

THE YIELD ANALYSIS OF THE POME FRUITS IN THE NORTH BOHEMIAN REGION

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*Growing of fruit trees has had a long tradition in the region of North Bohemia. Climatic conditions allow a cost-effective cultivation of a wide variety of fruit species in lowlands of the lower Elbe region. Pome fruits, which include apples (*Malus domestica* Borkh.), pears (*Pyrus communis* L.), medlar (*Mespilus germanica* L.), quince (*Cydonia oblonga* Mill.) and service tree (*Sorbus domestica* L.) have been grown in this region for several hundred years. The yield analysis deals with the examination of the time series of yields of apples and pears in relation to weather conditions in the North Bohemia region and the Czech Republic. A data set of average yield of apples and pears in the period of 1977 - 2014 and monthly meteorological data were used for the analysis. The trend analysis was performed and both trend values and deviations from the realized yield from the trend value were calculated for each year. The years with an extremely low value of the yield were determined according to the quantile of 25 %. The significant reduction in the yields of pears with the deviation from the trend value of $-6.43 \text{ kg}\cdot\text{plant}^{-1}$ in the North Bohemia and $-4.96 \text{ kg}\cdot\text{plant}^{-1}$ in the Czech Republic occurred in 1987. The lowest deviation from the trend values ($-3.61 \text{ kg}\cdot\text{plant}^{-1}$) from the yield of apples was the lowest in the North Bohemian region in 1984 and $-6.34 \text{ kg}\cdot\text{plant}^{-1}$ in the Czech Republic in 1981. In 1987, the yield of fruit trees was negatively affected by extreme freezing in March, low temperatures and the occurrence of ground frost in the first half of August, the frequent occurrence of hailstones and uneven rainfall during the growing season of fruit trees in the Czech Republic. The second extreme year was 1981, when crops were damaged by freeze and heavy rainfalls in July. The rainfall reached 305 % of normal in this month in the region of North Bohemia. The inter-annual variability of apples and pears yields has a decreasing tendency and it was the lowest in the last third of the monitored period. The North Bohemia region has higher long-term yields of apples and pears in comparison to the average of the Czech Republic.*

Keywords: yield, apple, pear, North Bohemia, weather

INTRODUCTION

Fruit trees have been an integral part of the landscape for a long time and they have participated in the formation of the landscape in the Czech Republic. Fruit growing was first mentioned in 1088 in Žitnice, North Bohemia. Fruit trees were initially grown in gardens and along the roads. A significant development of fruit growing and cultivation of new varieties started in the Czech Republic in the 18th century. The biggest development occurred in the mid-19th century in the Czech Republic. The most significant region was the area of North Bohemia, primarily the territory around the lower reaches of the Elbe, around the Třebenice and the Třebivlice regions. The fruit orchards formed 40 – 60 % of the agricultural land there. In North Bohemia, the most important species of fruits grown now include pears, apples, cherries, plums, apricots, and service trees, medlars and almonds in the past. Collectivization of agriculture and displacement of the locals led to the centralization of fruit production and fruit breeding in the 1950s. It resulted in the decrease of regional varieties and the change of the landscape not only in North Bohemia. Climatic conditions of the North Bohemia region are very diverse and an extraordinarily varied mezzo- and microclimatic mosaic is typical for them. The dissected relief with steep climatic gradients and the geological composition or the ability of the soil to warm up rank among the factors that affect the climatic conditions (Culek, 1996). Apple and pear trees are the most frequently grown fruit trees in the Czech Republic. The ten-year average of the number of trees was 11,584 thousand for apple trees and 779 thousand pear trees in the agricultural sector in 2014. The long-term annual consumption of fresh fruits in the Czech Republic ranks from 70 to 90 kg per capita; the apples account for 30 % and pears 4 % (CSO, 2015). The most suitable areas for apple trees growing are those up to the altitude of 350 m, with the average annual temperature of 7.0 – 8.0 °C and the annual precipitation total of 600 - 800 mm.

Some studies show apple trees' higher demands on the annual precipitation total of 900 – 1,200 mm (Peiker and Kyncl, 1962). Soils rich in nutrients, rolling areas and a hilly land with the soil reaction of pH from 6.2 to 7.5 are suitable for apple trees. The pear trees have lower demands on precipitation compared with apple trees. They thrive in the areas with the annual precipitation total of 500 – 800 mm and the average annual temperature of 8.0 – 9.0 °C (Ivičič et al., 1985). Winter varieties of pears require warm regions, such as the České středohoří Mountains.

Pear trees have higher demands on light compared with apple trees. Budding of pear trees begins at the temperature of about 6.0 – 7.0 °C and the pollination occurs at the temperature higher than 15.0 °C (Nečas, 2010). The critical temperature for blossoming of apple and pear trees is -1.7 °C. During the flowering phase, the risk threshold for apple buds is slightly below -2.0 °C (Richardson et al., 1975). The pear trees have higher temperature requirements compared with apple trees. They blossom earlier than the apple trees by about 10 days and they are at a higher risk of freezing in the phase of blossoming (Blažek, 1998). The resistance of blossoms to low temperatures decreases with the increasing degree of differentiation of blossom organs; however, stigmas are endangered by freezing in most species in the fully open blossoms at the temperature of -0.5 °C (Mezey, 2005). The perianths, stamens and pistils are formed as early as in autumn before the period of dormancy in the bud starts. Thus differentiated blossoms start to evolve only when the dormancy with low temperatures passes. The requirement for the cold period is approximately from 620 to 1,540 hours at temperatures below 7.0 °C for pear trees (Nečas, 2010). The mixed bud burst of pears comes at the end of March (26th) and at the beginning of April (15th), the first blossoms appear in the last decade of April and the end of flowering comes in the first decade of May (Hájková, 2012). The mixed bud burst of apples comes on average in the Czech Republic between 26th March and 17th April. The first generative

phenophase the inflorescence emergence begins on average between 12th April and 5th May, the flowering is between 19th April and 7th May and the end of flowering comes on average between 3rd and 20th May (Hájková, 2012). The length of phenophases of sprouting and blossoming is 15 - 20 days at the average daily temperature of 8.0 – 10.0 °C. This period is shorter during dry weather and it extends during wet weather for up to 5 days (Zeman, 2004). Dates of blossoming and its duration are very difficult to influence by agrotechnical measures.

Table 1. Cardinal temperatures for the frost resistance (Mezey, 2005)

	Temperature [°C]				
	root	wood	flower buds	full blossoming	after blossoming
Apple	-15.5	-30.0 to -35.0	-2.8 to -3.9	-1.7 to -3.9	-1.2 to -2.2
Pear	-9.0	-30.0 to -35.0	-1.7 to -3.9	-1.7 to -2.3	-1.2 to -2.2

The main objectives of this study were to describe the variability of the yield of pears and apples in the Czech Republic and the North Bohemia region and determine of the meteorological factors that affect decrease of the yield.

MATERIALS AND METHODS

The two of the most frequently cultivated fruit trees (apple trees and pear trees) in North Bohemia have been selected for the yield study. The yield of fruit trees is stated as kg.plant⁻¹. In this study, average annual yields of apples and pears in North Bohemia (now the Ústí nad Labem and Liberec regions) and the average of the Czech Republic for the period 1977 - 2014 were used. The data set of yields was provided by the Czech Statistical Office and the set of meteorological data by the Czech Hydrometeorological Institute. The trend was done by fitting different curves to the time series: 1st, 2nd, 3rd and 4th order polynomial equation. However, the 2nd order polynomial curve fitted the trend of fruit trees better. The yield series was divided with regard to the changes in the technology of cultivation in three periods: from 1977 to 1989, from 1990 to 2002 and from 2003 to 2014 for the purpose of a trend analysis. The trend value $y_i^{(t)}$ was calculated according to the equation of the trend for each year. The annual deviation $y_i^{(v)}$ of the realized yield y_i^0 from the trend values $y_i^{(t)}$ was calculated by the methodology (Potop et al., 2010) according to the equation:

$$y_i^{(v)} = y_i^0 - y_i^{(t)}$$

The analysis of calculated deviations from the trend value of yields was done in the programme Statistica using the method of nonparametric descriptive statistics. The years with an extremely low value of the yield were determined according to the quantile of 25 %.

RESULTS

In the monitored period of 1977 - 2014, the yield of apples ranged in the interval from 6.86 kg.plant⁻¹ in 2011 to 21.93 kg.plant⁻¹ in 1989 in North Bohemia and from 5.52 kg.plant⁻¹ in 1981 to 21.46 kg.plant⁻¹ in 1982 in the Czech Republic. In North Bohemia, the yield of pears was the lowest (3.72 kg.plant⁻¹) in 2008 and the highest (20.78 kg.plant⁻¹) in 1986. At the country level, the yield of pears was the lowest (3.93 kg.plant⁻¹) in 2003 and the highest (14.30 kg.plant⁻¹) in 1986. The inter-annual variability of yields of apples and pears was high during the first third of the monitored period between 1977 and 1989. This trend is evident in the high-yielding fruit growing area (North Bohemia) as well as in the average for the whole Czech Republic. This high variability of yields is related to the age structure of orchards and the unused protection against adverse meteorological events. Stabilization of yields

mainly in the last third of the reporting period is shown in Fig. 1 and 2, when the protection agents against extreme meteorological events are used in production orchards. Irrigation systems are used as protection against freeze damage to the blossoms. This sprinkling system prevents the freezing of the bud tissues by exploiting the release of latent heat which follows the freezing of water in the apparatus covering the whole orchard. But their expansion depends on the availability of water in the orchards (Eccel, 2009). Another protection from extreme meteorological events is protective mesh covers against the hailstones. The change of shape of fruit trees is yet another technological factor influencing the yield trend. Apple and pear trees were grown as standard and bush shapes in the past. The shape of a dwarf bush tree dominated the first third of the reporting period. The spindle shapes in apple trees or Belgian fence espalier by pear trees dominated the last third. The numbers of trees per hectare are the case of a spindle form by apple from 1,800 to 4,200 and Belgian fence espalier for pear trees from 1,900 to 3,300. This technological change caused a reduction in the yields of apples and pears (kg.plant⁻¹) in the last third of the reporting period (Fig. 1 and 2).

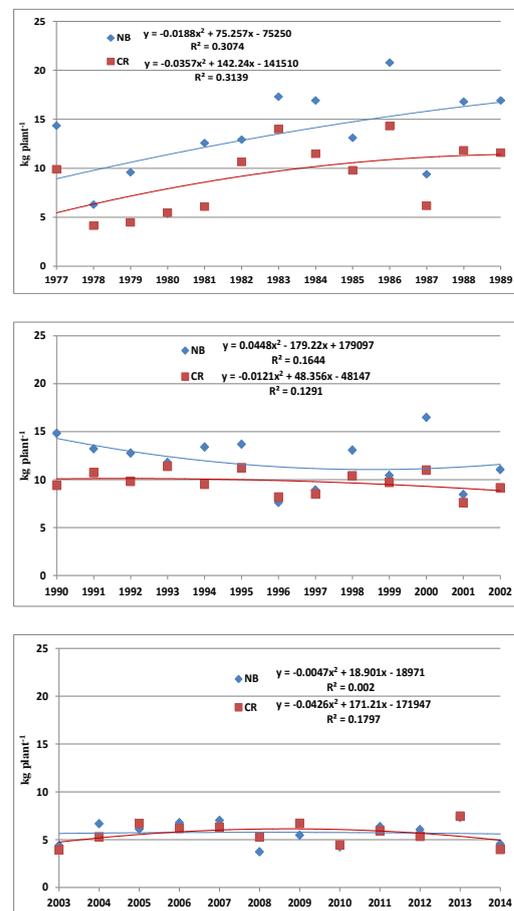


Fig. 1 The yield of pears and the polynomial trendline

When analyzing the variations of yields from the trend value the most reduction of yields of pome fruit (apples, pears) was found in 1981 and 1987 in the Czech Republic and in North Bohemia but the year 1980 applied only for pears. In 1980, the deviation of the yield from the trend value for pears was -6.04 kg.plant⁻¹ in North Bohemia and -2.45 kg.plant⁻¹ in the Czech Republic. In that year, the whole growing season of fruit trees was below normal temperatures in North Bohemia and in the Czech Republic.

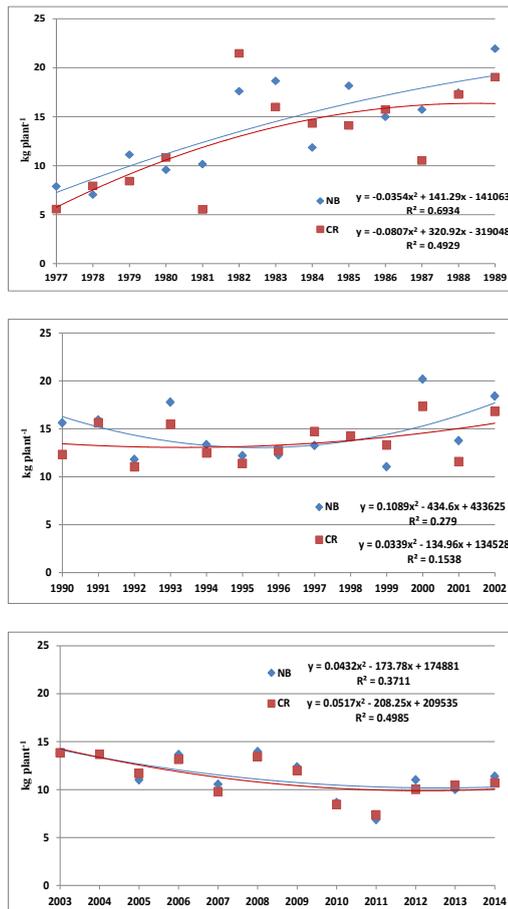


Fig. 2 The yield of apples and the polynomial trendline

Deviations from monthly air temperatures from the normal were $-2.4\text{ }^{\circ}\text{C}$ in April, $-2.2\text{ }^{\circ}\text{C}$ in May and $-2.4\text{ }^{\circ}\text{C}$ in July in the Usti region. At the Doksany station, May 1980 with the average monthly air temperature of $11.2\text{ }^{\circ}\text{C}$ was the second coldest month in the past 52 years and the lowest air temperature in May ($-2.7\text{ }^{\circ}\text{C}$, May 5th) in the past 52 years was measured there as well. The deviation of yield from the trend value for apples was $-6.34\text{ kg}\cdot\text{plant}^{-1}$ in the Czech Republic and $-2.22\text{ kg}\cdot\text{plant}^{-1}$ in North Bohemia in 1981. The pears were reduced in the yield below quintile 25 % only for the average of the Czech Republic ($-2.51\text{ kg}\cdot\text{plant}^{-1}$). In 1981, the late spring frost had a significant effect on the reduction of yields of fruit trees. The air temperature minimum of $-2.1\text{ }^{\circ}\text{C}$ was measured at the Doksany station on May 3rd, 1981. Among other negative factors ranked unevenly distributed precipitation during the growing season of fruit trees and extremely high total precipitation in July: 305 % of normal in the Czech Republic and 206 % of normal in the Usti region. Extremely low variations of the yield from the trend value for apples and pears were also in North Bohemia and in the Czech Republic in 1987. In that year, the deviations of yield of pears were the lowest for the reporting period, which meant $-4.96\text{ kg}\cdot\text{plant}^{-1}$ in the Czech Republic and $-6.43\text{ kg}\cdot\text{plant}^{-1}$ in North Bohemia. The severe frost in March 1987 affected all planting area in the Czech Republic. The buds of fruit trees were damaged in this period. On March 5th, 1987 the minimum air temperature of $-15.7\text{ }^{\circ}\text{C}$ was measured, and the average of air temperature in March was $-0.6\text{ }^{\circ}\text{C}$, its lowest value for the past 52 years at the Doksany station. In the first third of May 1987, the hailstones damaged many orchards mainly in West and North Bohemia and hailstorm repeated in the first half of August. In 1987, the growing season of fruit trees had subnormal temperatures with the deviation of air temperature in August to $-5.0\text{ }^{\circ}\text{C}$ in the Czech Republic as well as in North Bohemia. The first ground frost of $-1.4\text{ }^{\circ}\text{C}$ occurred at the

Doksany station already on August 7th, 1987. The year 1987 was significant due to uneven precipitation. The months May, June and July had the monthly precipitation above the normal in North Bohemia.

CONCLUSION

Among the conclusions arising from this study and the literature were the suggestions that: (i) Late spring frosts in particular have a negative effect on the yield of apples and pears, low temperatures damage the buds, blossoms and unripe fruits; (ii) The hailstones and uneven precipitation during the growing season of fruit trees are other negative factors; (iii) The yield of pears and apples was most reduced by extreme meteorological events in 1981 and 1987; and (iv) The fruit growing region of North Bohemia has a higher long-term yields compared to the average of the Czech Republic. In the analyzed period of 1977 - 2014, the highest inter-annual variability of yields of apples and pears appeared in the first third (1977 – 1989) of the analyzed period and the lowest one in the last third, where there was a decrease in the yield of $\text{kg}\cdot\text{plant}^{-1}$ as the result of the technological changes of cultivation.

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LITERATURE

- Blažek, J., Beneš, V., Dlouhá, J., Janečková, M., Kneifl, V., Kosina, J., Lánský, M., Paprštejn, F., Pražák, M., Plíšek, B., Svoboda, A., Staněk, J., Sus, J., 1998, *Ovocnictví. Květ. Praha. 383 p., ISBN: 80-85362-33-3.*
- ČSÚ, 2015, *Czech Statistical Office [online]. [cit. 2015-06-23]. available from: <https://www.czso.cz/>*
- Culek, M. [ed.], 1996, *Biogeografické členění České republiky. – Enigma, Praha.*
- Eccel, E., Rea, R., Caffarra, A., Crisci, A., 2009, *Risk of spring frost to apple production under future climate scenarios: the role of phenological acclimation. International journal of biometeorology, 53(3), 273-286.*
- Hájková, L., Voženilek, V., Tolasz, R., 2012, *Atlas of the phenological conditions in Czechia. Czech hydrometeorological institute, Praha - Olomouc. 311p. ISBN: 978-80-86690-98-8.*
- Ivičič, L., 1985, *Ovocnictví. Praha. 475 p. ISBN: 18-717884-211*
- Mezey, J., 2005, *Ovoce z vlastní zahrady. CP Books. Brno. 95 p. ISBN: 80-251-0253-X*
- Nečas, T., 2010, *Pěstujeme hrušně a kdouloně. Grada Publishing as.112p. ISBN: 978-80-247-2500-0*
- Peiker, J., Kyncl, F., 1962, *Ovocnictví. SZN. Praha. 544 p. ISBN: 07-046-62-04/44*
- Potop, V., Türkott, L., Kožnarová, V., Možný, M., 2010, *Drough episodes in the Czech Republic and their potential effects in agriculture. Theor. Appl. Climatol, 99. p. 373-388.*
- Richardson, E. A., Ashcroft, G. L., Anderson, J. L., Seeley, S. D., Walker, D. R., Alfaro, J. F., Griffin, R. E., Keller, J., 1975, *Pheno-climatography of selected fruit trees as used in programming sprinkling for bloom delay. Paper No. 75-4053, American Society of Agricultural Engineers, Davis, California, June 22-25.*
- Zeman, V. 2004. *Štíhlá větvena na zahrádce. Květ. Praha. 34 p., ISBN: 80-85362-54-6.*