# Alpe Adria Trial - Sweet Cherry Regina on Three Dwarf Rootstocks and Different Plant Distances

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**Keywords:** cherry rootstock, plant distance, vigour, productivity, fruit size

**Abstract**

A trial with sweet cherry cultivar Regina on three dwarf rootstocks and three different plant distances was carried out from 2006 to 2013 in Alpe Adria region. The countries included were Italy, Austria, Croatia and Slovenia; the rootstocks Gisela 3, Gisela 5 and Weiroot 72 and the plant distances between trees 1.5 m, 2.0 m and 2.5 m. After seven year period the results of tree vigour, cumulative yield (2008-2013), yield efficiency and fruit weight were evaluated. Tree vigour, measured and calculated as trunk cross sectional area (TCSA), was affected by interactions location x rootstock, location x distance and rootstock x distance. The most vigorous trees were on Weiroot 72 in Haidegg (Austria) and the least vigorous on Gisela 3 in Bilje (Slovenia) and Zagreb (Croatia). The ANOVAs for the averages of cumulative yield show that the interaction among location, rootstock and distance was statistically significant. Cumulative yield was the highest in Sondrio on Gisela 5 at 2.5 m (36.4 kg) and the lowest in Bilje on Gisela 3 at 1.5 m. (9.3 kg/tree). Yield efficiency was calculated as ratio of cumulative yield (2008-2013) to TCSA. The interactions location x rootstock and rootstock x distance were significant. The highest yield efficiency was calculated for Zagreb on Gisela 3 (0.77 kg/cm$^2$) and the lowest for Maribor on Weiroot 72 (0.19 kg/cm$^2$). The results of seven-year-trial show that location, rootstock and plant distance significantly affected growth, productivity and fruit weight of Regina sweet cherry.

## INTRODUCTION

The first experiences with dwarf cherry rootstocks in some countries of Alpe Adria region (particularly for Slovenia and Croatia) were obtained with our first common trial, planting in spring 1997. The results of tree vigour, yield, yield efficiency, fruit weight show large differences between rootstocks and locations (Siegler et al., 2000; Usenik et al., 2008; Bassi et al. 2012; Fajt et al., 2014). Different experiences with dwarf rootstocks express also

many researchers all over the Europa (Hilsendegen, 2005; Hrotko, 2005; Balmer, 2008; Grzyb et al., 2008; Franken-Bembeneck, 2011; Lugli et al., 2011; Szabo et al., 2011; Biško et al., 2013; Sansavini and Lugli, 2014).

The objective of our study was to determine the impact of rootstocks Gisela 3, Weiroot 72 and Gisela 5 and three planting distances on vegetative growth, yield efficiency and fruit weight of sweet cherry cultivar 'Regina'.

## MATERIALS AND METHODS

In spring 2006 several countries of Alpe Adria region (Italia, Austria, Slovenia, Croatia) planted sweet cherry cv. Regina on three dwarf rootstocks Gisela 3 (G 3), Gisela 5 (G 5) and Weiroot 72 (W 72) in a common trial with a different distances between trees 1.5 m, 2.0 m and 2.5 m. Unfortunately, Gisela 5 as a standard rootstock, wasn't planted in all stations (for example in Haidegg, in Zagreb only on plant distance 2.0 m), also tree number/rootstock was not the same in all stations. In order to obtain homogeneous plant material for all locations, the trial trees were propagated by the same German nursery. Sweet cherry cv. Durone 3 was included as a pollinator for cv. Regina. Geografical and pedo-climatic characteristics for five locations Sondrio (Italy), Haidegg (Austria), Zagreb (Croatia), Maribor (Slovenia) and Bilje (Slovenia) were different. Pedo-climatic characteristics were as follows; Sondrio: 46° 10’ N geographical latitude, 517 m altitude, 990 mm of average year precipitation (AYP), sandy and fertile soil, sub-acid with high organic content; Zagreb: 45°49’ N geographical latitude, 155 m altitude, 852 mm AYP, heavy-loamy soil, sub-acid with medium organic and mineral content; Haidegg: 47°49’ N geographical latitude, 353 m altitude, 900 mm AYP, sandy-loamy soil, sub-acid with medium organic and mineral content; Maribor: 46°62’ N latitude, 292 m altitude, 1000 mm AYP, heavy–loamy soil, sub-alcaline, poor organic and mineral content; Bilje 45°53’ N latitude, 50 m altitude, 1400 mm AYP, sandy soil with stone content, sub-acid with medium organic and mineral content. Trees were trained to the spindle training system, all trees were irrigated, when it was necessary, but with different irrigation systems (in Sondrio with classic sprinklers, in Zagreb and Haidegg with drip irrigation, in Maribor and Bilje with micro yet sprinklers). Orchards were hail protected with black net systems, in Maribor, Haidegg, and Bilje were also rain protected. Pest and disease control was carried out as integrated production (Bilje, Maribor, Haidegg) and as traditional production (Sondrio, Zagreb). Agrotechnical orchard management was specific for each station. The data per tree were annually collected till 2013. Tree mortality per rootstock, and tree distance was annually noticed in each location as well.

Trunk diameter was measured 20 cm above the graft union, from which trunk cross-sectional area (TCSA) was calculated ($P=\pi*r^2$). From 2008 to 2013 yield/tree (kg) was measured. Yield efficiency ($kg/cm^2$) was calculated using the ratio of cumulative yield (2008-2013) to TCSA in 2013. Average fruit weight (g) was calculated from a representative sampling of 100 fruits per cultivar and rootstock combination from 2009 to 2011. Statistical analyses were conducted with R program (R Development Core Team). Analysis of variance (ANOVA) for three factor experiment design was used for analysis of the effect of rootstock,

location, plant distance and their interactions on growth, yield and fruit weight of sweet cherry cv. Regina. Differences were compared using Duncan's multiple comparison test at $p<0.05$, $p<0.01$ and $p<0.001$.

## RESULTS AND DISCUSSION

### Tree vigour

Tree vigour was significantly affected by rootstock, location, plant distance and interactions rootstock/location, location/distance and rootstock/distance. Significantly more vigorous were trees on Gisela 5 in Maribor on plant distance 2.5 m (139.4 $cm^2$) and the least on Gisela 3 in Bilje on plant distance 2.0 m (22.1 $cm^2$) expressed as TCSA increment (Fig. 1,Tab. 2,). If we compared tree vigour on standard rootstock Gisela 5 in several locations, the most vigorous trees were in Sondrio and Maribor without significant differences between them and the least vigorous in Bilje and Zagreb. G 5 tree was less vigorous than W 72 and more vigorous than G 3. The influence of location and rootstock on tree vigour was already described by many researches (Siegler et al., 2000; De Salvador et al., 2005; Usenik et al., 2008; Bassi et al., 2012).

### Mortality Rate

Tree mortality was influenced by location, rootstock and distance (Tab. 1). The highest tree mortality rate was noticed in Sondrio on W 72 on plant distance 1.5 m (100 %) and in Zagreb on G 3 on plant distance 2.0 m (53 %). The reason for a great mortality rate in Sondrio could be the replant soil, causing higher tree mortality rate also on G 3. In Germany trial Stehr (2014) find out also low tree survival rates on Gisela 3. All other stations had tree mortality rate from 0 to 40 %, depending on rootstock, location and plant distance. G 5 expressed low tree mortality (0 – 20 %) like reporting of Stehr (2014) and Hilsendegen (2005) regarding Regina on G 5, which didn't express any tree mortality.

### Yield and yield efficiency

Interaction location/rootstock had a high significant effect on cumulative yield and yield efficiency ($p>0.001$). Plant distance significantly influenced only yield efficiency in interaction with rootstock and cumulative yield in interaction with location/rootstock ($p<0.05$). The highest cumulative yield was registered on G 5 on plant distance 2.5 m in Sondrio (36.4 kg/tree), the lowest on G 3 on plant distance 1.5 m in Bilje (9.4 kg/tree), all other rootstock and plant distance combinations were between those two values (Tab. 2). Productivity varied between the locations, depending on rootstock and plant distance (Fig. 2-4). The highest yield efficiency was calculated on G 3 on plant distance 2.5 m in Zagreb (0.81 $kg/cm^2$). The results of this study confirmed some findings of our previous research (Usenik et al. 2006; Biško et al., 2013; Fajt et al., 2014).

### Fruit weight

Effect of rootstock, location and plant distance on fruit weight was shown in Fig. 5. The average fruit weight was influenced by location, rootstock and interaction location/rootstock. The largest fruit weight was measured in Sondrio on G 5 on plant distance 2.0 m (11.3 g) and the smallest (7.6 g) in Zagreb on G 3 on plant distance 2.0 m. The average fruit weight varied also among years and locations, expecialy in 2012 and 2013 because of severe spring frost,

when some locations didn't have any production (Zagreb) or very small production (Bilje, Maribor). Big problems with birds occured on some locations (Haidegg, Maribor) in certain years. That's why we analyzed fruit weight of only three more or less productive years.

## CONCLUSIONS

The results show that vegetative and generative parameters of Regina on Gisela 3, Weiroot 72 and Gisela 5 were more affected by location and rootstock than plant distance. Plant distances significantly influenced only TCSA (statisticyally significant interactions distance/location and distance/rootstock).

In accordance with knowledge about quite different local grown environmental conditions of observed rootstocks, we can conclude that the best yield results we found on rather vigorous trees (for exp. Gisela 5), either they didn't show the best yield efficiency.


## ACKNOWLEDGEMENTS

Thanks to Agricultural Ministries of included countries for financial support of this international trial.


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## Tables

Table 1. Tree mortality rate (%) of cv. Regina after 7 year period of Alpe Adria trial.

| Location | GiSelA 3 | | | GiSelA 5 | | | Weiroot 72 | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1.5 m | 2 m | 2.5 m | 1.5 m | 2 m | 2.5 m | 1.5 m | 2 m | 2.5 m |
| Bilje-SLO | 20 | 13 | 7 | 20 | 0 | 0 | 20 | 13 | 0 |
| Maribor-SLO | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 27 |
| Sondrio-I | 27 | 40 | 40 | 0 | 17 | 0 | 100 | 33 | 33 |
| Zagreb-CRO | 40 | 53 | 20 | | 0 | | 7 | 27 | 20 |
| Haidegg-A | 7 | 0 | 0 | | | | 0 | 13 | 13 |

Table 2. Effect of location (Loc.), rootstock (Root.) and plant distance (Dist.) on TCSA ($cm^2$) in 2013, on cumulative yield 2008-2013 (kg), on yield efficiency ($kg/cm^2$) and on average fruit weight (g) in 2009-2011.

| Loc. | Root. | Dist. | TCSA | | Cumulative yield | | Yield efficiency | | Average fruit weight | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\bar{x}$ | sd | $\bar{x}$ | sd | $\bar{x}$ | sd | $\bar{x}$ | sd |
| **Bilje (SLO)** | Gisela 3 | 1.5 | 26.08 | 7.94 | 9.35 | 5.80 | 0.34 | 0.15 | 8.7 | 0.7 |
| | | 2.0 | 22.10 | 5.53 | 9.50 | 4.52 | 0.42 | 0.12 | 8.5 | 0.7 |
| | | 2.5 | 28.25 | 5.97 | 11.86 | 4.71 | 0.42 | 0.15 | 8.8 | 1.2 |
| | Gisela 5 | 1.5 | 36.56 | 11.05 | 12.56 | 3.74 | 0.35 | 0.06 | 9.7 | 0.5 |
| | | 2.0 | 37.73 | 10.96 | 16.48 | 6.94 | 0.43 | 0.09 | 9.4 | 0.2 |
| | | 2.5 | 50.95 | 8.49 | 16.85 | 5.81 | 0.34 | 0.14 | 9.9 | 0.5 |
| | Weiroot 72 | 1.5 | 62.60 | 17.07 | 19.80 | 6.95 | 0.32 | 0.10 | 9.3 | 0.7 |
| | | 2.0 | 47.06 | 16.81 | 15.90 | 6.24 | 0.34 | 0.08 | 8.8 | 0.9 |
| | | 2.5 | 68.87 | 18.58 | 25.26 | 9.65 | 0.39 | 0.17 | 9.1 | 0.4 |
| **Maribor (SLO)** | Gisela 3 | 1.5 | 40.45 | 14.75 | 14.19 | 4.47 | 0.38 | 0.15 | 7.7 | 0.5 |
| | | 2.0 | 42.71 | 10.88 | 15.98 | 5.43 | 0.41 | 0.18 | 8.3 | 1.1 |
| | | 2.5 | 45.08 | 37.49 | 18.65 | 5.96 | 0.55 | 0.27 | 8.6 | 0.9 |
| | Gisela 5 | 1.5 | 69.85 | 20.92 | 21.65 | 7.77 | 0.32 | 0.11 | 9.2 | 0.5 |
| | | 2.0 | 97.94 | 16.62 | 34.38 | 4.84 | 0.36 | 0.08 | 9.5 | 0.7 |
| | | 2.5 | 139.38 | 35.52 | 32.74 | 7.94 | 0.25 | 0.08 | 10.3 | 0.8 |
| | Weiroot 72 | 1.5 | 80.75 | 17.51 | 14.24 | 3.78 | 0.18 | 0.05 | 9.9 | 0.7 |
| | | 2.0 | 93.51 | 22.19 | 18.50 | 3.46 | 0.21 | 0.07 | 10.1 | 1.0 |
| | | 2.5 | 118.64 | 36.57 | 18.72 | 6.09 | 0.17 | 0.07 | 9.4 | 2.9 |
| **Haidegg (A)** | Gisela 3 | 1.5 | 83.22 | 19.79 | 22.50 | 4.26 | 0,29 | 0.09 | - | - |
| | | 2.0 | 89.39 | 22.76 | 21.79 | 4.12 | 0.26 | 0.08 | - | - |
| | | 2.5 | 84.15 | 26.72 | 22.56 | 8.05 | 0.28 | 0.08 | - | - |
| | Gisela 5 | 1.5 | - | - | - | - | - | - | - | - |
| | | 2.0 | - | - | - | - | - | - | - | - |
| | | 2.5 | - | - | - | - | - | - | - | - |
| | Weiroot 72 | 1.5 | 95.72 | 30.01 | 23.16 | 3.87 | 0.26 | 0.09 | - | - |
| | | 2.0 | 113.93 | 42.36 | 25.52 | 6.64 | 0.25 | 0.10 | - | - |
| | | 2.5 | 102.14 | 25.05 | 25.94 | 6.60 | 0.28 | 0.13 | - | - |
| **Sondrio (I)** | Gisela 3 | 1.5 | 94.03 | 59.29 | 23.84 | 7.24 | 0.34 | 0.22 | 10.7 | 1.2 |
| | | 2.0 | 117.14 | 29.09 | 26.74 | 8.96 | 0.24 | 0.10 | 11.2 | 1.1 |
| | | 2.5 | 79.71 | 46.43 | 23.13 | 12.29 | 0.35 | 0.27 | 10.8 | 1.3 |
| | Gisela 5 | 1.5 | 78.45 | 11.77 | 36.13 | 2.75 | 0.47 | 0.10 | 11.2 | 0.6 |
| | | 2.0 | 79.86 | 54.28 | 20.93 | 14.10 | 0.32 | 0.15 | 11.3 | 1.1 |
| | | 2.5 | 126.47 | 37.84 | 36.43 | 9.39 | 0.31 | 0.13 | 11.1 | 0.8 |
| | Weiroot 72 | 1.5 | - | - | - | - | - | - | - | - |
| | | 2.0 | 109.12 | 83.94 | 16.48 | 4.59 | 0.19 | 0.11 | - | - |
| | | 2.5 | 74.24 | 10.30 | 24.48 | 9.36 | 0.34 | 0.17 | - | - |
| **Zagreb (CRO)** | Gisela 3 | 1.5 | 27.31 | 5.67 | 19.84 | 6.00 | 0.72 | 0.15 | 9.0 | 0.9 |
| | | 2.0 | 34.26 | 8.34 | 26.09 | 6.27 | 0.76 | 0.06 | 7.6 | 2.8 |
| | | 2.5 | 31.89 | 12.20 | 26.94 | 13.00 | 0.81 | 0.17 | 8.3 | 0.8 |
| | Gisela 5 | 1.5 | - | - | - | - | - | - | - | - |
| | | 2.0 | 43.19 | 10.88 | 30.96 | 10.30 | 0.70 | 0.11 | 8.1 | 0.6 |
| | | 2.5 | - | - | - | - | - | - | - | - |
| | Weiroot 72 | 1.5 | 46.28 | 13.88 | 27.22 | 6.00 | 0.61 | 0.13 | 9.1 | 0.8 |
| | | 2.0 | 54.55 | 17.07 | 30.05 | 9.95 | 0.55 | 0.11 | 8.7 | 1.1 |
| | | 2.5 | 58.50 | 17.55 | 32.55 | 10.30 | 0.57 | 0.13 | 9.0 | 1.0 |

| | | | | |
|---|---|---|---|---|
| loc. | *** | *** | *** | *** |
| root. | *** | *** | *** | *** |
| dist. | ** | *** | NS | NS |
| loc. x root. | *** | *** | *** | *** |
| loc .x dist. | ** | NS | NS | NS |
| root. x dist. | *** | NS | * | NS |
| loc. x root. x dist. | NS | * | NS | NS |

NS – not significant, *, **, *** - significant at P=0.05, P =0.01 and P =0.001; mean separation by Duncan's New Multiple Range Test

## Figures

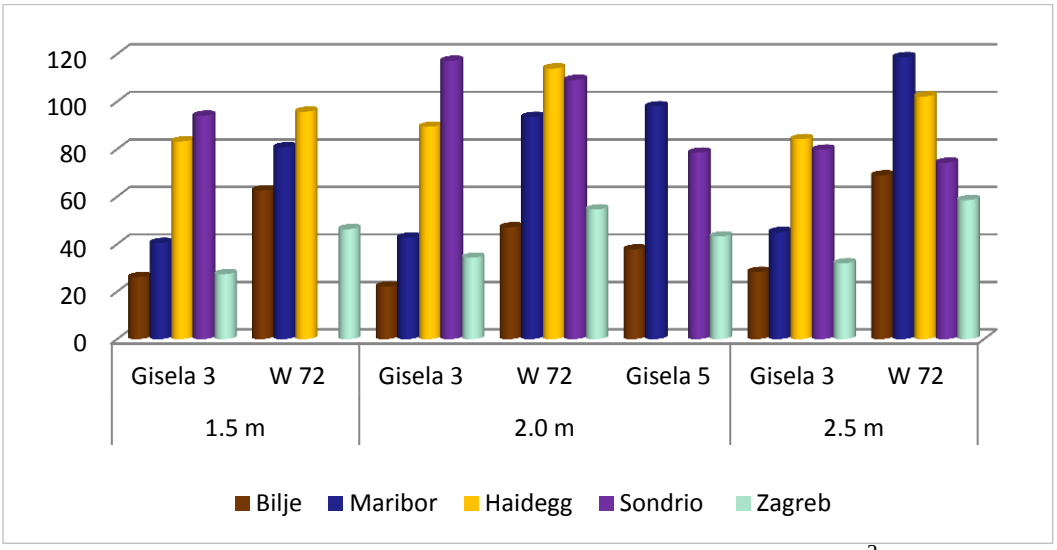


Fig.1. Effect of rootstock, location and plant distance on TCSA ($cm^2$) of cv. Regina in 2013.

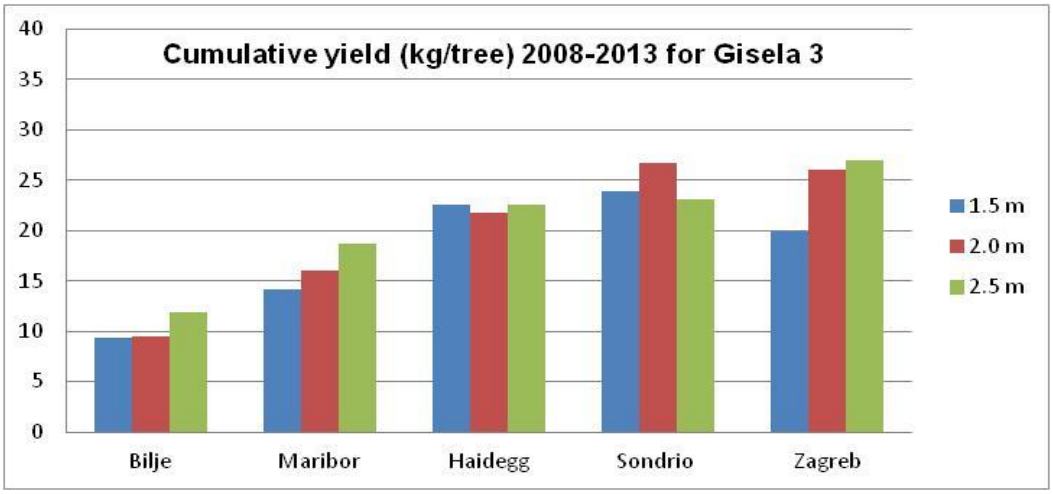


Fig. 2

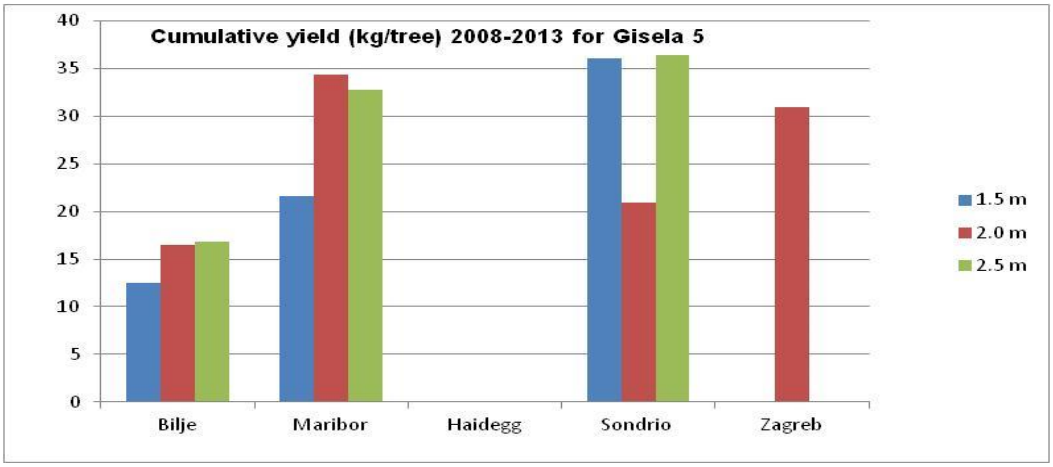


Fig. 3

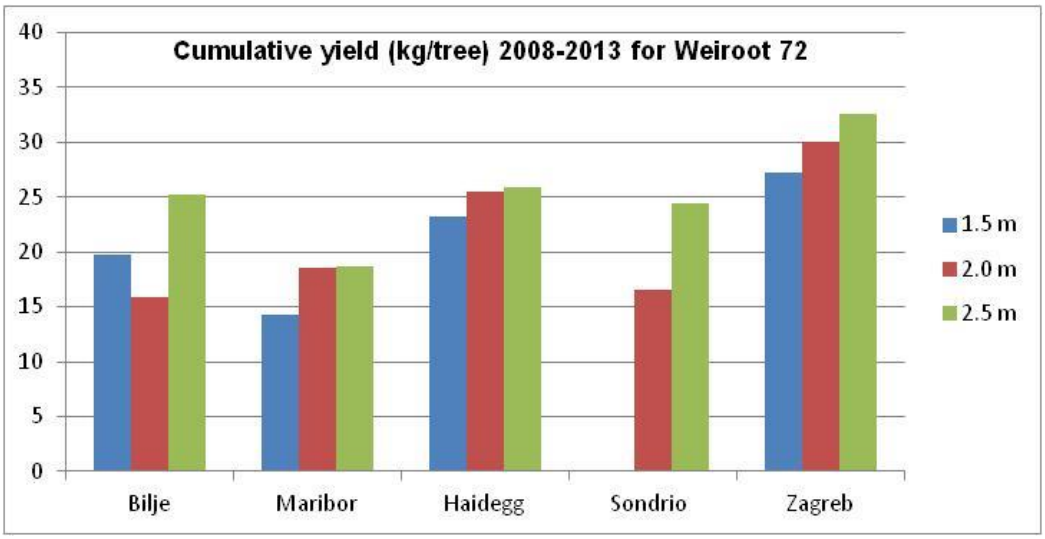


Fig. 4

Fig. 2 – 4. Effect of rootstock, location and plant distance on cumulative yield (kg/tree) of cv. Regina (2008-2013).

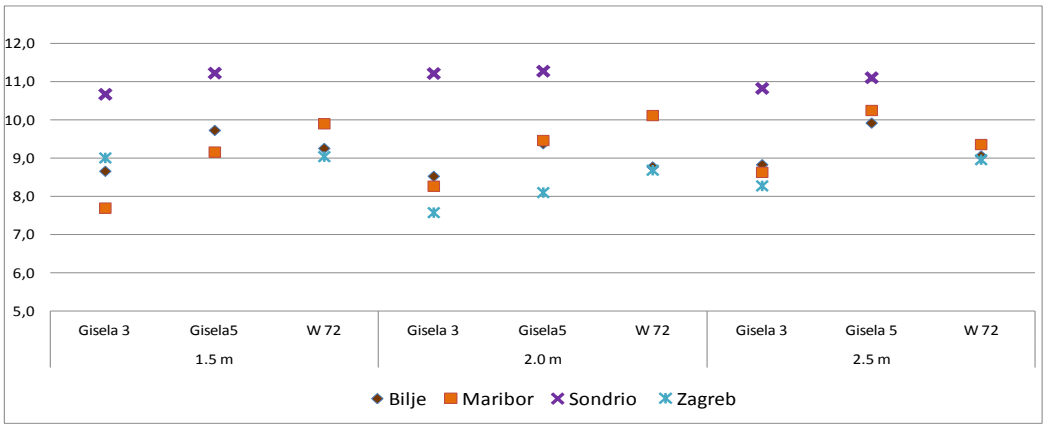


Fig. 5. Effect of rootstock, location and plant distance on average fruit weight (g) of cv. Regina (2009-2011).