 seconds. The situation was well foreseen, still unknown for the horse and it induced fear in the animal, so it was quite unwilling to perform the task. It is assumed that the intensity of the reaction to the stimulus depends on the temperament. The length of time and the way of fulfilling the task suggests about its ability of situations-perceiving and problem-solving (e.g. walking over the tarp), and of manageability, obedience and trust towards people (accepts being led by a person in an unfamiliar situation). The horses showed very calm behaviour during the test and did not cause any accidents or dangerous situations. No jumping away, jumping over the tarp or denying tasks occurred. The test was carried out in a relatively short time (the accumulated average result was 18.72 seconds).

Hucul horses made a convincing impression during the bridge test, the foreseen stimulus inducing fear did not scare them off, and they produced calm reactions. They carried out the task quickly, behaved in a balanced way during the test and proved to be manageable and controllable. The average point was 4.76.

Table 4. The results of the experiments measuring fear and manageability

The results of fear and manageability tests carried out on Hucul horses	Temperament test II.			Results measured in fear test			
	Neophobia/New object test			Tarp test		Umbrella test	
	Focu-sing time	Time spent until first touch	Number of touches	Average seconds	Went through tarp	Average seconds	Touched the umbrella
	seconds		average	time		time	
Kruskall-Wallis test (p)	0.252	0.638	0.290	0.001**		0.001**	
Hucul breed N=65	3.51	5.52	0.74	18.92	65/65	10.28	65/65
Gyűrűs N=19	2.63	8.35	0.68	22.95	19/19	15.11	19/19
Szigecsép N=25	4.16	4.64	0.80	23.36	25/25	9.52	25/25
Jósvafő N=21	3.52	4.05	0.71	10.00	21/21	6.81	21/21

**p<0.01

Table 5. The scores of the fear tests

The results of fear and manageability tests carried out on Hucul horses	Scores given on manageability in fear tests			
	Tarp test	Umbrella test	Water squirt test	PET bottle test
	Average score given on manageability/executing task			
	Average scores			
P-value of the Khi-square test	0.465	0.326	0.182	0.105
Average of Hucul bred N=65	4.76	4.85	4.78	4.85
Huculs in Gyűrűs Herd N=19	4.89	4.79	4.79	5.00
Huculs in Szigecsép N=25	4.64	4.92	4.80	4.84
Huculs in Jósvafő N=21	4.7	4.81	4.71	4.71

The aim of the umbrella test is to examine the reaction of the horse to unknown and unforeseen stimuli and its fear. The horse is led towards the helper during the test, and when the helper is about 1.0-1.5 metres from the horse, the helper suddenly opens an umbrella. Then the person leading the horse tries to get the horse closer to the umbrella. The examination ~~is~~ finishes, when the horse touches the umbrella with its nose. We measured the time between opening the umbrella and the horse touching it and marked the behaviour of the horse during the test (5 points for keeping calm and carrying out the task, 1 point for being strongly reactive and resistant. The horse had 180 seconds to carry out the task. If the horse was unable to touch the umbrella, however well it managed to cope with the situation (did not get scared), it could get only one point. Hucul horses needed 10.21 seconds on average to overcome the scare caused by the suddenly opened umbrella and touch it with their nose. There was no horse in the group which got scared (jumped away, resisted, rushed away), getting surprised is a better term to describe the situation. For behaviour they got 4.85 points (out of 5.00) on average. Hucul horses behaved impeccably during the test, and showed maximum cooperation and manageability. They were not scared by the frightful and sudden stimulus, they were rather surprised (with the exception of some) and they fulfilled the task (of touching the umbrella with their nose) obediently without any resistance.

A slight difference could be seen between the times the tasks had been carried out in the case of the different breedings in the tarp and umbrella tests. But they are not too big to influence the excellent use traits significantly.

Carrying out the water squirt test was aimed at examining the reactions of the group given to sudden and maybe unpleasant but familiar stimuli. To examine this, the leader person stopped the horse, and the helper sprinkled some water on the neck of the horse two or three times. Time could not be measured in this particular test but the behaviour of the horse was averaged from the points given by the leader and the helper. The marking system was similar to that of the previously described two tests. Behavioural traits perceived during the tests - and their intensity - suggested about the temperament and the situation-perceiving of the horses. The horses of the examined group averaged 4.78 points out of 5.00, meaning that the horses did not mind the squirt test.

Getting scared is a really unfavourable characteristic in a world overwhelmed with technology. Hoses at riding schools, in open fields and in the stables are highly exposed to constant noise and sound effects. For the sake of their own and the peoples' safety their reactions should not be ignored. That is why, besides the visual tests, we consider it extremely important to put an audio test in their ethological examinations. The aim of the PET bottle test is to examine how the horses react to a sudden, unnatural, unfamiliar and very loud unexpected sound effect. We used empty PET bottles for the examination that, when pressed, can produce really loud, and sharp noises. The leader made the horse stand up calmly, and then the helper steps to the horse and suddenly presses a PET bottle near the ear of the horse. Time could not be recorded during the test, and the evaluation system is the same as that of the previously described tests.

Hucul horses put in an excellent performance at the audio test, out of 5.00 points they got 4.85 points on average, which means they are not affected by noises. Quite unexpectedly (based on our tests on other breedings) and to our surprise no horse got scared, jumping or stepping away. They gave resigned reactions occasionally lifting up their heads and turning their ears towards the direction of the noise, the tether remained loose in the leader’s hand.

The examined groups averaged between 4.50 and 5.00 which indicated balanced temperament and immaculate behaviour. There were no significant differences between the groups in connection with the points given for manageability.

Conclusions

Behavioural tests chosen for the intrinsic examination of Hungarian training horses proved to be reliable their results confirm the practical experiences of breeders. Thus, taking the positive characteristics of the type into consideration, they can well be recommended for children and adults alike. In accordance with the breeders’ concordant opinion Hucul horses are ideal hobby and family horses.

Hucul horses can widely be used based on their observed advantageous temperamental characteristics; advantageous work skills and behavioural traits. They can be an ideal choice for riding schools as their calm temper makes them suitable for training or therapy. Unfortunately, considering the size of the Hungarian Hucul stock, these possibilities are far from being exploited.

According to the results of our tests, the selection efforts set up in the Hucul breed’s breeding program, the skills test system and the evaluation of behaviour meets the objectives to be achieved (favourable temperament, manageability, working skills, reliability) and their use created integrated, homogeneous stocks in the examined Hucul breedings in Hungary.

The findings of the examinations on Hucul horses confirm that the spread of the type would be useful, and therefore not only the breeders would get an advantage but also the owners. The survival and genetic variability of the breed would be granted by bigger stocks.

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