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The effect of crop year on fruit weight and internal quality characteristics of selected plum cultivars in the Újfehértó Fruit Gene Bank

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SUMMARY

The competitiveness of the plum sector in Hungary has gradually declined over the past decade, and the area under cultivation has been steadily decreasing. In contrast, plum production has increased at the European Union level. The main causes of the domestic decline include the disappearance of plantations, severe frost damage following mild winters, and extremely dry weather conditions. Plums from the Balkans are gradually displacing Hungarian plums from the European market. In recent years, climate change, labour shortages, and increasing input costs have posed significant challenges to the sector. Therefore, research related to plum cultivation is essential to improve the market position of the plum industry.

In this study, we examined plum cultivars from the gene bank collection of the Research Institute of the University of Debrecen, AKIT Újfehértó, as follows:

1. *Evaluation of the quality characteristics and fruit traits of the selected plum cultivars,*
2. *Investigation of the effects of different years on the quality characteristics of the selected cultivars,*
3. *Determination of correlations among the quality traits of the plum cultivars.*

Keywords: *plum; fruit weight; acidity; Brix index*

INTRODUCTION

The native range of the plum (*Prunus domestica* L.) extends from Central Asia through the Caucasus to Central Europe. The species was first cultivated in Syria, Iran, Armenia, Turkey, and Greece (Kassai and Dimény, 2007).

The cultivation characteristics and market value of plum varieties were described in detail by Zoltán Szabó (Szabó, 1988). The fertilization characteristics of the varieties were clarified by Tóth (1969), who established that the self-fertility of cultivars is a stable trait. Local landraces developed through the selection effects of environmental factors rather than through breeding (Csambalik and Divéky-Ertsey, 2016). These landraces have been preserved in gene banks because they represent significant cultural, historical, landscape, and nature conservation values. The preserved landraces may serve as raw material for breeding, and *in vivo* gene preservation is an activity of both cultural and economic importance (Tóth, 2013).

Due to changing market demands, early- and late-ripening cultivars with large fruits are most suitable for fresh market sale. Over the past two decades, according to these new requirements, the Serbian-bred cultivar 'Čačanska lepotica' has become widespread; in addition, 'Stanley', 'Bluefre', and 'President' are the most commonly planted varieties (Surányi, 2006; Gonda, 2008; Kállay, 2008).

In 2023, the National Variety List included 14 plum cultivars. The ripening season of plums lasts for about three months, from early July to the end of September. In Hungary, blue plums are preferred for both fresh consumption and processing. The utilization potential of plums is largely determined by their fruit characteristics (Nyéki et al., 2012). For the fresh market, large-fruited and flavourful cultivars are the most suitable. The most important cultivation characteristics of plum varieties are vigour, canopy shape at fruiting age, productivity, and the onset of bearing (Kovács et al., 2012).

According to the UPOV (International Union for the Protection of New Varieties of Plants) guidelines for the conservation of rare and endangered plant genetic resources and microorganisms *ex situ*, the following fruit traits are decisive for plum varieties: fruit size, shape, base colour, flesh colour, stone adherence, flowering time, and beginning of ripening (I1). The characteristics of plum cultivars fundamentally determine their role in cultivation and market share. In this article the fruit size, shape, base colour, flesh colour, stone adherence, were evaluated between 2021–2023 according to the UPOV guidelines.

MATERIALS AND METHODS

The research was conducted over three consecutive years (2021, 2022, and 2023) at the University of Debrecen, Institutes for Agricultural Research and Educational Farm, Research Institute of Újfehértó. The gene collection at the institute includes obsolete cultivars, collected landraces, varieties related to cultivated plums, and various breeding lines and hybrids. From this gene bank, nine plum cultivars were selected for study: 'Petrovka', 'Purpovovaja', 'Methley', 'Carmen', 'NP13', 'KTK', 'Penyigei', 'Nagrada', and 'Silvia'. The cultivars were planted in the same growing area, with free spindle crown shape, and were subjected to identical phytotechnical, agrotechnical, and plant protection treatments. All cultivars were grafted onto 'Myrobalan' rootstock,

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using a spacing of 5 m between rows and 3 m between trees. The 'Methley', 'Nagrada', and 'Silvia' in 2002, 'Carmen' in 2004 and 'KTK', 'Penyigei', 'Petrovka', 'Purpovovaja', 'NP13' in 2011 were planted.

The soil of the experimental site is slightly acidic, sandy in texture, and weakly humic, with no measurable carbonate content. The measured pH (in water) was 6.1, and the humus content was 0.78%. The groundwater level was below 2.5 m. Meteorological data for the study area are shown in *Figures 1–3*.

Figure 1. **The main meteorological characteristics of the year 2021**(Research Institute of Újfehértó)

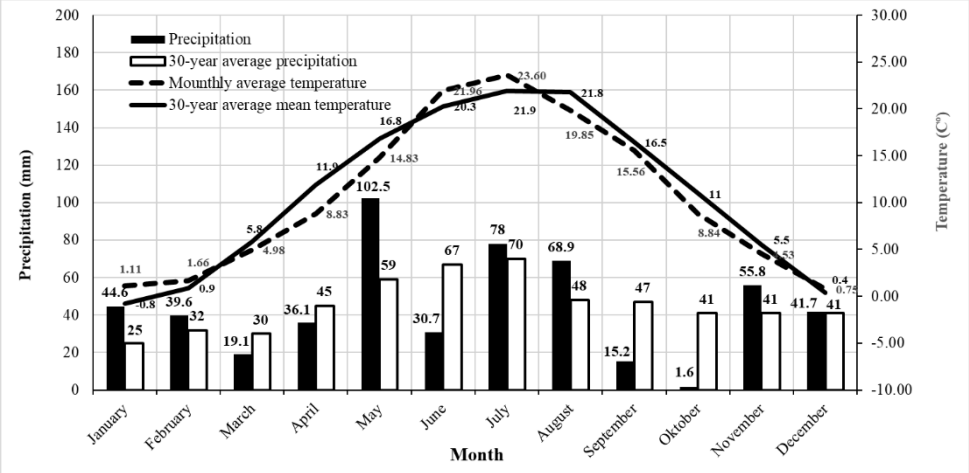


Figure 2. **The main meteorological characteristics of the year 2022** (Research Institute of Újfehértó)

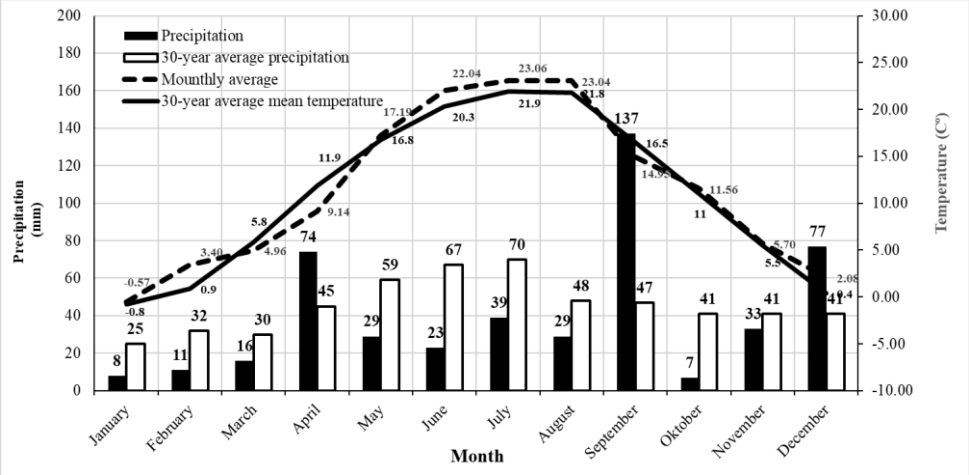
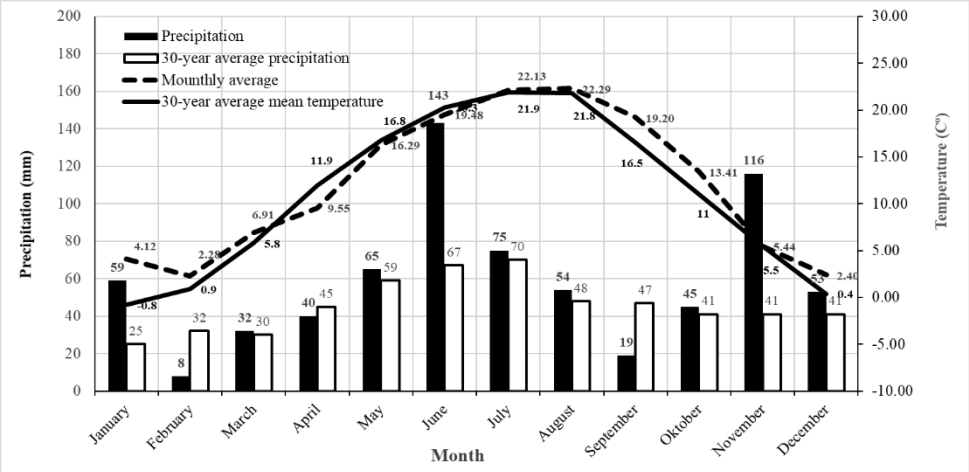


Figure 3. **The main meteorological characteristics of the year 2023** (Research Institute of Újfehértó)



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In general, the three examined years differed significantly in precipitation. The year 2021 was favorable, 2022 was extremely dry, and 2023 had abundant rainfall. In 2021, total precipitation was 533.8 mm, which is 12.2 mm less than the 30-year average (546 mm). June, September, and October were particularly dry months. Overall, precipitation was adequate that year, although certain months were considerably below the average.

In 2022, total precipitation was 483 mm, 63 mm less than the 30-year average. From January to August, the weather was extremely dry, with 147 mm less rainfall than the long-term mean. Only April, September, and December exceeded the 30-year monthly averages.

In contrast, 2023 was a very wet year with a total of 709 mm precipitation, which is 163 mm more than the 30-year average. January, June, and November were exceptionally rainy months, while the other months showed only minimal deviations from the long-term average.

The examination of the plum fruit characteristics followed the UPOV guidelines (I1).

Sample collection was carried out randomly from each tree (10 fruits/tree, totally 30 fruits/3 tree), including the stem.

Physical measurements were first taken: two fruit widths and two lengths per sample, measured with a caliper. After removing the stem, the fruit weight (g) was recorded.

Fruits were then cut in half to evaluate flesh colour, stone adherence, bloom (wax coating), and coverage of the overcolour.

After destoning and pressing, the juice samples were analyzed using an ATAGO BRIX refractometer to determine the soluble solids content (Brix index), in three replicates per sample (1 ml juice each).

The acidity (%) was measured with an ATAGO CITRIC ACID (%) refractometer, using 1 ml of fruit juice diluted 10-fold with distilled water.

In addition, the length and weight of the fruit stems were measured. The cleaned and dried stones were weighed after reaching constant dry weight using an MV-300T laboratory scale.

Statistical analyses were performed in the R 4.1.3 environment (R Core Team, 2023) using the RStudio graphical interface and the "agricolae" package. Figures were created with Microsoft Excel 2019. The effects of cultivar and year were analyzed according to the measurement model by Huzsvai and Balogh (2015):

```
> model = aov(lenght~treatment*year+Error(tree_identifier/year), data = experiment)
> summary(model)
```

The comparison of the plum cultivars' fruit mass and quality characteristics was performed using the Least Significant Difference (LSD) method (Huzsvai & Balogh, 2015):

```
> df=df.residual(ism$"fa")
>mse=deviance(ism$"fa")/df
>effect<with(experiment, LSD. test (lenght, variety, df, mse, console=T))
```

In the figures, columns marked with the same letter do not differ significantly; different letters indicate statistically significant differences between groups.

RESULTS AND DISCUSSION

We examined one of the most important value-determining traits of the studied plum cultivars – the fruit weight – during the years 2021, 2022, and 2023 (*Figure 4*).

The 'Carmen' cultivar had the highest and statistically significant fruit weight, with an average of 72.55 g per fruit over the three years. The 'Silvia' cultivar ranked second (53.15 g/fruit), which also differed significantly from the other varieties. The *'KTK', 'Methley', 'NP13', 'Penyigei', and 'Petrovka'* cultivars had the lowest fruit weights (12.8–16.6 g/fruit), with no significant differences among them. Yield per tree was not determined, as this is not required for gene bank evaluations.

Figure 5 presents the average fruit weights of the cultivars across the three years. No significant difference was found between 2021 and 2022, when the average fruit weight ranged between 25.25–28.01 g/fruit.

The highest average fruit weight was observed in the rainy year of 2023, reaching 31.61 g/fruit, which was significantly higher than in the previous years.

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Figure 4. **The fruit weight of the plum varieties in the average of the examined years**
(Research Institute of Újfehértó, 2021–2023)

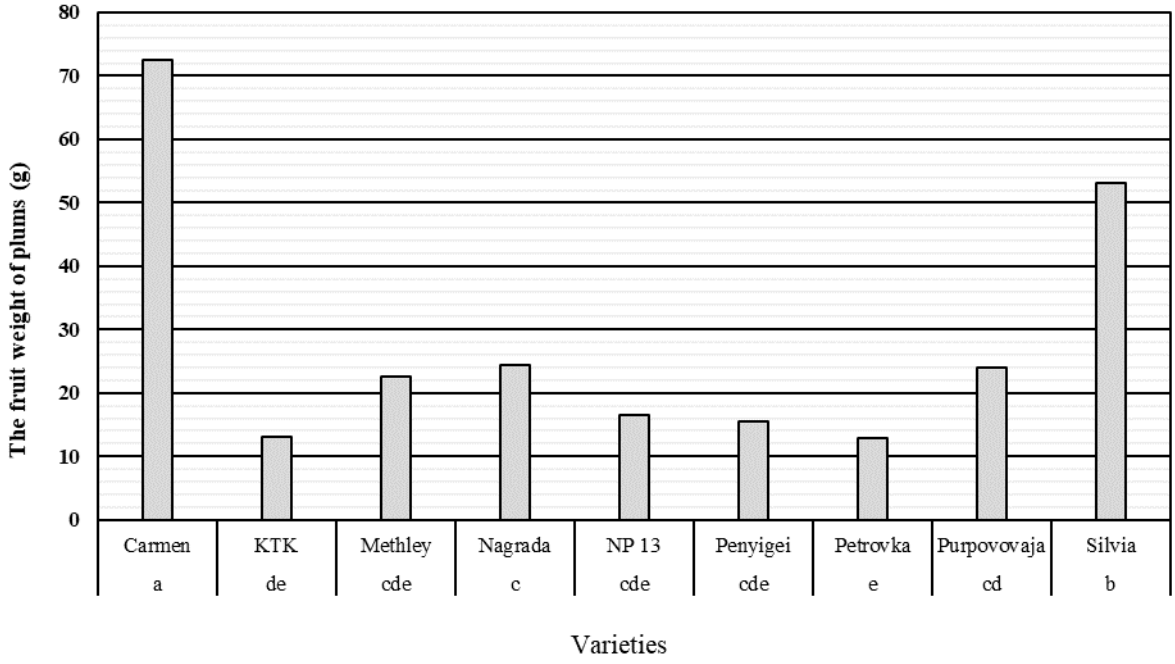

Figure 5. **The fruit weight of plums in the average of the examined varieties across different years**
(Research Institute of Újfehértó, 2021–2023)

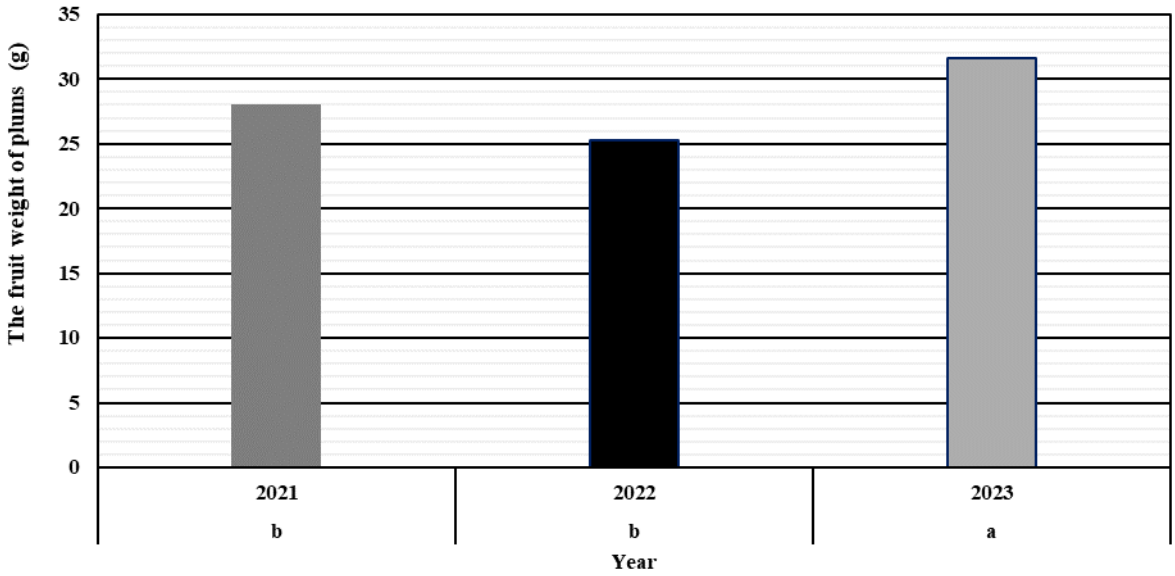

Figure 6 shows the fruit weights by cultivar and year. The 'Carmen' cultivar exhibited exceptionally high fruit weight in 2021 (84.11 g/fruit). There were no significant differences between the 'Carmen' fruit weights in 2022 and 2023 and those of 'Silvia' in 2021 and 2023 (60.97–68.8 g/fruit).

In the dry year of 2022, 'Silvia' responded very sensitively to drought, with a markedly lower fruit weight (33.74 g/fruit).

The lowest fruit weights were recorded for 'KTK', 'Methley', 'NP13', 'Penyigei', and 'Petrovka'.

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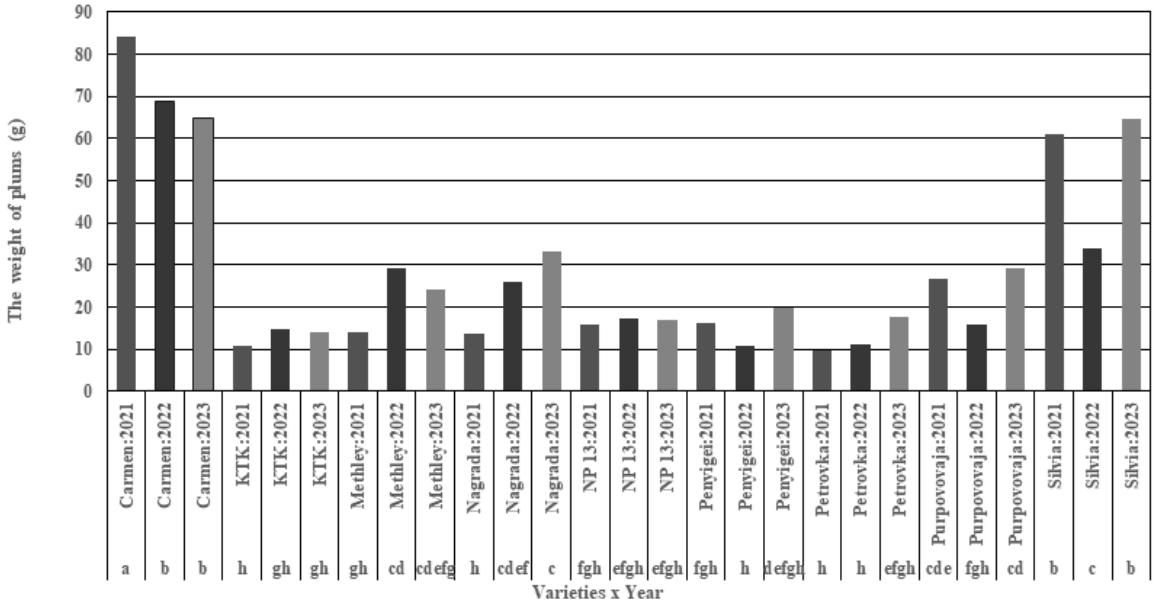
Figure 6. **The fruit weight of the plum varieties in the experimental years**
(Research Institute of Újfehértó, 2021–2023)



During processing, the fruit juice was extracted, and the soluble solids content was determined in degrees Brix (*Figure 7*).

On average over the examined years, no significant difference was found in sugar content (Brix index) among the cultivars.

The 'Carmen' cultivar showed the lowest Brix index, although the difference was not statistically significant.

Figure 7. **The Brix index of the plum varieties in the average of the examined years**
(Research Institute of Újfehértó, 2021–2023)

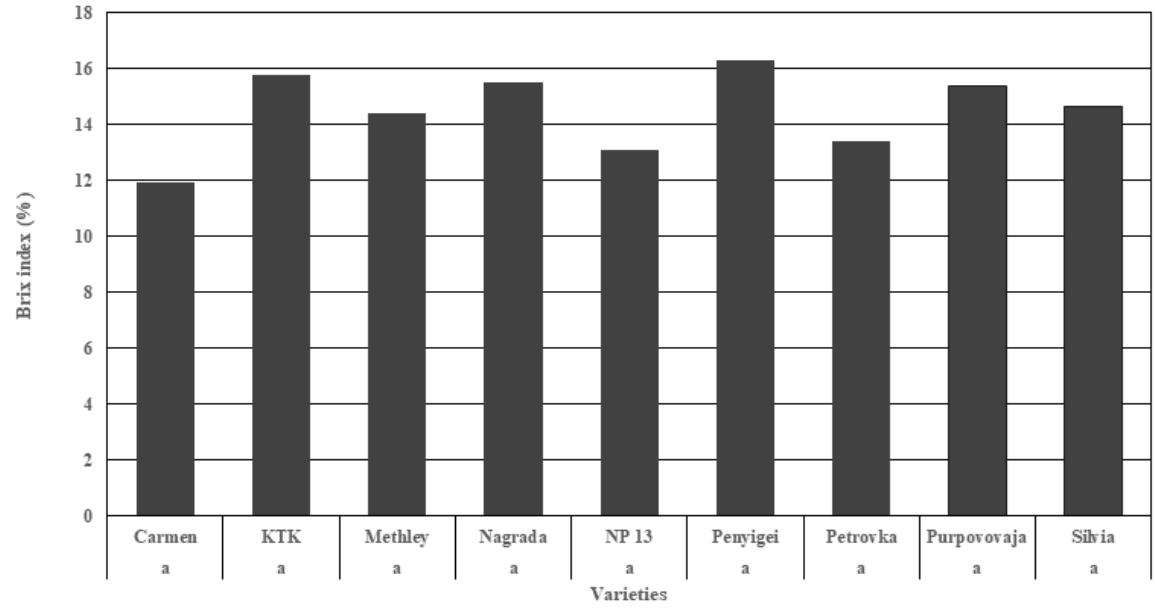


Figure 8 illustrates the average sugar content of the cultivars across years.

No significant difference was found between 2021 and 2022 (15.07–15.87%), while the Brix index was significantly lower in 2023 (12.51%), the year with high precipitation.

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Figure 8. **The Brix index of plum fruits in the average of the examined varieties across different years**
(Research Institute of Újfehértó, 2021–2023)

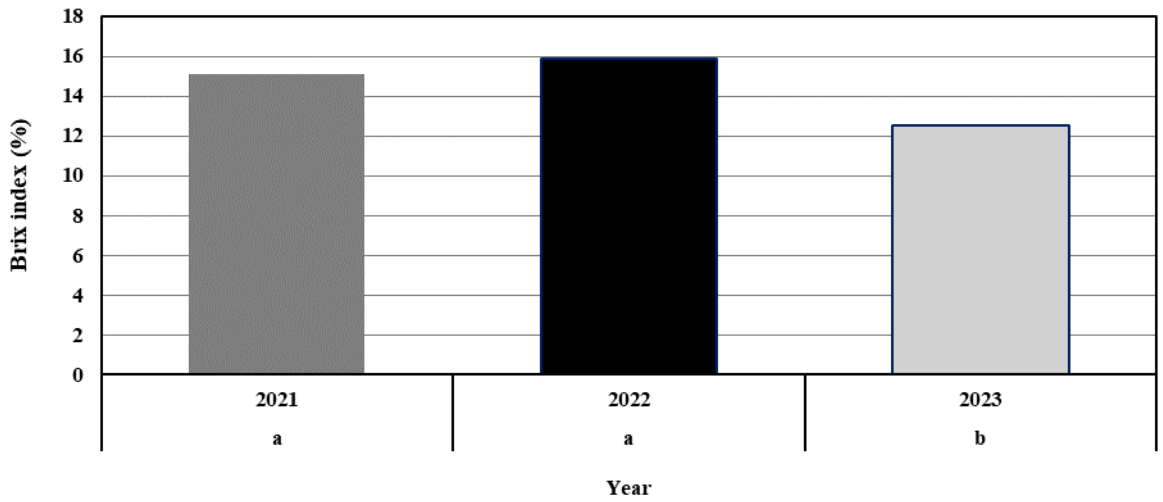
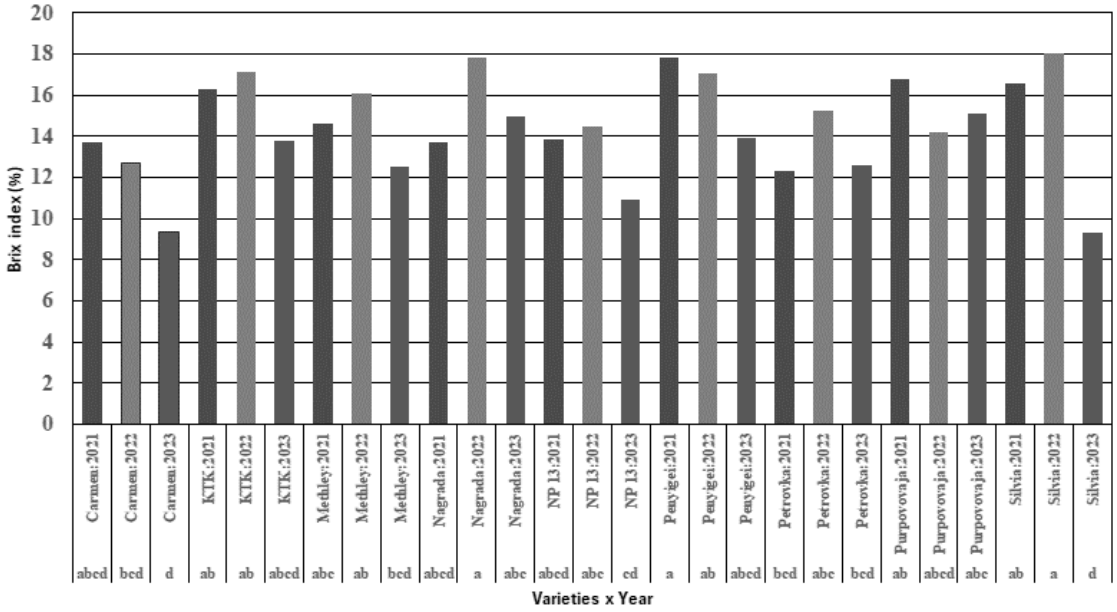


Figure 9 shows the sugar content of each cultivar by year. In most cases, no significant differences were found between cultivars or years. However, the large-fruited 'Carmen' and 'Silvia' cultivars exhibited lower sugar content in the wet year 2023, while the small-fruited 'Nagrada' and 'Penyigei' cultivars had higher sugar content.

Similar effects of water deficit on fruit quality were also reported by Guizani and Maatallah (2022), who found that drought stress increased total sugar content but reduced acidity in plums.

Figure 9. **The Brix index of the plum varieties in the experimental years**
(Research Institute of Újfehértó, 2021–2023)



Among the examined plum cultivars, 'Nagrada' showed the highest acid content (1.78%). There were no significant differences in acidity between 'Carmen', 'KTK', 'Methley', 'Penyigei', 'Petrovka', and 'Silvia'. The lowest acid contents were measured for 'NP13' (1.16%) and 'Purpovovaja' (1.20%). Overall, differences in acidity among the cultivars were minor, ranging between 1.2–1.62% (*Figure 10*).

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Figure 10. **The acid content of the plum varieties in the average of the examined years** (Research Institute of Újfehértó, 2021–2023)

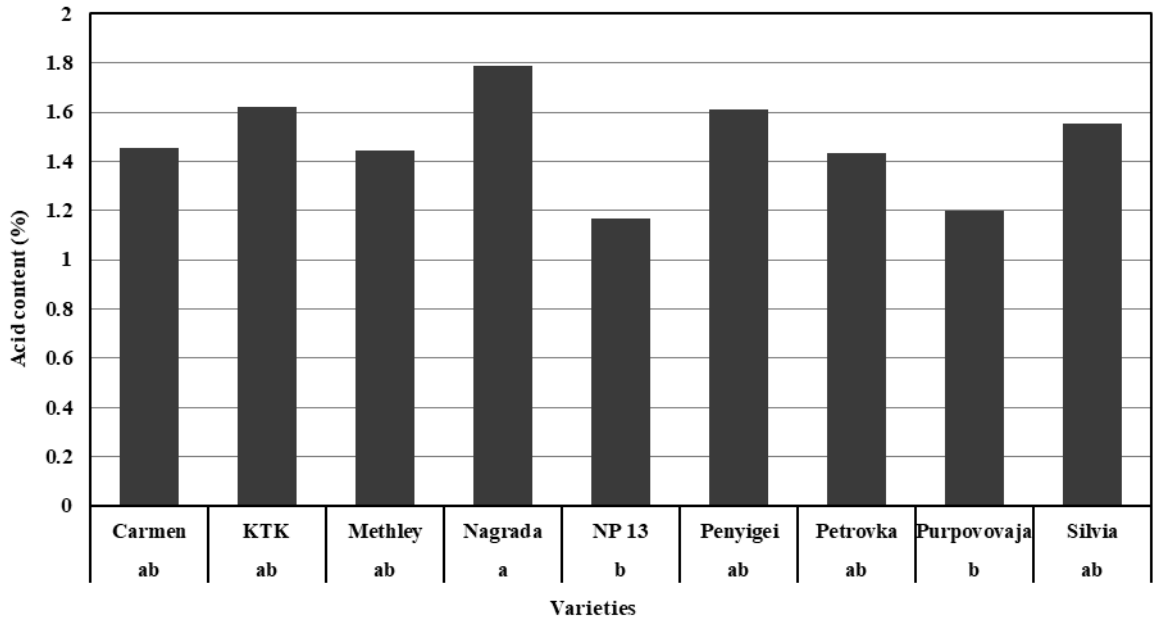

Figure 11 presents the average acid content across years. In the moderately wet year of 2021, significantly higher acidity was measured (1.63%). In contrast, in 2022 and 2023, acidity levels were significantly lower (1.37–1.41%), though the difference between these two years was not significant. Thus, it can be concluded that average rainfall in 2021 favored higher acidity, whereas both the dry conditions of 2022 and the excessive rainfall of 2023 resulted in lower acidity.

Figure 11. **The acid content of plum fruits in the average of the examined varieties across different years** (Research Institute of Újfehértó, 2021–2023)

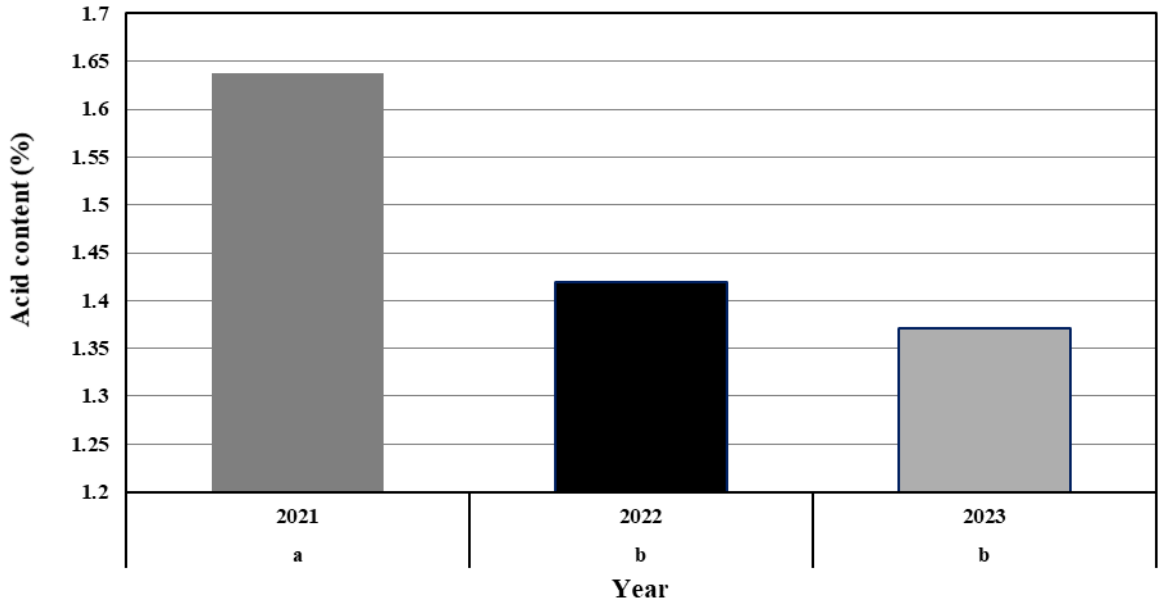

Figure 12 shows the acidity of the nine plum cultivars over the three years. The 'Nagrada' cultivar had significantly higher acidity in 2023 (2.1%), and also high in 2022 (2.0%). The 'Purpovovaja' cultivar had the lowest acidity in 2022 (0.43%), while 'NP13' also had low values in 2022–2023 (0.8–0.9%). No significant differences were observed among the other cultivars.

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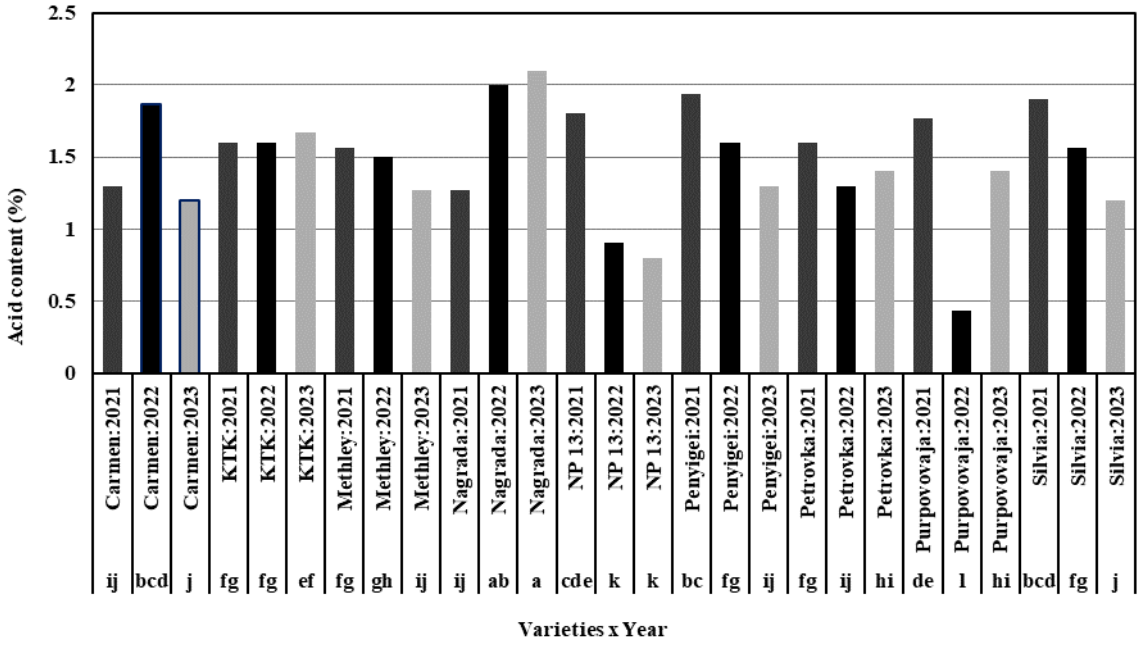
Figure 12. **The acid content of the plum varieties in the experimental years**
(Research Institute of Újfehértó, 2021–2023)



During the study, three parameters were evaluated for the nine plum cultivars in the Újfehértó gene bank, allowing numerical characterization of their quality traits. The relationships among these characteristics were analyzed using Pearson's correlation (*Table 1*). The determination coefficient (R^2) indicates how well the regression model explains the variance in the data. Values between 0.7 and 1 represent a strong relationship; an R^2 of 1 indicates a perfect relationship. The Brix index showed a positive but weak correlation with acidity ($R^2 = 0.48$) and a weak positive correlation with fruit mass.

Table 1. **The results of the analysis of relationships among the fruit characteristics of the examined plum varieties**

	Fruit mass (g)	Brix index (%)	Acidity (%)
Fruit weight (g)	1	0.32	0.07
Brix index (%)		1	0.48
Acidity (%)			1

CONCLUSIONS

The characteristics of plum fruits are important factors in determining their potential uses. Small- and medium-sized cultivars are well suited for industrial processing and are appropriate for mechanical harvesting. Consumer demand for fresh plums has increased, leading to the cultivation of numerous large-fruited varieties. This trend has also expanded the production of dual-purpose cultivars suitable for both fresh consumption and processing.

Studies conducted in gene bank orchards can therefore help identify individual cultivars and determine their most appropriate utilization purposes.

An exceptionally high fruit weight was recorded for the 'Carmen' cultivar in 2021, with an average of 84.11 g per fruit. No significant difference was found between the fruit weights of 'Carmen' (in 2022 and 2023) and 'Silvia' (in 2021 and 2023), which ranged from 60.97 to 68.8 g/fruit. In 2022, 'Silvia' responded very sensitively to drought conditions, producing significantly smaller fruits (33.74 g/fruit). The lowest fruit weights were observed in the 'KTK', 'Methley', 'NP13', 'Penyigei', and 'Petrovka' cultivars.

On average, there were no significant differences in Brix index among the cultivars; however, it was clearly observed that rainy years resulted in lower Brix percentages.

Regarding fruit acidity, no significant differences were found among cultivars across years, although the highest acid content occurred in the average-rainfall year.

Correlation analyses were also performed among the quality parameters of the plums. The Brix index showed a weak correlation with acidity ($R^2 = 0.48$) and with fruit weight. No correlation was found between fruit weight and acidity.

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