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The influence of grafting on yield of two tomato cultivars (*Lycopersicon esculentum* Mill.) grown in a plastic house

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ABSTRACT

The influence of different grafting methods on the success of grafting and fruit yield of two tomato cultivars (*Lycopersicon esculentum* Mill.) was studied in a greenhouse trial in Ljubljana. The cultivars used as scion were 'Monroe' and 'Belle', and as rootstock 'PG 3' and 'Beaufort'. Two grafting methods were applied: cleft grafting and tube grafting. Grafted plants were then hand planted in a plastic house. The treatments applied in each cultivar were: cleft grafting onto 'PG 3' and 'Beaufort', and tube grafting onto 'PG3' and 'Beaufort', and ungrafted control. The following measurements were recorded: number of plants that survived until the transplanting date; fruit yield (g plant^{-1}) and total number of fruits harvested per plant. The high percentage (79-100%) of succesful grafting observed for both tomato scions and rootstocks, using cleft and tube grafting methods, indicated that both grafting methods are suitable for tomato grafting. A positive effect of grafting was recorded when 'Monroe' was used as scion, and 'Beaufort' as rootstock. When 'Belle' was used as scion, a negative effect of grafting was observed, since the total fruit yield of non-grafted plants was significantly higher than that of plants grafted onto both rootstock cultivars. Grafting is thus considered an important technique for sustainable greenhouse production of fruit-bearing vegetables.

Key words: tomato (*Lycopersicon esculentum* Mill.), grafting method, scion, rootstock, fruit yield

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IZVLEČEK

VPLIV CEPLJENJA NA PRIDELEK DVEH KULTIVARJEV PARADIŽNIKA (*Lycopersicon esculetnum* Mill.) V PLASTENJAKU

V raziskavi smo proučevali vpliv različnih tehnik cepljenja na uspešnost cepljenja ter na pridelek dveh kultivarjev paradižnika (*Lycopersicon esculentum* Mill.). Za žlahtni del – cepič smo uporabili hibridni sorti 'Monroe' in 'Belle' za podlago pa kultivarja paradižnika 'PG 3' in 'Beaufort'. Uporabili smo dve tehniki cepljenja: v zarezo in cepljenje s spajanjem s pomočjo cevke. Uspešno cepljene sadike smo ročno presadili v plastenjak. Pri vsakem kultivarju smo izvedli obe tehniki cepljenja, tako da so bila obravnavanja naslednja: 'Monroe' cepljen v zarezo in s cevko na podlagi 'Beaufort' in 'PG 3' ter 'Belle' cepljen v zarezo in s cevko na omenjeni podlagi. Na osnovi števila preživelih rastlin po cepljenju smo ovrednotili uspešnost cepljenja, ob spravilu pa pa smo vrednotili maso ter število plodov na rastlino. Visok odstotek preživelih – uspešno cepljenih rastlin (70-100%), ki smo ga ugotovili pri vseh cepljenih kombinacijah nakazuje, da sta tehniki cepljenja v zarezo in s pomočjo cevke primerni za cepljenje paradižnika. Pozitivni učinek cepljenja smo zabeležili pri kultivarju 'Monroe', ki je bil cepljen na podlago 'Beaufort'. Pri kultivarju 'Belle' pa je imelo cepljenje negativni učinek na končni pridelek, saj je bil skupen pridelek plodov necepljenih rastlin statistično značilno večji kot pri cepljenih rastlinah. Zato je cepljenje tehnika, ki postaja čedalje bolj pomembna pri integrirani – naravi prijazni pridelavi plodovk v rastlinjakih.

Ključne besede: paradižnik (*Lycopersicon esculentum* Mill.), tehnike cepljenja, cepič, podlaga, pridelek plodov

1 INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a crop of high economic importance in many countries.About 189.7 ha are cultivated annually in Slovenia, of which 51.4 ha for market and of this 18.3 ha in indoor areas (greenhouses, plastic houses and tunnels) (Statistični letopis RS, 2002).

Continuous cropping is inevitable in vegetable production in indoor areas, and this reduces the yield and quality of produce. Oda (2004) reported that most of the damage from continuous cropping is caused by soil-born diseases and nematodes. Since soil sterilization can never be complete, grafting has become an essential technique for the production of repeated crops of fruit-bearing vegetables grown in indoor areas.

Fusarium (*Fusarium oxysporum f.sp.lycopersici,* race 1 and race 2) and Verticillium wilts (*Verticillium dahliae*, races 1 and races 2), bacterial speck (*Pseudomonas syringae p.v. tomato*), root knot nematodes (*Melodogyne* spp.) and corky root (*Pyrenocheata lycopersici*) have been reported to be among the most important soil-borne pathogens of covered tomato crops (Besri, 2002, Augustin et al. 2002, Poffley, 2003). These pathogens used to be controlled by fumigants from which methyl bromide is the most popular because of its high inherent toxicity to almost all-living organism (bacteria, fungi, insects, nematodes) and its good distribution in the soil, penetrating it to great depths and killing pathogens at sites not accessible to other fumigants (Vakalounakis, 1990). However, in 1992, in the Copenhagen Amendment to the Montreal Protocol, methyl bromide was added to the list of substances that deplete the ozone layer. The European Community and most Member States have ratified the Copenhagen Amendment. Consequently, under the Montreal Protocol, the States of the European Community, including Slovenia, should phase out methyl bromide by 1 January 2005. Research and technology transfer will therefore be necessary to fully implement an alternative to methyl bromide pest management systems for covered vegetable crops (Batchelor, 2001).

The production of grafted plants first began in Japan and Korea in the late 1920s with watermelon (*Citrullus lanatus* Matsum et Nakai) grafted onto gourd rootstock. Eggplant was grafted onto scarlet eggplant (*Solanum integrifolium* Poir) in the 1950s. Since then, according to Lee (1994) and Oda (1995), the cultivation of grafted fruit-bearing vegetable plants has increased greatly and grafting is an important technique for the sustainable production of fruitbearing vegetables in Korea, Japan, and some Asian and European countries, where land use is very intensive and continous cropping is common. Oda (1995) reported that the proportion of area in Japan producing grafted watermelon, cucumber, melon, tomato and eggplant reached 59% of the total production area in 1990.

In Greece, grafting is highly popular, especially in southern areas, where the ratio of the production area using grafted plants to the total production area, amounts to 90-100% for early cropping of watermelon and 40-50% for melons under low tunnels, 2-3% for tomato and egg plants, and 5-10% for cucumbers (Traka-Mavrona et al., 2000). According to Oda (2004), inter-generic grafting is used in the production of many fruit-bearing vegetables; i.e. cucumber (*Cucumis sativus* L.) grafted on pumpkin (*Cucurbita* spp.), watermelon (*Citrullus lanatus* Matsum et Nakai), on bottle gourd (*Lagenaria siceraria* Standl.), melon (*Cucumis melo* L.) on white gourd (*Benincasa hispida* Cogn.). Inter-specific grafting is generally applied to eggplant (*Solanum melongena* L.). Scarlet eggplant (*Solanum integrifolium* Poir.) and *Solanum torvum* Swartz are popular rootstock for eggplant production.

Researchers from the Asian Vegetable Research and Development Center (AVRDC) (2003) reported that tomatoes are difficult to grow during the hot-wet season, because flooding, waterlooged soils, diseases and high temperatures can significantly reduce yields. They recommended grafting tomato scions onto selected rootstocks of eggplant or tomato to minimize problems caused by flooding and soil-born diseases. According to Oda (2003), there are many grafting methods for different types of fruit-bearing vegetables: tomato plants and eggplants are mainly grafted by conventional cleft grafting. Tube grafting has been developed for vegetable seedlings grown by plug culture. The survival ratio of grafted *Cucurbitaceae* plants is higher if a tongue approach to grafting is used, especially for cucumber. This is because the root of the scion remains until the formation of the graft union. Slant-cut grafting is easy to do and has recently become popular for watermelon and melon. This method was developed for robotic grafting.

Grafting methods and the influence of grafting on the yield of fruit-bearing vegetables in Slovenia have not been precisely studied as yet. The aim of this research was to examine the effects of different grafting methods on the success of grafting and yield of two tomato cultivars.

2 MATERIAL AND METHODS

The experiment was conducted in a glasshouse and in a plastic house, at the Biotechnical Faculty (latitude: 46° 04' N, longitude 14° 31' W, 300 m above M.S.L), University of Ljubljana, from March to September 2003. The cultivars used as scions were 'Monroe' and 'Belle' (Enza Zaden) and 'PG 3' and 'Beaufort' (De Ruiters) were used as rootstocks. The cultivars 'Monroe' and 'Belle' belong to the *L. esculentum* Mill., beef type tomato group. ‘Monroe’ is fairly and ‘Belle’ medium early maturing, with round and oblate shape, respectively, and with high quality beef. They are usually grown indoors.

In our experiment, the seeds of rootstocks and scions were sown on 10 and 17 March, respectively, in a seedling tray filled with peat-based substrate. Seedlings were grafted on 28 April and the grafted plants were planted on 29 May in a plastic house. Cleft (C) and tube (T) graftings were applied as indicated by Oda (2003): with *cleft grafting* the stem of the scion (at the fair-leaf stage), and the rootstock (at the four to five-leaf stage) were cut at right angles, each with 2-3 leaves remaining on the stem. The stem of the scion was cut in a wedge, and the tapered end fitted into a cleft cut in the end of the rootstock. The graft was then held firm with a plastic clip.

With *tube grafting* the optimum growth stage for grafting varies according to the kind of plug tray used. Plants in small cells must be grafted at an earlier growth stage, and require tubes with a smaller inside diameter. In our experiment, the rootstocks were cut at a slant. The scions were cut in the same way. Plastic tubes with a side-slit were placed onto the cut end of the rootstock. The cut ends of the scions were then inserted into the tube, splicing the cut surfaces of the scions and rootstock together.

Grafting was carried out in a glasshouse, in a shady place sheltered from the wind, to avoid wilting of the grafted plants. Grafting plants were healed and acclimatised in a plastic tunnel covered with silver/white cheese-cloth (outside) and transparent film (inside) to provide shade and maintain inside humidity:

After the grafting, the grafted plants were kept at 28-30 ºC and with more than 95% relative humidity for three days of healing, which promotes the survival rate. The relative humidity was then gradually lowered and the light intensity increased. If wilting was observed, foliar spraying of grafted plants with water was effective in helping them survive.

The grafted plants were then hand planted at a 0.80 m row spacing, with a 2 m row length, spaced 0.50 m apart, and grown vertically in the plastic house. Normal cultural practices for the experiment were followed for irrigation, fertilization and pesticide application. A randomized complete block design was adopted, with three replications, each consisting of 4 plants. The treatments applied with each cultivar were: cleft grafting onto 'PG 3' and 'Beaufort', and tube grafting onto 'PG 3' and 'Beaufort', and ungrafted control. The experiment was terminated on 5 September 2003.

The following measurements were recorded: (a) number of plants which survived until the transplanting date; (b) fruit yield (g plant^{-1}) and (c) total number of fruits harvested per plant. Yield measurements were recorded on ripe fruits, which were gently hand-harvested and transported to the laboratory, where they were counted and weighed. Data were analysed using analysis of variance to examine treatment effects, and means were separated by Duncan's multiple range test at $P \leq 0.05$.

3 RESULTS AND DISCUSSION

The survival rate of tomato transplants grafted onto 'Beaufort' and 'PG 3' rootstocks using the cleft grafting method was 100% with cv. 'Monroe' and 92 and 93% with cv. 'Belle', respectively. With the tube grafting method, the survival rate was 79 and 92% with cv. 'Monroe', respectively, and 88% with cv. 'Belle' (Fig. 1).

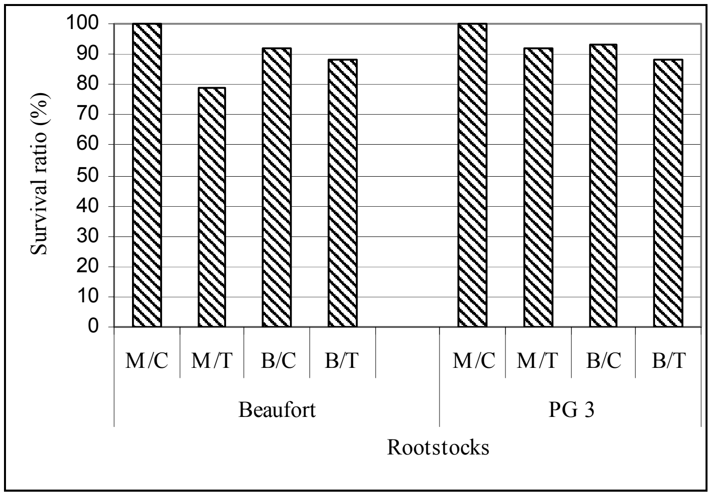

Figure 1. Survival rate of plants of 'Monroe' (M) and 'Belle' (B) cultivars grafted onto 'Beaufort' and 'PG3' rootstocks, using cleft grafting (M/C and B/C) and tube grafting (M/T and B/T) methods.

Observations on scion/rootstock compatibility, revealed that both 'Beaufort' and 'PG 3' as rootstocks gave a satisfactory survival rate of grafts with both scions, 'Monroe' and 'Belle'. Better results were obtained from cleft grafting, namely a 100% survival rate was recorded with cv. 'Monroe' grafted onto both rootstocks and 92% and 93% survival rate with cv. 'Belle' grafted onto 'Beaufort' and 'PG 3', respectively. The lowest survival ratio, was obtained with cv. 'Monroe' grafted on 'PG 3' rootstock, using the tube grafting method (79%).

The effects of grafting on fruit yield (g/plant) for the two tomato cultivars, grafted onto different rootstocks, irrespecitve of grafting method used, are given in Table 1.

Table 1. Fruit yield (g/plant) and total number of fruits picked per plant of grafted and non-grafted plants grown in the plastic house.

Scion	Rootstock	Fruit yield (g/plant)	Fruit number/plant
'Belle'	'PG 3'	3343.0 a*	15.4 ab
	'Beaufort'	3251.0 a	14.9 a
	Non-grafted	4802.0 b	20.4 b
'Monroe'	'PG 3'	3183.0 a	14.0 a
	'Beaufort'	4622.0 b	20.0 b
	Non-grafted	3376.2 a	14.5 a

* Means in the same column followed by the same letter are not significantly different (P≤0.05) according to Duncan's multiple range test..

A positive effect of grafting was obtained when 'Monroe' was used as scion, and 'Beaufort' as rootstock. In that grafted combination, the total fruit yield per plant increased significantly in comparison with that of the nongrafted plants or when 'PG 3' was used as rootstock. A negative effect of grafting was, however, shown when 'Belle' was used as scion. The total fruit yield of non-grafted plants was significantly higher in comparison with that of the plants grafted onto both rootstock cultivars.

The effects of different grafting methods on fruit yield (g/plant) and total number of fruits, picked per plant are presented in Table 2.

Table 2. Fruit yield (g/plant) and total number of fruits picked per tomato plant, grafted by cleft and tube grafting methods.

Scion	Grafting methods	Fruit yield (g/plant)	Fruit number/plant
'Belle'	Cleft	3004.0 a	14.3 a
	Tube	3591.3 ab	16.1 ab
	Non-grafted	4802.0 b	20.4 b
'Monroe'	Cleft	4718.0 a	20.1 a
	Tube	3091.0 b	13.7 b
	Non-grafted	3376.2 ab	14.5 ab

* Means in the same column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test..

When 'Belle' was used as scion, the fruit yield of tomato was not significantly affected by using the different grafting methods, but was significantly affected with the cultivar 'Monroe', where the cleft grafting method significantly increased the total fruit yield per tomato plant.

4 CONCLUSIONS

On the basis of the high percentage of successful grafting observed for both tomato scions ('Monroe' and 'Belle') and rootstocks ('PG 3' and 'Beaufort'), using cleft and tube grafting methods, it can be concluded that both methods are suitable for tomato grafting.

The yield advantage of grafted plants has been shown to be clear when they are grown on infested soil (Vuruskan and Yanmaz, 1990, Poffley, 2003; Augustin et al. 2002, Besri, 2002). In our experiment, there was no obvious advantage of grafted plants, because the plants were grown in pathogen-free soil. The higher yield of tomato fruit of the cv. 'Monroe' grafted onto 'Beaufort' was probably attributed to the vigurous root system of the rootstock. According to Lee (1994,) the increased yield of grafted plants is also believed to be due to enhanced water and mineral uptake.

The effect of the two rootstocks on the agronomic characteristics of the two tomato cultivars, allow a series of considerations on the feasibility of this technique in the cultivars tested. In agreement with Lee (1994) and Oda (1995), there seems to be an interaction between rootstocks and scions, resulting in a fruit yield enhancement.

The fact that the grafted plants produce better results than non-grafted ones when grown on infested soils indicates the potential economic value for a grower of growing grafted plants (Bletsos, 2003).

Since grafting gives increased disease tolerance (Besri, 2002, Poffley, 2003; Augustin et al. 2002) and vigour to crops (Table 2), it should be useful for low-input sustainable horticulture of the future.

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