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# EFFECT OF THE FORECAST CLIMATE CHANGE ON THE PLUM TREE WATER REQUIREMENTS IN THE BYDGOSZCZ REGION

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***Abstract***

The aim of the present research has been an attempt at evaluating the water requirements of plum trees over 2016-2050 in the Bydgoszcz region drawing on the forecast changes in temperature. The paper draws on the forecasting of mean monthly temperature for the Bydgoszcz region in 2011-2050 according to the climate change scenario for Poland SRES: A1B (Bąk, Łabędzki 2014). The water requirements of the plum tree have been determined based on the indispensable precipitation determined by Kemmer and Schulz. The water requirements were calculated for the period January through December and May through September for each year in the 35-year period (2016-2050). The reference period was made up by a 35-year period immediately preceding it (1981-2015). In 2016-2050 in the Bydgoszcz region, in the light of the forecast temperature change scenarios, one should expect an increase in the water requirements of the plum tree. The annual (January-December) optimal total precipitation determined according to the Kemmer and Schulz method will increase for the plum tree from 712 mm to 807 mm (by 95 mm, which accounts for 13%). The optimal precipitation trend equations show that in the reference period (1981-2015), calculated, drawing on the Kemmer and Schulz number, the optimal annual precipitation was increasing in the plum tree in each pentad by 7.1-7.5 mm. In the forecast period (2016-2050) the water requirements will increase, however, in each pentad within a much smaller range, from 2.6 to 3.0 mm. In the summer period (May-September) determined by Kemmer and Schulz, the total precipitation optimal for the plum tree, expressing water requirements, in 2016-2050 will increase by 47 mm.

**Key words**: plum tree, water requirements, optimal precipitation, forecast climate change, Bydgoszcz region

## INTRODUCTION

The plum tree, next to the apple tree, represents fruit trees with high water requirements (Dzieżyc 1988, Rzekanowski 2009). According to Słowik (1973), plum trees demonstrate very high, even greater than apple trees, water requirements, which makes them yield best in the regions with a higher precipitation (Subcarpathia, the seaside region). A relatively shallow plum tree root system, on the other hand, is responsible for the fact that plum trees produce satisfactory yields in average and heavy soils showing a high water holding capacity. Podsiadło et al. (2009) report on plum fruit yields in non-irrigated plots depending significantly and directly proportionally on precipitation over the vegetation period. Grzy and Rozpara (2007) point to the precipitation distribution throughout the year and claim that it is good if annual precipitation for plum trees is at least 600 mm, and much of it coincides with spring.

More than 40 % of the horticultural crops production in the Bydgoszcz region is covered by orchards. The production effects are not always satisfactory, which is due to a considerable (more than 30%) share of light soils and the variation in weather conditions in the vegetation period. It is estimated that, to ensure a high yielding, orchard plants should receive additionally, thanks to irrigation, from 100 to 200 mm of water (Rzekanowski et al. 2001).

Temperature and precipitation change scenarios in Poland differ a lot, as compared with the summer period (June-July-August) (Łabędzki 2009). All the models forecast an increase in temperature, and only few – an increase in precipitation, while some – even a decrease in precipitation (Łabędzki 2009). It is estimated that the forecasted climate change will increase the water requirements of plants (Łabędzki 2009).

The aim of the present research has been an attempt at evaluating the water requirements of plum trees in 2016-2050 in the Bydgoszcz region based on the forecast changes in temperature.

## MATERIAL AND METHODS

The paper draws on the forecasting of mean monthly temperature for the Bydgoszcz region in 2011-2050 according to the climate change scenario for Poland SRES: A1B (Bąk, Łabędzki 2014). The water requirements of the plum tree have been determined based on the indispensable precipitation determined by Kemmer and Schulz (Słowik 1973, Dzieżyc 1988). The authors have considered the optimal annual (January-December) precipitation for fruit trees in average soil (of average compaction) to depend on mean temperature in summer (May-September), yet assuming that at least 50% of precipitation coincides with the period from 1 May to 30 September (Treder, Pacholak 2006). With the table values for the plum tree provided by Dzieżyc (1988), the regression equation was determined (Figure 1). Then the water requirements were calculated for the period January through December and May through September for each year in the 35-year period (2016-2050). The reference period was made up by a 35-year period immediately preceding it (1981-2015). Each of the two 35-year periods was divided into seven pentads for which optimal mean total precipitation values were determined. There were also defined trends for the plum-tree-optimal precipitation time variation in successive 35 years (n=35) or 7 five-year periods (n=7). Excel spreadsheet was used.

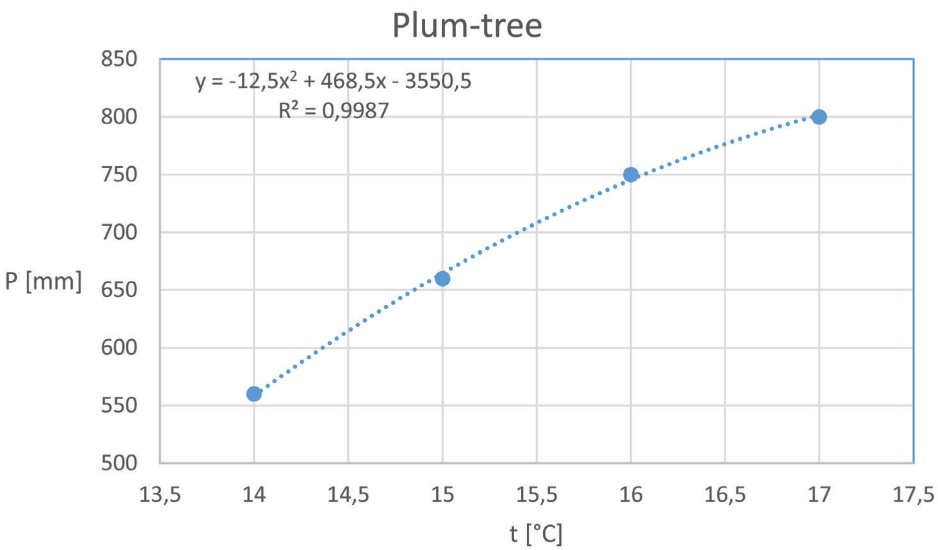


**Figure 1**. Relation between the mean temperature in summer (May-September) and optimal annual precipitation for plum-trees according to Kemmer and Schulz in a soil of average compaction. The own elaboration on the base of the table values for the plum tree provided by Dzieżyc (1988)

## RESULTS AND DISCUSSION

The water requirements of the plum tree, determined as the optimal annual precipitation according to Kemmer and Schulz, showed a lower variation in the forecast period (2016-2050) than in the reference period (1981-2015) (Table 1). Calculated (based on temperature) precipitation indispensable for the plum tree, respectively for those periods, ranged from 706 to 839 mm and from 577 to 826 mm.

**Table 1.** Statistical characteristics of the plum-tree-optimal annual precipitation

| Specification | Period | |
|---|---|---|
| | 1981-2015 | 2016-2050 |
| Minimum (mm) | 577 | 706 |
| Maximum (mm) | 826 | 839 |
| Median (mm) | 728 | 823 |
| Average (mm) | 712 | 807 |
| Standard deviation (mm) | 61.3 | 41.5 |
| Variation coefficient (%) | 8.6 | 5.1 |

The analysis of the trend equations for the precipitation optimal for the plum tree (Table 2, Figure 2, Figure 3) shows that in the reference period (1981-2015) the optimal annual precipitation was increasing in each five-year period by 7.1 mm, whereas in the forecast period (2016-2050) it will increase, in each pentad, by 3 mm.

**Table 2**. Equations of the trend of the plum-tree-optimal annual precipitation in consecutive years

| Period | Equations of the trend | $R^2$ | Tendency of the plum-tree-optimal annual precipitation (mm·pentad$^{-1}$) |
|---|---|---|---|
| 1981-2015 | $y = 1.4297x + 686.55$ | 0.0571 | 7.1 |
| 2016-2050 | $y = 0.6092x + 795.85$ | 0.0226 | 3.0 |

For a better depiction of the optimal precipitation, the mean annual precipitation was additionally broken down for successive pentads in the 35-year periods (Table 3). The indispensable mean annual precipitation was higher in each pentad of the 2016-2050 period, as compared with the reference period (1981-2015). In other words, the lowest mean pentad annual precipitation of the forecast period (2050) was higher than the highest (per pentad) mean precipitation of the reference period (1981-2015).

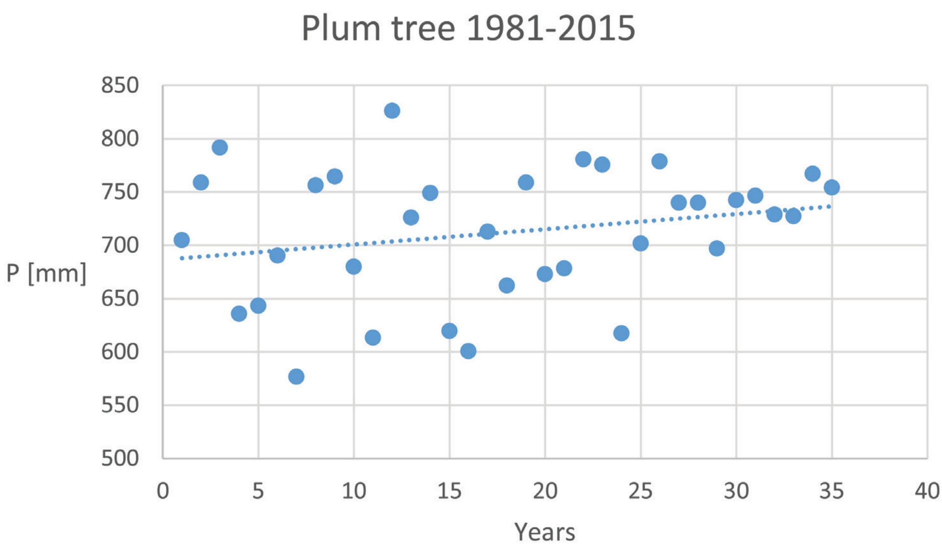


**Figure 2**. Temporal variability of the plum-tree-optimal annual precipitation in consecutive years of the reference period 1981-2015

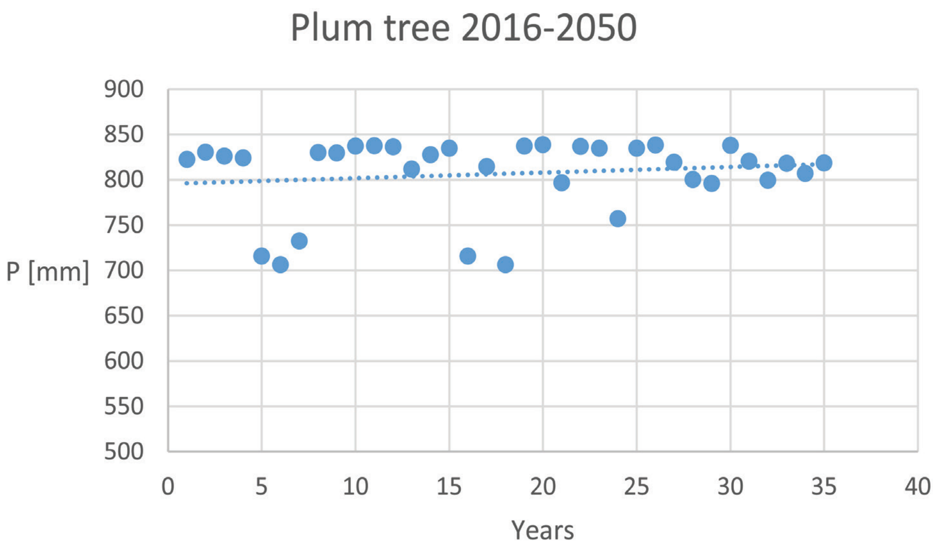


**Figure 3**. Temporal variability of the plum-tree-optimal annual precipitation in consecutive years of the forecasted period 2016-2050

**Table 3**. The plum-tree-optimal annual precipitation according to Kemmer and Schulz in consecutive pentads for the compared periods (mm)

| Reference period 1981-2015 | | Forecasted period 2016-2050 | |
|---|---|---|---|
| Pentad | P (mm) | Pentad | P (mm) |
| 1981-1985 | 707 | 2016-2020 | 804 |
| 1986-1990 | 694 | 2021-2025 | 787 |
| 1991-1995 | 707 | 2026-2030 | 830 |
| 1996-2000 | 682 | 2031-2035 | 783 |
| 2001-2005 | 711 | 2036-2040 | 812 |
| 2006-2010 | 740 | 2041-2045 | 819 |
| 2011-2015 | 745 | 2046-2050 | 813 |
| Average for 1981-2015 | 712 | Average for 2016-2050 | 807 |

The comparative analysis of the trend equations for the precipitation optimal for the plum tree in successive pentads (Table 4, Figure 4, Figure 5) shows that in the reference period (1981-2015) the optimal annual precipitation was increasing in each five-year period by 7.5 mm, while in the forecast period (2016-2050) it will increase in each pentad by 2.6 mm.

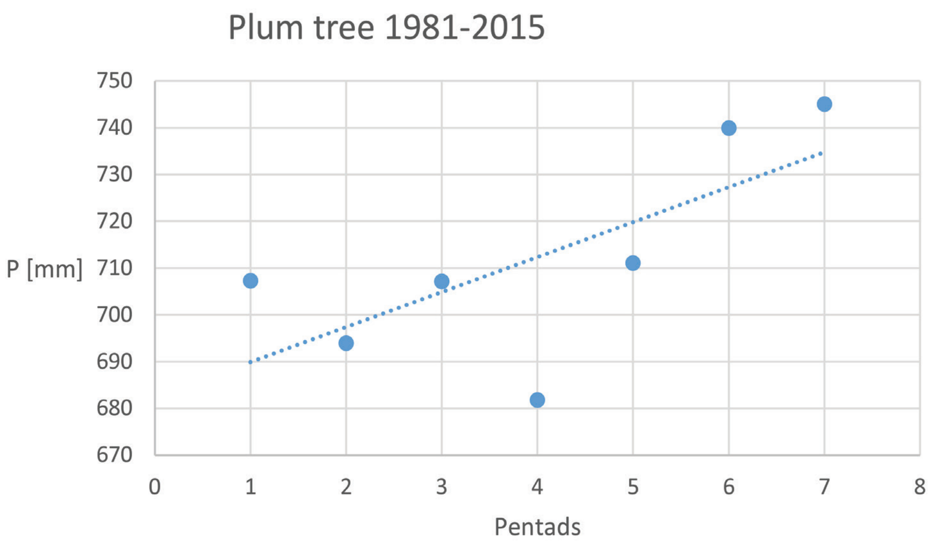


**Figure 4**. Temporal variability of the plum-tree-optimal annual precipitation in consecutive pentads of the reference period 1981-2015

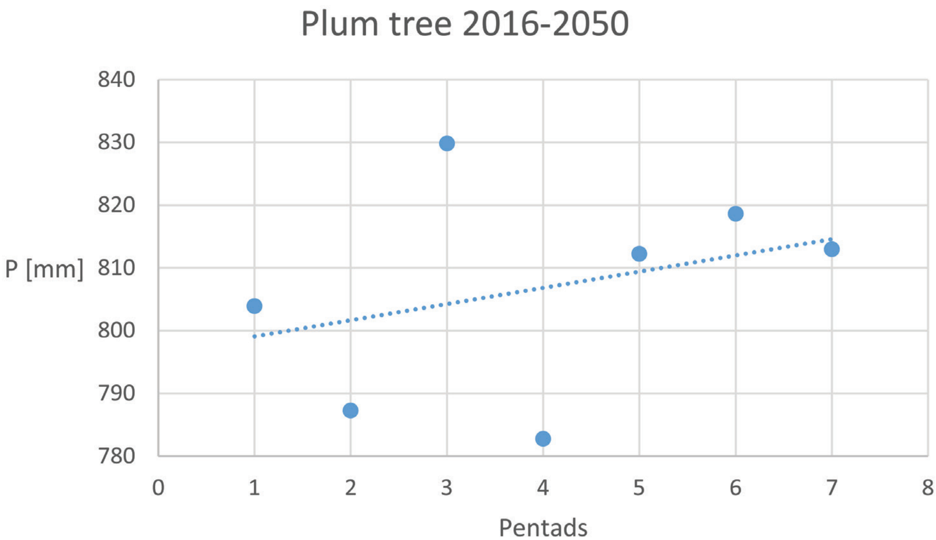


**Figure 5**. Temporal variability of the plum-tree-optimal annual precipitation in consecutive pentads of the forecasted period 2016-2050

**Table 4**. Equations of the trend of the plum-tree-optimal annual precipitation in consecutive pentads of compared periods

| Period | Equations of the trend | $R^2$ | Tendency of the plum-tree-optimal annual precipitation (mm·pentad$^{-1}$) |
|---|---|---|---|
| 1981-2015 | y = 7.4777x + 682.37 | 0.496 | 7.5 |
| 2016-2050 | y = 2.58x + 796.5 | 0.1093 | 2.6 |

**Table 5**. Comparison of the optimal mean precipitation for the plum tree according to Kemmer and Schulz for the compared periods (mm)

| Period | January-December | May-September |
|---|---|---|
| 1981-2015 | 712 | 356 |
| 2016-2050 | 807 | 403 |
| (2016-2050) – (1981-2015) | + 95 | + 47 |
| Change (%) | +13 | |

A comparison of the optimal mean annual precipitation for the many-year periods shows that it will increase for the plum tree from 712 mm to 807 mm (by 95 mm, which accounts for 13%) (Table 5).

An increase in the water requirements of the plum tree comes mostly from the forecast increase in temperature. As reported by Bąk and Łabędzki (2014), the highest increase in temperature in 2011-2050 is forecast in July and August; as compared with the reference period (1971-2000), it will be 1.5°C and 1.2°C, respectively.

To compare, the optimal annual precipitation for the plum tree determined with the Kemmer and Schulz method for the Lubostroń region (north-western ends of the Kujawy region), and determined by Rzekanowski (1989), in 1981-1985 ranged from 624 mm to 748 mm (an average of 677 mm). As reported by Rzekanowski et al. (2001), on the other hand, evaluated with the Drupka method (1976), the water requirements of fruit trees May through September in the Bydgoszcz region (the 1971-1995 mean) were 391 mm in compact soils and 457 mm in sandy soils.

Following the assumptions by Kemmer and Schulz, the precipitation optimal for the plum tree from 1 May to 30 September in 2016-2050 will increase by 47 mm (Table 5). To compare, precipitation deficits estimated by Rzekanowski (2009) in the Great Valleys Region in the vegetation period with high temperature (the 1890-1980 mean) for plum trees ranged from 160 to 190 mm.

It is assumed that the foreacast climate changes (e.g. an increase in temperature) will speed up the irrigation development in Poland, especially modern water – and energy-saving irrigation systems (drip irrigation, under-crown irrigation, mini-sprinkling), recommended in orchards (Łabędzki 2009, Rzekanowski et al. 2011, Treder, Pacholak 2006) and increase the production effects (Treder, Pacholak 2006, Rzekanowski, Rolbiecki 2000, Rzekanowski et al. 2001, Rzekanowski 2012). Under-crown irrigation in the plum tree enhances the pattern of photosynthesis and the use of water and mineral nutrients (Jaroszewska, Podsiadło 2013, Jaroszewska et al. 2015). Drip irrigation ensures a high production effectiveness; increased plum yields (Rzekanowski 1989, Treder et al. 1999, Rzekanowski, Rolbiecki 2000).

## RECAPITULATION AND CONCLUSIONS

With the assumptions, calculations and analysis made, one can formulate the following conclusions:

1. In 2016-2050 in the Bydgoszcz region, in the light of the forecast temperature change scenarios, one should expect an increase in the water requirements of the plum tree. The annual (January-December) optimal total precipitation determined according to the Kemmer and

Schulz method will increase for the plum tree from 712 mm to 807 mm (by 95 mm, which accounts for 13%).

2. The optimal precipitation trend equations show that in the reference period (1981-2015), calculated, drawing on the Kemmer and Schulz number, the optimal annual precipitation was increasing in the plum tree in each pentad by 7.1-7.5 mm. In the forecast period (2016-2050) the water requirements will increase, however, in each pentad within a much smaller range, from 2.6 to 3.0 mm.
3. In the summer period (May-September) determined by Kemmer and Schulz, the total precipitation optimal for the plum tree, expressing water requirements, in 2016-2050 will increase by 47 mm.

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