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# The effect of rootstocks on the development of fruit quality parameters of some sweet cherry (*Prunus avium* L.) cultivars, ‘Regina’ and ‘Kordia’, during the ripening process

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**Abstract.** Combinations of 5 rootstocks (‘GiSelA 5’, ‘GiSelA 6’, ‘Piku 1’, ‘PHL-C’, and ‘Weiroot 158’) and 2 scions (‘Regina’ and ‘Kordia’) were studied with regards to properties affecting consumer value, fruit appearance, and flavour. Rootstock effect is clearly identifiable in the development of fruit firmness, fruit weight, and sugar and acid content. Based on these properties, ‘PHL-C’ is recommended for ‘Kordia’ scion. For ‘Regina’, there is no obvious “best choice”; other factors must also be considered.

**Keywords:** scion-rootstock interaction, consumer value, flavour, fruit quality, total soluble solids, titratable acidity

# 1 Introduction

Owing to its early ripening, eye-appealing outward appearance and internal values, sweet cherry is one of the most popular summer fruits in Europe, as well as, some other parts of the globe. The world's sweet cherry production is about 1.2-1.4 megatons per year, of which Europe's participation is 60-70%. Cherry growers might be interested in knowing how their choice of rootstock influences fruit quality. Our work was meant to help them in their decision.

The performance of a fruit on the market depends primarily on appearance. Fruit size is an important factor in consumer liking and acceptance, as bigger fruits are generally considered to be more attractive to the eye and therefore sell more easily, and usually at a higher price per gram; therefore, varieties yielding larger fruits will be preferred commercially. Similarly to that of size, colour has an essential role in appearance, as consumers - regardless of their age, gender, or ethnicity - prefer darker coloured varieties [1].

The other key attribute is fruit firmness. Growers/exporters/outlets find much easier to handle, store, and transport firm fruits, which also tend to have a longer shelf-life than softer varieties. That does not mean that there is no place for softer varieties, it is just that their market resides locally to the region in which they are grown as they do not travel very well [2].

Whatever the appearance and firmness, a fruit cannot achieve lasting success if the values of the inner content are poor, for the final judgment given by the consumer is based on flavour. Flavour is a combination of taste and smell, influenced by certain chemical compounds like sugars, organic acids, phenolics, and more specialized flavour compounds, including an extensive range of aroma volatiles. The taste of the fruit depends primarily on sugar and acid content, more precisely, on their balanced development. Table 1 demonstrates this balance [2].

Table 1: Acid – sugar balance in sweet cherry fruit

| | | Sugars | |
|---|---|---|---|
| | | High | Low |
| Acids | Moderate to high | Best flavour combination | Sour, tart |
| | Low | Sweet | Tasteless |

All these attributes are, basically, characteristics of the scion; however, rootstock genotype can also have a great impact on them. By controlling the transport of water and other vital substances, rootstock determines many aspects of tree physiology and fruiting. The Tareen brothers [3] found significant differences between rootstocks with regards to yield, skin colour, and total soluble solids. Gonçalves et al. [4] investigated scion-rootstock interaction by measuring, among others, fruit mass, firmness, total soluble solids, and titratable acids. They demonstrated that any rootstock species found to be the best choice for a particular scion cultivar can also be the worst choice for another cultivar. Spinardi et al. [5] reported that rootstock influences the accumulation of sugars, acids, polyphenols, anthocyanins, and vitamins in cherry fruit.

## 2 Materials and methods

We studied the effect of 5 distinct sweet cherry rootstocks ('GiSelA 5', 'GiSelA 6', 'Piku 1', 'PHL-C', and 'Weiroot 158') on the fruit quality of 2 scion species ('Regina' and 'Kordia'). The sampling location was in the research centre of BOKU in Jedlersdorf, the testing location was the Laboratory of Horticulture and Viticulture Department, at the University of BOKU, in Vienna.

All measurements were taken with randomly selected fresh sweet cherry fruits. From each of the 10 scion-rootstock combinations, fruit samples were taken at 3 different stages of ripening: at the beginning of fruit coloration (Term 1), at 80% ripeness (Term 2), and at full ripeness (Term 3).

The studied physical parameters were: fruit removal force, fruit diameters (length, width, height), weight of fruit and stone, colour of surfaces, and fruit firmness. The studied chemical parameters were: total soluble solids (TSS), titratable acidity (TA), and electrochemical parameters: pH, rH, redoxpotential, conductivity, electric resistance, P-Value.

*Fruit removal force*:

By definition, this is the force required to remove the cherry fruit from the stem. It was determined by a Pesola spring scale (max. capacity: 1000 g).

*Measurement of fruit diameters*:

Fruit diameters were determined by a vernier calliper. 3 types of diameters were measured: height ($h$), length ($l$), and width ($w$). Height is the distance from the stem cavity to the blossom end while length and width are two horizontal diameters in right angle to each other, as shown in Fig. 1. From these 3 diameters was calculated the Fruitformindex (FFI), which shows the fruit shape, with the following formula:

$$FFI = h^2/(l * w)$$

*Measurement of fruit and stone weight*:

Fruit and stone weights were determined by a precision electronic weight scale (FA-2000S, Sartorius Mechatronics Austria GmbH).

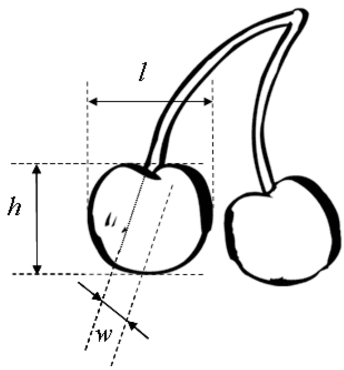


Figure 1: Diameters of a cherry fruit: height, length, and width

*Fruit firmness measurement*:

Fruit firmness is defined as the force required to rupture the exocarp. It was measured by a Penetrometer Microprocessor force gauge M 1000 E (Mecmesin, Austria) with a 0.5 $cm^2$ pressure seal. The penetrometer shows the force in g/0.5 $cm^2$ unit. The point of measurements was the same on each tested fruit: the centre of a randomly selected cheek, around halfway from the blossom end.

*Colour measurement*:

Fruit colour was determined by direct reading using chroma meter (MINOLTA model: CR-200). The following colour values were obtained: L* (brightness/darkness), a* (redness/greenness), and b* (yellowness/blueness). The measurements were taken with randomly selected fresh fruits at the same fruit parts: the opposite side of the suture, around halfway from the blossom end.

*Extraction from and analysis of fresh fruits:*

Cherry fruit juice for each cultivar was prepared using a juice extractor (Model: BRAUN-MP80). Each sample was made out of 20 randomly selected cherry fruits of the same tree, and for each scion-rootstock combination there were 8 trees. Juiced samples were filtered using filter paper (grade 3, 20-25 $\mu$m, Whatman GmbH, D-37586 Dassel) to obtain pure supernatant for TSS (total soluble solids) and TA (titratable acidity) measurements. TSS content was measured using a digital hand refractometer (Model: PT-32) and expressed in °brix at 20°C [6]. Five cm$^3$ of supernatant was diluted in 15 cm$^3$ of distilled water to measure TA using a TitroLine alpha plus automatic titrator (Model: SCHOTT TA20 plus). The sample was titrated to pH 8.1 using 0.1mol/dm$^3$ NaOH [7]. TA was expressed in cm$^3$ consumption/dm$^3$ sample.

*Electrochemical properties*:

Cherry fruit juice for each cultivar was prepared using juice extractor (model BRAUN-MP80; Braun, Kronberg, Germany). Eight juiced samples from each cultivar were prepared, as described above. Samples were filtered using filter papers (grade 4, 20-25 $\mu$m, D-37586 Dassel, Whatman GmbH) to obtain pure supernatant for pH, rH, and R measurement. Then, fruit pH (0-14 scale), rH (mV), and R ($\Omega$) were measured using BE-T-Analyse n. Prof. Vincent (model; MT 732-Fa MED-Tronik, Friesenheim, Germany), as indicated in [8] and [9]. The P-value, an integrating value of these three parameters expressed in micro watts ($\mu$W), was calculated using the formula below, considering a specific temperature during the measurement [10], [11]:

$$P = (30 * (rH - 2pH))^2/R$$

# 3 Results and discussions

*Physical attributes*:

The fruit removal force, though important from the point of view of storage and transportation, is not dealt with in this publication. Most of the tested cherries were out of specification for the spring scale, i.e. their fruit removal force was above the maximum measurable value. The few values we got were not enough to lead to any conclusion.

The other most important factor affecting storage stability is fruit firmness. Fig. 2 shows the average firmness values for all scion-rootstock combinations in Term 3. Apparently, ‘Regina’ cherries have generally better firmness than cv. ‘Kordia’s. Rootstock effect is also evident. ‘GiSelA’ rootstocks have the most conspicuous behaviour, producing the firmest fruits with ‘Regina’, but the softest ones with ‘Kordia’.

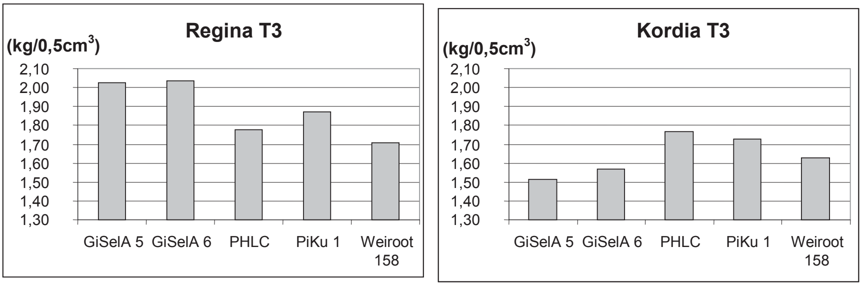


Figure 2: Fruit firmness of ‘Regina’ and ’Kordia’ cherries on different rootstocks in T3

When it comes to marketing, the size of a cherry is a substantial factor. Fig. 3 shows the average diameters for all scion-rootstock combinations in Term 3. Regina’s average size is very stable and reliably constant, regardless of the rootstock. ‘Kordia’, on the other hand, is more susceptible to rootstock effect.

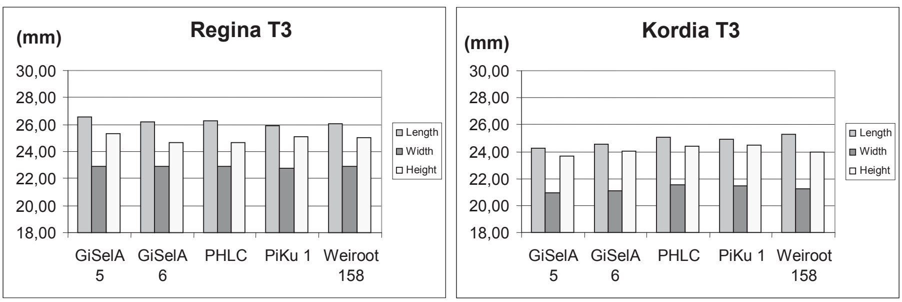


Figure 3: Fruit diameters of ‘Regina’ and ‘Kordia’ cherries on different rootstocks in T3

Simple diameter values are not adequate to describe fruit size. More conspicuous is the development of fruit mass. Fig. 4 shows the average cumulative fruit mass of 8 cherries. ‘Regina’ cherries are obviously much bigger, and a rootstock effect is well apparent. ‘GiSelA 5’ and ‘PHL-C’ display again that the best rootstock for one scion can be the worst one for another scion.

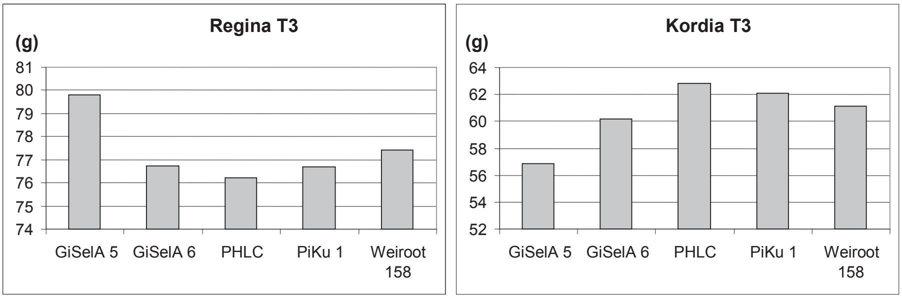


Figure 4: Fruit masses of 'Regina' and 'Kordia' cherries on different rootstocks in T3

*Chemical attributes*:

One would expect the sugar content of any fruit to increase with time, during the ripening process. 'Regina' cherries met these expectations as their sugar content showed a very strong (cca. 30%) increase. Fruits of 'Kordia', on the other hand, seemed to lose some of their sugar content between Term 2 and Term 3. Sugar contents of 'Regina' fruits were found to be significantly higher than those of 'Kordia', regardless of rootstock (Fig. 5).

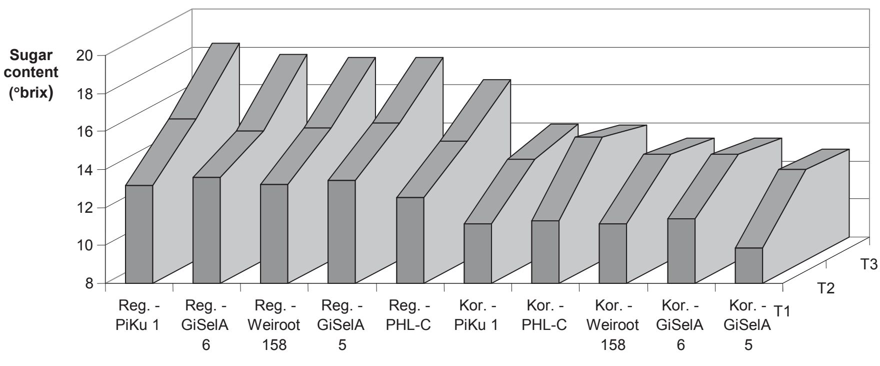


Figure 5: Development of sugar content

Within both scion species, rootstock effect is also well recognizable. Between the lowest and highest sugar content of fruits harvested in Term 3, a difference of 10-12% was observed. The order of rootstocks also showed some variance. Fruits on 'Piku 1' were found to be the sweetest of all, while 'GiSelA 6' and

'Weiroot 158' were reliably of middle sugar level, with both scions. However, 'GiSelA 5' and 'PHL-C' rootstocks behave totally differently when grafted with 'Regina' and 'Kordia'. (Fig. 5)

With regard to total acids (Fig. 6.), again, there was a huge difference between 'Regina' and 'Kordia'. The acid content of 'Regina' fruits showed a monotonous rise with time, and also quite similar results for all rootstocks, except for 'GiSelA 5', which had notably lower acid contents than the rest. On the other hand, cherries taken from 'Kordia' showed a different behaviour. Acid content, in general, decreased substantially during ripening. The variance between rootstocks was about 15%. The decrease was not always monotonous, but it was very rapid in the later stages of ripening.

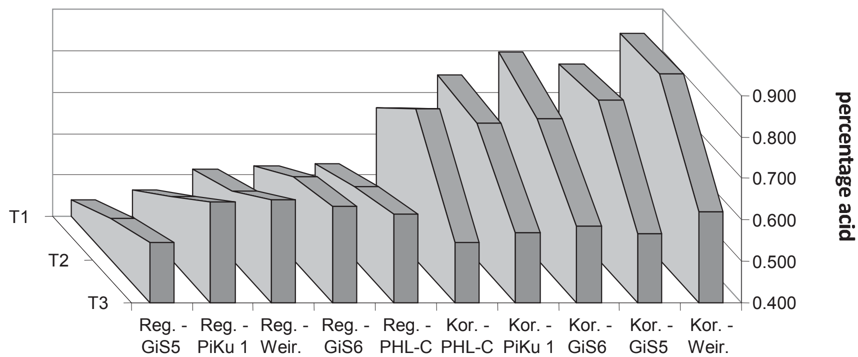


Figure 6: Development of acid content

The conductivity (Fig. 7) of the cherry fruit is important, primarily, for the processability in food industry. For 'Kordia' cherries, a general impression is that conductivity decreases sharply with ripening. However, 'PiKu 1' rootstock is a special case as it shows a sharp conductivity increase between Terms 2 and 3. For 'Regina' cherries, on the other hand, it is quite difficult to find any regularity. Conductivity always decreases during the ripening process, but the actual values as well as the shapes of the diagrams show a wide variety.

Sugar - acid relations: Sugar/acid ratios can be calculated from their parent values. However, this ratio does not characterize fruit flavour adequately. It is equally important, as described in the introduction, that the acquisition of both sugar and acid is balanced. Cherries accumulate sugar and acid from the plant during ripening. If harvested too early, they are unable to accumulate enough quantities to enhance their taste to the levels desired by consumers, and will be, therefore, considered commercially unacceptable.

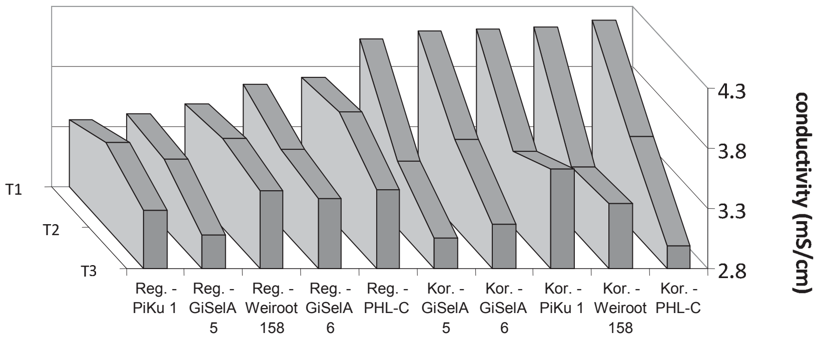


Figure 7: Development of conductivity

Fig.8 shows the sugar-acid distribution of each analysed cherry sample. The black arrow across represents a constant sugar/acid ratio, with the arrow's direction indicating a better fruit flavour. The upper area is relatively rich in acids while the lower one is relatively rich in sugars.

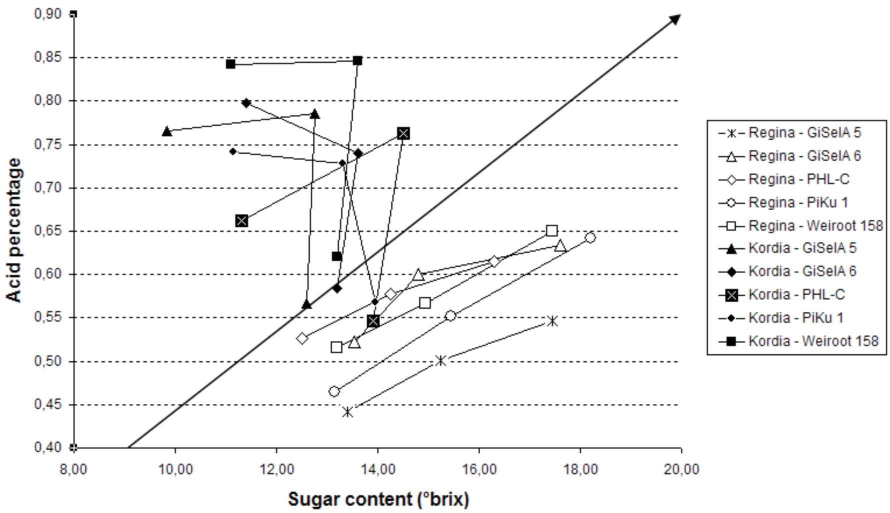


Figure 8: Sugar/acid distribution

'Regina' fruits are located in the lower region, indicated by more or less linear graphs. It is well apparent that the taste quality of 'Regina' cherries monotonously improved during ripening. Best taste quality was observed in-side the big circle, i.e. when 'Regina' was grafted on 'Weiroot 158', 'GiSelA 6', and 'PiKu 1'.

Graphs of 'Kordia' fruits are located in the upper region of the chart. The graphs are broken lines. In all but one case, both sugar and acid content was observed to decrease during the last stage of ripening. It all means that the taste quality of 'Kordia' cherries had actually declined. This unexpected result forecasts that direct sensory observation of fruits may not be the most accurate method to determine the stage of ripeness.

In any case, the best flavour quality was associated with the 80% ripe fruit of 'Kordia' grafted on 'PHL-C', because while all 'Kordia' cherries showed relatively high acid content; only this particular combination, indicated by the small circle, had reached a sugar content of 14°brix.

Averages of test results can be found below, in Table 2.

Table 2: Acid – sugar balance in sweet cherry fruit

| | | Fruit Weight (g, 8 pcs) | | | Stone Weight (g, 8 pcs) | | | Fruit Form Index | | | Fruit Firmness (kg/0.5 cm$^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scion | Rootstock | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 |
| Kordia | GiSelA 5 | 30.270 | 40.890 | 56.890 | 3.275 | 3.160 | 2.970 | 1.305 | 1.179 | 1.107 | 2.67 | 1.97 | 1.51 |
| | GiSelA 6 | 30.720 | 44.720 | 60.200 | 3.080 | 3.350 | 3.230 | 1.309 | 1.179 | 1.123 | 2.83 | 2.25 | 1.57 |
| | PHLC | 35.195 | 44.780 | 62.830 | 3.675 | 3.175 | 2.945 | 1.200 | 1.154 | 1.110 | 2.75 | 2.08 | 1.77 |
| | PiKu 1 | 31.230 | 47.500 | 62.120 | 3.150 | 3.445 | 2.955 | 1.266 | 1.175 | 1.126 | 2.69 | 1.83 | 1.73 |
| | Weiroot 158 | 31.265 | 46.520 | 61.095 | 3.095 | 3.520 | 2.780 | 1.224 | 1.119 | 1.072 | 2.38 | 1.97 | 1.63 |
| Regina | GiSelA 5 | 61.310 | 71.340 | 79.810 | 3.990 | 4.820 | 5.135 | 1.010 | 1.027 | 1.052 | 3.07 | 2.43 | 2.02 |
| | GiSelA 6 | 60.155 | 69.545 | 76.715 | 4.050 | 4.950 | 4.825 | 1.000 | 0.997 | 1.014 | 2.66 | 2.35 | 2.04 |
| | PHLC | 67.075 | 66.970 | 76.235 | 4.115 | 4.730 | 5.065 | 1.020 | 1.033 | 1.014 | 2.47 | 2.17 | 1.78 |
| | PiKu 1 | 61.820 | 67.535 | 76.690 | 3.985 | 4.790 | 5.135 | 1.057 | 1.012 | 1.075 | 2.62 | 2.36 | 1.87 |
| | Weiroot 158 | 64.870 | 70.440 | 77.415 | 4.065 | 4.865 | 4.955 | 1.008 | 1.001 | 1.049 | 2.34 | 2.20 | 1.71 |

| | | TSS (°Brix) | | | Acid (cm$^3$) | | | Percentage acid | | | Conductivity (mS/cm) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scion | Rootstock | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 | T1 | T2 | T3 |
| Kordia | GiSelA 5 | 9.85 | 12.75 | 12.60 | 5.72 | 5.86 | 4.23 | 0.766 | 0.785 | 0.567 | 2.67 | 1.97 | 1.51 |
| | GiSelA 6 | 11.40 | 13.60 | 13.20 | 5.95 | 5.52 | 4.36 | 0.798 | 0.740 | 0.585 | 2.83 | 2.25 | 1.57 |
| | PHLC | 11.30 | 14.50 | 13.90 | 4.94 | 5.69 | 4.08 | 0.662 | 0.763 | 0.546 | 2.75 | 2.08 | 1.77 |
| | PiKu 1 | 11.15 | 13.30 | 13.95 | 5.54 | 5.43 | 4.24 | 0.742 | 0.728 | 0.568 | 2.69 | 1.83 | 1.73 |
| | Weiroot 158 | 11.10 | 13.60 | 13.20 | 6.28 | 6.32 | 4.63 | 0.842 | 0.847 | 0.621 | 2.38 | 1.97 | 1.63 |
| Regina | GiSelA 5 | 13.40 | 15.25 | 17.45 | 3.30 | 3.74 | 4.08 | 0.442 | 0.501 | 0.546 | 3.07 | 2.43 | 2.02 |
| | GiSelA 6 | 13.55 | 14.80 | 17.60 | 3.90 | 4.48 | 4.73 | 0.522 | 0.600 | 0.633 | 2.66 | 2.35 | 2.04 |
| | PHLC | 12.50 | 14.25 | 16.30 | 3.93 | 4.31 | 4.59 | 0.526 | 0.577 | 0.615 | 2.47 | 2.17 | 1.78 |
| | PiKu 1 | 13.15 | 15.45 | 18.20 | 3.47 | 4.12 | 4.79 | 0.465 | 0.552 | 0.642 | 2.62 | 2.36 | 1.87 |
| | Weiroot 158 | 13.20 | 14.95 | 17.45 | 3.85 | 4.23 | 4.85 | 0.515 | 0.567 | 0.650 | 2.34 | 2.20 | 1.71 |

# 4 Conclusion

Fruit quality is clearly affected by rootstock species. For 'Kordia' scion, based on fruit taste, weight, and firmness, 'PHL-C' seems to be the best rootstock choice. With 'Regina', the choice is more difficult. 'Weiroot 158', 'GiSelA 6', and 'PiKu 1' can equally compete for the title. Even 'GiSelA 5' should not be ruled out because its slightly lower taste quality is compensated by an outstanding fruit size. 'PHL-C' is the least recommended.

It should also be noted that the quality properties of 'Kordia' variants change very rapidly in the later stages of ripening. Thus, growers should consider very carefully timing the harvest of 'Kordia' cherries because the quality of the fruit will change significantly in just a few days. Growers of 'Regina' have more freedom in this regard.

Moreover, the final decision should consider other parameters, which we have not touched upon, such as fruit yields, plant resistance to diseases, etc.

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