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Effect of grafting on the quality and apperance of eggplant fruit

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ABSTRACT

Grafting is a connection of two plant tissues, which are forced to develop vascular connection and grow as a single plant. Vegetable grafting has been used in *Solanaceae* family and *Cucurbitaceae* family for several reasons e.g. increasing tolerance against biotic and abiotic stresses, improving plant growth and yield. Fruit quality and appearance of vegetables may be influenced by grafting methods. Researchers have found contradictory results of fruit quality and appearance even in eggplant grafting due to different production environments, types of rootstock/scion combinations. In current review, we summarise available information on the effects of grafting and different rootstocks on eggplant fruit quality.

KEYWORDS

browning index, fruit firmness, fruit quality, vegetable grafting

INTRODUCTION

Fruit quality presents a different point of view for breeder, grower, food industry and consumers. Based on the FAO and WHO, the quality standard of fresh vegetables mostly considers external quality attributes (size, shape, colour and freshness) whereas internal quality

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attributes (texture, flavour and health promoting compound) are not considered. The eggplant (*Solanum melongena* L.) is one of the top ten vegetables that originated from Southeast Asia; it has a high antioxidant capability and nutrient value. According to UNECE Standard FFV-05 (edition 2017), the quality of eggplant fruit is defined as intact, fresh in appearance, firm, free from pests, sufficiently developed without the flesh being fibrous or woody; without over-development of the seeds and provided with a calyx and peduncle which may be slightly damaged.

Vegetable grafting is an asexual plant propagation technique by connecting two plant parts to grow together and form a new plant. This environmentally friendly technique induces resistance against soilborne disease, low and high temperatures, reduces uptake of persistent organic pollutants from agricultural soils, raises salt and flooding tolerance, and limits the negative effect of boron and copper toxicity (Mozafarian and Kappel, 2019, 2020). Despite all the advantages some problems of grafting still exist; for instance, labour and technique are essential for grafting process (Kumar and Sanket, 2017), the price of grafted seedling and automated grafting machine are too high (Tsaballa et al., 2013).

Grafting has been used in *Solanaceae* family i.e. tomato (*Solanum lycopersicum* L.), eggplant (*S. melongena* L.) and pepper (*Capsicum annuum* L.) and *Cucurbitaceae* family i.e. watermelon (*Citrullus lanatus* (Thunb.)), melon (*Cucumis melo* L.), cucumber (*Cucumis sativus* L.), pumpkin (*Cucurbita pepo* L.) and bitter gourd (*Momordica charantia* L.) (Bie et al., 2017). This method can increase the yield and productivity in pepper (9.2%), eggplant (27.7%) and tomato (5.4–80.3%) and can improve the quality of fruit (Fernández-García et al., 2004; Kyriacou et al., 2017; Martínez-Ballesta et al., 2010).

Grafting eggplant was practiced in 1950s by using scarlet eggplant (*Solanum integrifolium*) as rootstock (Edelstein et al., 1999). In Hungary, nearly all greenhouse tomato and 75% of watermelon production are cultivated with grafted seedlings while using grafting method in eggplant is not common. Every rootstock may not be compatible to use for eggplant grafting even though they are resistant to abiotic and biotic stresses Wang et al. (2017). *Solanum torvum* is the most common rootstock and researchers tried to find alternative compatible rootstocks for eggplant. Most of previously published papers focused on laboratory fruit quality test by different methods and rarely used sensory evaluation. Moreover, information on grafted eggplant fruit quality is conflicting (Table 1). The aim of this paper is to review the recent literature about fruit quality harvested from grafted eggplants and methodology of quality measurement.

Fruit shape index (ratio of equatorial and longitudinal diameter) can be affected by grafting in eggplant. For instance, grafting eggplant onto *S. torvum* caused a longer fruit (Cassaniti et al., 2011). Our finding showed that grafting eggplant cv. Madonna onto tomato rootstocks (cv. Optifort and Emperador) decreased the fruit length relative to control (Mozafarian et al., 2020) (Fig. 1). Similar result was reported by Sabatino et al. (2016); Gisbert et al. (2011) and Passam et al. (2005). Fruits of cv. Blackbell grafted onto cv. Beaufort had the more elongated than self-grafted fruit while the opposite record was observed at fruit of cv. Epic and cv. Galine grafted onto cv. Beaufort (Kacjan Maršic et al., 2014).

Calyx pickle as an undesirable trait for handling eggplant can affected by grafting. Kacjan Maršic et al. (2014) reported a significant impact of rootstocks on decreasing calyx pickles. Chromatic characteristics showed that interaction of grafting and cultivar significantly influence calyx colour; the calyx of cv. Birgah fruits from non-grafted plants had higher values of lightness

Table 1. Effect of different rootstock of eggplant yield and fruit quality

Rootstock	Scion	Fruit yield	Texture	Brix	Skin colour	Pulp colour	Seed number	Phenol content	Calyx pickle	Reference
Solanum torvum	Madonna	+	−	0	0	0	+			Mozafarian et al. (2020)
Solanum melongena × *Solanum integrifolium*	Madonna	+	−	−	0	0	+			Mozafarian et al. (2020)
Solanum grandiflorum × *Solanum melongena*	Madonna	+	0	0	0	0	+			Mozafarian et al. (2020)
Solanum integrifolium	Madonna	+	−	0	0	0	0			Mozafarian et al. (2020)
Optifort (*Solanum Lycopersicum*)	Madonna	0	−	−	−	−	0			Mozafarian et al. (2020)
Emperador (*Solanum Lycopersicum*)	Madonna	0	−	−	−	−	0			Mozafarian et al. (2020)
Solanum aethiopicum (accession 1)	Scarlatti	−	0	0		0				Sabatino et al. (2019)
Solanum aethiopicum (accession 2)	Scarlatti	0	0	+		+				Sabatino et al. (2019)
Solanum melongena × *Solanum aethiopicum*	Scarlatti	0	0	0		0				Sabatino et al. (2019)
Solanum torvum	Scarlatti	0	0	-		0				Sabatino et al. (2019)
Solanum macrocarpon	Black Beauty	−					0	+	+	Gisbert et al. (2011)
Solanum torvum	Black Beauty	0					0	0	0	Gisbert et al. (2011)
Emperador (*Solanum Lycopersicum)*	AndraF1	+								Bogoescu and Doltu (2015)
Emperador (*Solanum Lycopersicum)*	SharapovaF1	+								Bogoescu and Doltu (2015)
Hikyaku	Hikyaku	+								Bogoescu and Doltu (2015)
Hikyaku	AndraF1	0								Bogoescu and Doltu (2015)

(continued)

Table 1. Continued

Rootstock	Scion	Fruit yield	Texture	Brix	Skin colour	Pulp colour	Seed number	Phenol content	Calyx pickle	Reference
Solanum torvum	Bianca	+						+		Sabatino et al. (2016)
Solanum torvum	Birgah	0			+	-		−		Moncada et al. (2013)
Solanum torvum	Black Bell	0			+	0				Moncada et al. (2013)
Solanum torvum	Black Moon	−			+	0				Moncada et al. (2013)
Solanum torvum	Longo	0			+	0				Moncada et al. (2013)
'Heman' (*Lycopersicon hirsutm*)	Rima	+ (greenhouse) + (open-field)		0			+			Khah (2011)
'Primavera' (*Lycopersicon esculentum*)	Rima	+ (greenhouse) − (open-field)		0			+			Khah (2011)
'Heman' (*Lycopersicon hirsutm*)	Rima	+					+			Khah (2005)
'Primavera' (*Lycopersicon esculentum*)	Rima	0					+			Khah (2005)
Solanum torvum	Tsakoniki		−					−		Arvanitoyannis et al. (2005)
Solanum sisymbriifolium	Tsakoniki		−					−		Arvanitoyannis et al. (2005)
Beaufort F1 *(S. lycopersicum* L. × *S. habrochaites)*	Blackbell F1					+		−	−	Kacjan Maršic et al. (2014)
Beaufort F1 *(S. lycopersicum* L. × *S. habrochaites)*	Epic F1					−		−	−	Kacjan Maršic et al. (2014)

'+' indicated as increase; '−', a decrease as a '0' no change in fruit characterises.

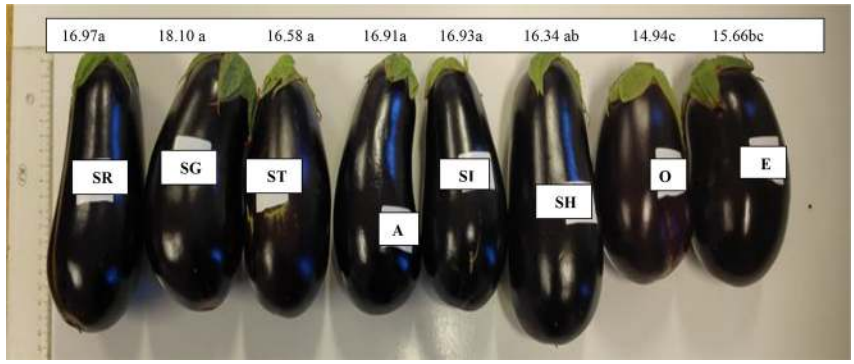

Fig. 1. Effect of different rootstock combinations on fruit length (cm). SR = self-root; SG = self-grafting; ST = *S. torvum*; A = *S. integrifolium*; SI = *S. melongena* × *S. integrifolium*; SH = *S. grandiflorum* × *S. melongena*; O = Optifort; E = Emperador

and a more vivid colour in comparison with the grafted ones while the opposite result was found in cv. Black Bell and cv. Black Moon.

Evaluation of fruit quality as regards marketability and nutritive value is very important (Moncada et al., 2013). Colour, gloss and appearance attract the consumers. Colour can be measured by pigment extraction, spectrophotometry and instrumental methods. Colour (L^*, a^* and b^* parameters – CIELab) can be measured on calyx and fruit skin by a tristimulus Minolta Chroma meter CR-400. Chroma (C^*) and Hue angle (H°) can also be calculated.

Skin or flesh colour of fruit can be influenced by grafting and different rootstocks. Moncada et al. (2013) indicated that grafting eggplant onto *S. torvum* resulted in a darker and less vivid colour to the fruit harvested from control. Mozafarian et al. 2020Mozafarian and Kappel, 2019 reported that skin colour cv. Madonna was influenced by different rootstock while CIRG index was similar between grafted and non-grafted plants. Stripped fruit skin colour was observed in self-grafted plants and cv. Langada (Krommydas et al., 2018).

In case of eggplant, late browning in pulp is important. The whitening index of eggplant pulp and skin colour can be measured according to the standards of CIE. Colour space may be divided into a three-dimensional (L^*, a^* and b^*) such that L^* (lightness; 0 black and 100 white); a^* (red to green) and b^* (blue to yellow). The CIE $L^*a^*b^*$ values of the pulp can be determined and the whiteness index (WI) is calculated by the following Eq. (1) (Amanatidou et al., 2000):

$$WI = 100 - \left((100 - L)^2 + \left(a^2 + b^2\right)\right)^{0.5} \quad (1)$$

Also, the colour differences (CDs) of eggplant pulp can be measured by CIE $L^*a^*b^*$ values at time 0 and 30 or 60 min (2).

$$CD = \left[\left(L^*_{30} - L^*_0\right) + \left(a^*_{30} - a^*_0\right) + \left(b^*_{30} - b^*_0\right)\right] \quad (2)$$

Moreover, the oxidation potential (browning index) was measured by International Commission on Illumination (CIE) L*a*b* values using the following Eq. (3):

$$\Delta L_{30} = (L_0 - L_{30}) \text{ and } \Delta L_{60} = (L_0 - L_{60}) \quad (3)$$

Kacjan Maršic et al. (2014), Moncada et al. (2013) and Mozafarian et al. (2020) found that the lightness of fruit pulp was similar in grafted and non-grafted plants. However, Kacjan Maršic et al. (2014) reported that browning index after 10 min was influenced by grafting ($\Delta L_{10} = 2.8$) relative to self-grafting plant ($\Delta L_{10} = 4.8$) and after 30 min no significant differences were observed. Similar result was obtained by Mozafarian et al. (2020) who reported that grafting eggplant cv. Madonna decreased browning index of pulp. Opposite result was reported by Moncada et al. (2013) who found the same browning level in grafted and non-grafted fruit.

Difference in post cutting browning can be due to level of phenolic compound or the activity of polyphenol oxidase enzyme. Kacjan Maršic et al. (2014) found the reduction of the phenolic concentration by grafting which can be the reason of lowest browning in fruit. Greater phenolic compound in fruit harvested from grafted plant in comparison with non-grafted and self-grafted plants was observed by several researchers (Gisbert et al., 2011; Sabantino et al., 2016).

After visual appearance, the texture of fruit is the most important factor for consumers and grafting can influence the firmness of fruit. It can be measured by destructive or non-destructive methods. Fruit firmness can be evaluated easily by hand operated or electric penetrometer through universal testing equipped with a plunger. Another equipment is the texture analyser; flat plate is a technique very similar to puncture and it can be carried out both in a destructive and non-destructive way.

The acoustic and impact response, ultrasonic methods are non-destructive methods. In the acoustic method, vibrational responses in the frequency range from 20 to 10,000 Hz are used. Moreover, an electromagnetic property (nuclear magnetic resonance) or a chemical property (electronic nose) can be used for fruit texture evaluation (Jiménez et al., 2012).

As shown in Table 1 grafting eggplant caused a reduction in fruit firmness (Cassaniti et al., 2011). Recently, we found that grafting cv. Madonna decreased the fruit firmness (Mozafarian et al., 2020).

Some researchers have described that sugar content is not influenced by grafting (Colla et al., 2008; Turhan et al., 2011; Nicoletto et al., 2013; Lopez-Marin et al., 2013). Lower pH and total soluble solids (TSSs) are observed, when eggplant was grafted onto *S. torvum* (Khah, 2011). They explained that grafting caused lower plant growth and fruit water content and resulted in higher soluble solids content (SSC) (Ntatsi et al., 2014; Rahmatian et al., 2014). On the other hand, Kumar et al. (2015) and Riga et al. (2016) reported sugar reduction in fruit due to increasing fruit water content. In another study, fruit harvested from cv. Emperador and Optifort rootstocks showed the lowest Brix value in comparison with fruit of control (Mozafarian et al., 2020). Vitamin C and firmness of eggplant fruit were negatively affected by grafting on *S. torvum* and *Solanum sisymbriifolium* (Arvanitoyannis et al., 2005).

Fruit taste, aroma and appearance can be evaluated by a trained sensory panel. Also, it can be measured by instrumental methods (pH, Brix). Total soluble solids (TSSs) as Brix and pH are determined by the juice of fruit flesh onto a digital refractometer or pH meter. Arvanitoyannis et al. (2005) evaluated the organoleptic properties of grafted eggplant for 10 days stored at two temperatures. Small pieces of the fruit were boiled and were immediately assessed for sweetness, colour, odour, tartness and non-boiled assessed for appearance. Higher rating of sweetness, acceptance and hardness of fruit were observed at non-grafted plants and no difference was found for overall acceptance between grafted and non-grafted plants (Arvanitoyannis et al.,

2005). In another experiment, grafting cv. Madonna onto *S. torvum* had the stronger sweet taste as compared to control fruits and fruits harvested from *S. melongena* × *Solanum integrifolium* showed significantly intensive odour (Mozafarian et al., 2020).

CONCLUSION

Grafting as one of the possible propagation methods can be used for increasing the quality and quantity of crop production. Whereas there are many reported advantages due to grafting it is widely used in cultivation practice in two vegetable families (*Cucurbitaceae* and *Solanaceae*) as well. At the same time there are many conflicting results of grafting effect on fruit quality due to different production environments, type of rootstock/scion combination used and harvest date. In the case of eggplants, such publications are even less clear. All results on rootstocks in eggplant grafting indicate conflicting effects, therefore, our aim was to summarise these previous studies and to highlight that also with eggplants the methods of examining the fruit quality of tomatoes and melons due to grafting can also be applied. However, the influence of grafting on postharvest is poorly understood; so additional knowledge is required on fruit shelf-life and consumer evaluation of eggplant fruits.

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